CONTRACT MANUFACTURING OPPORTUNITIES IN PRINTED ELECTRONICS

2013 EDITION

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Chapter 1 Introduction

1.1 Report Objectives and Scope

The objective of this report is to provide a macroeconomic understanding of the printed electronics (PE) market to interested equipment suppliers, materials and component companies, and solution/integration firms and electronics manufacturing service (EMS) firms worldwide.

This report is the latest effort to quantify the size of the PE market and the growth of emerging applications. In the past, this subject has been over-hyped and badly forecast despite its potential for replacing traditional electronics manufacturing. NVR has been tracking the PE market since 2007 and the electronics manufacturing services market since 1993. Consequently, we are in a strong position to understand how disruptive technologies can be as they begin to displace or replace traditional semiconductor electronics.

This latest report examines the PE market in over 40 product application areas, and forecasts the demand in real terms using 5-year forecasts. NVR tracks the PE and EMS markets with historic data, thus providing an analog for corroborating the most promising opportunites with emerging applications. While some applications are projected with a growth rate of in excess 100% CAGR (compound annual growth rate), others will expand only at 5% CAGR. The details can be found in this report.

For the last twenty years, the generic term “contract manufacturing” has been identified almost entirely with a very specific niche within the overall durable goods market—that of electronics equipment. This is ironic, as the notion of “contract manufacturing” could be applied to any industry segment (aerospace, appliances, automotive, construction, etc.) that manufactures finished goods, yet over the last few years it has been exclusively linked to the electronics—specifically the high-tech electronics—market segment. As the electronics manufacturing industry has evolved over the years, the term “electronics manufacturing services (EMS)” has come to refer both to the overall industry and a specific class of subcontractor.

The current report summarizes the entire CM electronics assembly market, but pays special attention to the production of advanced, state-of-the-art PE technologies which are having considerable impact on the world today. Not all application areas are equal in potential, but because of our long history in tracking the manufacturing cost of goods sold (COGS), our knowledge database and experience provide us with the best analysis in comparing and projecting the PE products with the most potential. It is probably fair to say that these products would not be so widespread were it not for the emergence of the EMS industry, which has lowered product costs and increased manufacturing efficiency.

1.2 Organization

This report is organized into seven chapters. Chapter 1, "Introduction," outlines the scope, organization, and methodology for the report. Chapter 2, "Executive Summary," presents top-level data from throughout the report.

Chapter 3, titled "Printed Electronics Technology," examines organic electronics and thin film materials, and PE manufacturing equipment by technology.

Chapter 4, "Printed Electronics Materials Market," analyzes conductive inks, conductive films, microcapsules, organic/inorganic transistors/polymers, and nanoparticles.

Chapter 5, "Printed Electronics Market Application," examines key products by leading market segments, including consumer electronics, medical, packaging, transportation (automotive and aerospace/defense), and other general applications that includes batteries, memory/logic and sensors.

Chapter 6, "Printed Electronics Market Forecasts," examines over 40 different PE applications and estimates their growth over the next five years. The highest growth markets are projected to expand over 125% CAGR, while others are as low as only 5% CAGR. Overall, the market for PE products is expected to almost triple over the next five years, achieving nearly $10 billion in 2017.

Chapter 7, "Company Profiles," analyzes the leading PE companies and suppliers by three dimensions – printing equipment (plus manufacturing production technology), advanced materials that provide thin film solutions, and the many solution/application providers who either develop technical solutions or successfully integrate one or more PE technologies. In all, 185 PE companies are profiled in this report and organized according to industry solution.

1.3 Assumptions

The following assumptions have been made with regard to information provided in this report:

- Respondents are providing truthful information to the best of their ability.

- Values are mainly provided in current US dollars.
- Revenues are converted from national currencies into US dollars by using the current Federal Reserve average annual rates.
- Wage rates were not adjusted to reflect the appreciation of the euro or the undervaluation of the Chinese yuan.
- All tables presented in this report are subject to small rounding errors. Therefore, column and row numbers, as presented, may not add up exactly to the total presented.

1.4 Definitions

Several critical terms will be used frequently in this report. They are:

- *PCB Assembly*: For this report, PCB assembly refers to the attachment of various electronic components onto a bare printed circuit board, plus any test activities performed at this level of assembly.
- *PCB Assembly Value*: The value (cost of goods sold, or COGS) of all material, labor, and overhead associated with an assembled printed circuit board.
- *OEM Assembly*: Electronics assembly performed by the OEM. If assembly is performed by a subcontractor that is held captive by the OEM or in a *keiretsu* arrangement such as exists in Japan, the assembly is considered OEM produced.

1.5 Research Methodology

Information for this report was collected from a number of external sources. Primary sources include direct interviews with marketing professionals, and with manufacturing and engineering directors in contract manufacturing firms. In many cases we have quoted individuals directly but there are also cases where information has not been quoted but integrated into our research findings.

Some individuals and companies were particularly helpful in taking the time to speak with us and provide supporting materials. They include the following (alphabetically by company): Kevin Chen and Eileen Tanghal, Applied Materials; Wayne Baker, Checkpoint Systems; Don Banfield, Conductive Compounds; Len Allison, Conductive Materials; Sriram Peruvemba, E Ink; Darrell Etter and Tim Luong, Fuji Dimatix; Gordon Smith, GSI Tehnologies; Steve Gilberton, Kammann; David Fyfe, Liquid X Printed

Metals; Scott White, Pragmatic IC; Chris Walker, Preco, Inc.; Mark Bohan, Print Industries of America; Richard Morris, Si-Cal; John Yundt, Spraylat; Andy Ferber, T-Ink; and Jennifer Ernest, ThinFilm, Inc.

Chapter 2 – Executive Summary

2.1 Printed Electronics Equipment and Materials

Printed electronics (PE) is a set of printing methods used to create electrically functional devices. PE is mainly a thin film coatings business today although many applications still involve the deposition of fine layers of conductive compounds. There is a wide variety of printed materials used in the coatings business for devices including conductive inks, transparent films, polymers, and other thin films that can be applied to various substrate surfaces consisting of silicon, glass, paper, plastic, metals, ceramics and inert materials. Key benefits of printed electronics are:

- Materials and manufacturing costs can be very low
- Factory costs may transfer to the printer on a home computer
- Fast turnaround of orders so that even a batch size of one is economical
- Design turnaround very rapid
- Circuits can be deposited onto flexible substrates such as plastic film and foils
- Lightweight designs leading to new applications, easier installation and maintenance
- Reduced cost and improved reliability (fewer interconnects) by co-deposition of many components
- Better environmental credentials
- Often cheap enough to be disposable and deployed in the Third World
- Very wide area formats possible
- Superior fault tolerance

The goal of printed electronics has been to utilize common printing equipment found in the graphic arts industry, such as screen printing, flexography, gravure, offset lithography and inkjet, as the means of creating electronic devices. Over the last 10-15 years, families of products have emerged that consist of active and passive devices, such as thin film transistors, resistors and capacitors, as well as finished products (such as solar cells and medical test products). Because of the inherent low cost of layering printed electronics coatings on to substrates, it is believed that large scale continuous devices can be made for simple applications not typically associated with conventional high performance (i.e., silicon-based) electronic devices.

It can be said without much exaggeration that the conductive inks and thin films that make up the PE market are the elixirs behind its success. This certainly has been the case with conductive membrane switches, photovoltiac (PV) films and electrophoretic displays. But the PE materials market is surprisingly dominated by one material – silver, in the form of silver paste (or flakes of micron size) and silver chloride – which accounts for up to 65 percent of the market today according to industry sources. Other materials that are also in use include di-electric insulating thin films, as well as conducting carbon/graphite compounds, and in limited cases gold, copper and aluminum. Exotic nanoparticles have emerged over the last several years, but nearly all have proven to be costly and none to date have been applied to volume applications. Table 2-1 summarizes the current worldwide PE materials market for 2012.

Table 2-1 Worldwide PE Materials Market by Product, 2012

Conductive Inks	Rev. ($M)	Percent
Silver flake	1,868	57%
Di-electric/insulator	721	22%
Silver chloride	262	8%
Carbon/graphene	197	6%
Copper/gold/platinum	98	3%
Carbon nanotube/silver/copper nanowire	33	1%
Other	98	3%
Total	**3,278**	**100%**

2.2 Printed Electronics Market Applications

The market for printed electronic assembly is still very much in its infancy after more than 10 years, but certain areas are slowly becoming established. Right now it hardly moves the needle as a measurable market compared with the current size of the traditional IC market that it will replace.

The definition of printed electronics is too limited today. While it clearly represents high opportunity in many product areas, the process of “printing” is not superior to “deposition”, as used in semiconductor manufacturing. In fact, PE roll-to-roll printing is technically inferior to vapor deposition, though it appears to have a higher potential for products with short turn-around time and customization. PE might appear to be more natural and efficient, but when all of the costs and production steps are taken into account, it is not clear if it is the most cost-effective solution in all cases.

Table 2-2 summarizes the current PE market in terms of revenue worldwide by application area for 2012.

Table 2-2 Worldwide PE Assembly Market by Application, 2012

PE Application	Rev. ($M)	Percent
Batteries	23	0.6%
Consumer electronics	426	11.1%
Displays	496	12.9%
Logic/memory	8	0.2%
Medical	223	5.8%
Packaging	12	0.3%
PCBs	402	10.5%
Photovoltaics	2,133	55.6%
RFID	21	0.5%
Sensors	36	0.9%
Transportation	43	1.1%
Textiles	12	0.3%
Other	6	0.2%
Total	**3,840**	**100%**

2.3 Printed Electronics Market Forecasts

The future market for PE has been over-hyped in forecasts for many years now. Yet, based on our field research, it seems clear that there are very strong application areas emerging today as identified above. It is hard not to be optimistic of high-technology electronics developments for two reasons: first, radically new technology does have the power to displace and sometimes eliminate conventional product technologies (think electronic internet replacing printed yellow pages), and second, low-growth markets rarely get much attention.

The PE market initially captured the imagination of the electronics industry, as it seems to be a fresh alternative to the intense and expensive path of semiconductor component manufacturing. Printing electronic devices can be cheaper in certain circumstances, as well as quicker and more practical than IC manufacturing (soldering of components on printed circuit boards is by nature labor-intensive). As a result, we are predicting a compound annual growth rate (CAGR) of nearly 20% over the next five years – with individual industry segments (and market applications – see Chapter 6) growing at a minimum of 8 percent and as high as 102 percent CAGR. Table 2-3 summarizes the worldwide PE market by industry segment from 2012-2017.

Table 2-3 Worldwide PE Market by Industry Segment ($M), 2012-2017

PE Industry Segment	2012	2013	2014	2015	2016	2017	CAGR
Consumer Products	426	479.3	544.4	622.3	715.0	826.5	14.2%
Displays & Lighting	496.0	561.5	640.9	728.3	826.5	936.9	13.6%
Medical Products	223.0	291.2	364.3	439.4	507.9	581.6	21.1%
Packaging	12.0	17.8	30.0	51.6	94.3	182.3	72.3%
PCBs	402.0	435.3	471.5	510.8	553.5	600.0	8.3%
RFID	20.5	21.6	23.1	25.2	27.8	31.0	8.6%
Solar PV	2,133	2,460	2,807	3,197	3,597	4,037	13.6%
Textiles	12.0	13.7	17.6	26.7	45.3	87.8	48.9%
Transportation	43.0	70.1	131.4	269.3	605.6	1,442.1	101.9%
Other General Apps	72.3	83.1	118.0	189.3	326.1	550.2	50.1%
Total	**3,840**	**4,434**	**5,148**	**6,060**	**7,299**	**9,275**	**19.3%**

Chapter 3 – Printed Electronics Technology

Printed electronics (PE) is a set of printing methods used to create electrically functional devices. PE is mainly a thin film coatings business today although many applications still involve the deposition of fine layers of conductive compounds. There is a wide variety of printed materials used in the coatings business for devices including conductive inks, transparent films, polymers, and other thin films that can be applied to various substrate surfaces consisting of silicon, glass, paper, plastic, metals, ceramics and inert materials. Key benefits of printed electronics are:

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The goal of printed electronics has been to utilize common printing equipment found in the graphic arts industry, such as screen printing, flexography, gravure, offset lithography and inkjet, as the means of creating electronic devices. Over the last 10-15 years, families of products have emerged that consist of active and passive devices, such as thin film transistors, resistors and capacitors, as well as finished products (RFID devices, solar cells and membrane switches to name just a few). Because of the inherent low cost of layering printed electronics coatings on to substrates, it is believed that large scale continuous devices can be made for simple applications not typically associated with conventional high performance (i.e., silicon-based) electronic devices.

Printed electronics differs from traditional semiconductor electronics in one signficant way. It is an additive production process as opposed to a subtractive one (i.e., material added only where it is required, versus blanket deposition and subsequent etching). This means that you only use as much material as is needed, eliminating waste and potentially reducing the bill for material so that a cheaper device can be manufactured – at least theoretically, as subtractive processes are still employed today.

Nearly all conventional semiconductor devices today, and most printed circuit board (PCB) technology, use subtractive wet or dry etching to remove unwanted material. This contrasts with PE's use of contact and non-contact printing technologies that create layers of conductive, semiconductive or insulating materials. The purported advantage of additive manufacturing is that you only use as much material as required, products can be created on an on-demand basis, and designs are not constrained by substrate size. Yet, in spite of the apparent advantages of PE, there has not yet evolved the "killer application" to drive volume and scale in production to the sort of levels that might compete effectively with traditional semiconductor electronics manufacturing. A major market has not emerged, with the possible exception of photovoltaics (PV), which is limited in terms of PE potential to the printing of bus bar circuit lines (a minor step in the whole assembly process). But this situation is changing.

PE technology starts with soluable material that has special electrical characteristics, and can be pasted or spread onto a surface (silicon, glass, plastic, paper, etc.), and then layered with other similar or dissimilar films to create a functional device. Not surprisingly, this is essentially what semiconductor manufacturing technology does except that it uses a vapor deposition approach, with etching or chemical washing processes to remove unwanted materials. The difference is that manufacturing traditional semiconductors is a time-consuming, laborious and expensive process, yet when done in a batch and on an enormous scale, yields amazingly cost-effective and productive devices that exhibit extraordinary functionality. The ROI in cost and yield via the batch-versus on-demand PE printing is still being played out, yet PE holds great potential in many exciting areas.

Printed electronics is particularly successful when applied to things such as disposable medical devices (glucose strips), flexible display surfaces, smart labels and patches, decorative and animated posters, and active, wearable clothing, sometimes called smart fabrics. Yet, PE products are mostly based on organic electronics or plastic electronics, where one or more functional inks are composed of carbon-based compounds. PE specifies the process of applying the material (e.g., solution-based, vacuum-based or other), which can be based on advanced organic semiconductors, inorganic semiconductors, metallic conductors, nanoparticles or nanotubes. These electronic thin-film materials are prepared by printing several functional layers on top of each other to simulate an electronic circuit by printing layers that resemble a traditional semiconductor integrated circuit.

3.1 Organic Electronics and Thin Film Technology

Organic Electronics (OE), plastic electronics and polymer electronics technology all employ conductive polymers, plastics, or small molecules. It is called "organic" because the polymers and small molecules are carbon-based, much like living organisms. Traditional electronics mainly relies on inorganic conductors such as copper and doped silicon which are electrically more efficient.

Organic conductors are lighter, more flexible, and less expensive than inorganic conductors. This makes them a desirable alternative in many applications so long as high performance is not a requirement. They also create the possibility of new applications, such as electronic paper or smart windows, which would be impossible using copper or silicon technologies. Additionally, organic conductive polymers are expected to play an important role in the emerging science of molecular computing.

Conductive polymers have a higher resistance and therefore conduct electricity slowly and inefficiently, as compared to inorganic conductors. Yet for simple applications such as RFID (radio frequency identification) or display packaging, an OE printed circuit is all that is needed. Yet for many applications, such as those that require complex logic and rapid response times, inorganic conductors will remain the only viable, albeit more expensive option.

Until now, however, circuits built with organic materials have allowed only one type of charge to move through them. The latest research provides for charges that flow both ways by positive and negative charges. Over the last 30 years, researchers have been working to make organic, or carbon-based, electronics by layering two complicated patterns one on top of the other, one that transports electrons and another that transports the positive holes. Over the past few years, polymers have been created with a donor and an acceptor element that can transport both positive and negative charges in one material. The material would allow organic transistors and other information-processing devices to be built more simply, in a way more akin to the manufacture of inorganic circuits.

Many of the major companies involved in organic electronics are directing their technology toward the production of displays. Electrophoretic displays are well suited for organic transistors because they are basically field- (voltage-) driven devices and require minimal current flow to drive them (power is required only to switch the state of the display). In the future, emissive devices, such as organic light-emitting diodes (OLEDs), made via printed applications, are expected to be integrated with organic transistor devices.

RFID tags have potential for using organic polymers to encode information. Since the mandates from Wal-Mart and the United States Department of Defense, there has been strong interest in using printing technologies for RFID. The critical economic threshold has been defined as the 1–5 cent price tag in order to drive demand into mass production and widespread use. The potential market for such tags could be in the billions of tags per year if economies of scale by printing the circuitry with antennas and additional functionality are attained (leading obstacles for RFID applications using organic materials involve high-frequency operation and rectification).

3.1.1 Organic Transistors

The first organic transistor was demonstrated in 1986, and as performance steadily increased throughout the 1980s and 1990s, integrated circuits were eventually fabricated. Organic complementary circuits, which are characterized by greater speed and lower power consumption compared with the first organic transistors, were first developed at Lucent Technologies (Bell Laboratories) in 1996. Since that time, depending on the composition of the materials, organic systems have been developed with deliberate semiconducting properties. This innovation immediately opened up a range of technology applications for conducting, insulating, and semiconducting polymers and organic transistors.

Organic transistors are thin film devices (referred to as OTFTs, or organic thin film transistors) constructed by successively depositing and patterning multiple layers of conductive material on an insulating substrate, similar to silicon semiconductors in which layers are typically etched and removed. An initial gate is deposited onto an insulating substrate such as glass, paper, or plastic, followed by the deposition of the gate insulator, which can consist of either an organic or inorganic dielectric film. The preferred screen printing method is flexographic (the forerunner of ink-jet) for polymer TFTCs (thin film transistor circuits) and related new materials, although traditional lithographic, gravure, and, more recently, spin coating technologies have been used on bar codes.

The primary goal of making organic transistors and integrated devices is to create circuits that are functional, inexpensive, and printable on demand. Organic thin film circuits can take the place of silicon circuits in applications that require short turnaround times, flexibility (not only for nonbrittle materials but also for variable configurations), and simple performance. Perhaps of more interest is that organic materials can be rendered into a liquid form and applied at room temperature and atmospheric pressure, and thus are ideal for printable formats. Thus, a new breed of low-cost electronics is emerging that can easily and quickly be applied via conventional ink-jet technologies at minimal cost.

3.1.2 Polymer Electronics

Only in the last few years has the field of polymer electronics emerged as technically and commercially viable. Compared with traditional ICs, which are cost effective only when produced in large batch quantities, continuous polymers can be cheaper, less sensitive to contamination, and more flexible for high-mix manufacturing. Traditional silicon electronics requires enormous precision and involves significant capital investment and process control. Consequently, the latest advances in organic electronic chemistry have presented the possibility of a new class of electronic circuits. Though still vastly inferior to silicon-based technologies, polymers have become attractive for applications that require low cost, flexibility, nonbrittle composition, and quick-turn manufacturing time. As a great variety of applications can tolerate these limitations, researchers and companies are beginning to explore products for new kinds of organic electronic materials.

There is a large variety of printable materials based on polymers which possesses conducting, semiconducting, electroluminescent, photovoltaic and other functional properties (until recently, most polymers were used as insulators and dielectrics). The starting point for the development of printable organic functional materials was the discovery of conjugated polymers (Nobel Prize in chemistry, 2000) and their development into soluble materials. This has led to the availability of many polymer materials in liquid form, i.e. as solution, dispersion or suspension.

Polymers today have varying electrical properties depending on their molecular structure. The material with the highest electrical conductivity is polymer PEDT (or PEDOT, polyethylenedioxythiophene). It is the basis for millions of polymer capacitors used in electronics today. More recently, nanoparticulate inorganic semiconductors or hybrid organic-inorganic semiconductor materials have been introduced that promise both the superior carrier mobility of inorganic semiconductors and the processability of organic materials. Finally, conductive inks are being developed that, when laid in complex paths imitating microvias, result in low-cost, functioning circuits. These materials can be applied using traditional printing techniques including lithographic (offset), flexographic, and gravure technologies.

Thin film electronics innovators have developed a specific group of polymers that are bistable and thus can be used as the active material in a nonvolatile memory application. In other words, they can be switched from one state to the other and maintain that state even when the electrical field is turned off. This type of polymer is “smart” to the extent that functionality is built into the material itself, including switchability, addressability, and charge storage. This is different from silicon and other electronic materials, in which such functions are usually only achieved by complex circuitry. “Smart” materials can be produced from scratch, molecule by molecule, allowing them to be built according to design.

Among the organic semiconductors most widely used in printed electronics are the conductive polymers poly(3,4-ethylene dioxitiophene), doped with poly(styrene sulfonate), and poly(aniline) (PANI). Both polymers are commercially available in different formulations and have been printed using inkjet, screen and offset printing or screen, flexo and gravure printing, respectively. Alternatively, silver nanoparticles are used with flexo, offset and inkjet printing, with the latter method also using gold particles. Many polymer semiconductors are processed using inkjet printing, with poly(thiophene)s like poly(3-hexylthiophene) (P3HT) and poly(9,9-dioctylfluorene co-bithiophene) (F8T2) frequently used. The latter material has also been gravure printed. Different electroluminescent polymers are used with inkjet printing, as well as active materials for photovoltaics (e.g. blends of P3HT with fullerene derivatives), which in part can also be deposited using screen printing (e.g. blends of poly(phenylene vinylene) with fullerene derivatives). A large number of printable organic and inorganic insulators and dielectrics exists, which can be processed with different printing methods.

By combining different print and production techniques, polymer electronics can be engineered in conductor paths of any desired length, with print layers of 1/1,000 millimeter in thickness. As the process technology evolves, polymer electronics will be able to integrate hybrid designs so that transistors, diodes, memory, and displays can be provided in a continuous and mass-printed form. To date, polymer electronics has produced touch-sensitive sensors (keys), digital memory (16–96 bits, depending on the available surface area on the substrate), processor logic, photovoltaic batteries, and color displays.

Color displays such as OLEDs (sometimes referred to as polymer OLEDs, or P-OLEDs) for cell phone screens, digital cameras, and handheld devices are one of the most promising and far-reaching applications for polymer electronics. By adding one or more organic materials in varying layers on substrate, low-cost circuits, logic devices, and even battery power sources have been manufactured on the same surface. A near-term application that utilizes all these technologies can be found in low-cost RFID (radio frequency identification) devices, which are expected to replace bar codes and be used in a wide range of logistics, control, and supply chain management applications.

3.1.3 Inorganic Materials and Composites

Inorganic materials and composites form a class of conductors with vastly better conductance and cost, and are ideal for producing superior printed laminar batteries, large electrophoretic, electroluminescent and electrochromic displays, and solar cells. Moreover, inorganic materials have been applied to quantum dot devices and used for transistor semiconductors such as logic and memory (zinc oxide) devices with ten times the frequency and mobility of organic devices, as well as providing greater stability.

Composites include oxides, amorphous mixtures and alloys. Increasingly, organic devices such as OLEDs employ a variety of inorganic materials such as boron, aluminum, titanium oxides and nitrides as barrier layers against water and oxygen. Similarly, aluminum, copper, silver and indium tin oxide are used as conductors, while calcium or magnesium can be developed as cathodes, cobalt-iron as nanodots, and iridium and europium used in light emitting layers on displays.

Starting in 2009, inorganic semiconductors were being sold from companies such as Kovio for RFID tags due to their much higher mobilities, as compared to organic semiconductors. Similarly, companies such as Pelikon and elumin8 have applied inorganic materials to flexible electroluminescent displays that involve six to eight layers, including a copper doped phosphor. These displays can be deposited on plastic or other film substrates that can cover an area of square meters and are capable of emitting a range of colors.

Solar cells offer some of the most promising applications for inorganic materials. For example, Spectrolab has demonstrated 40.7% efficiency with a gallium arsenide germanium solar cell, eight times that of the best organic (crystalline silicon) versions and far beyond the very best performance of poly-crystal silicon. One of the most popular solar cell technologies, CIGS (copper indium gallium diselenide) cells can be printed directly onto molybdenum coated glass sheets and other flexible substrates. In general, these materials are several orders of magnitude higher in cost than conventional polysilicon and a-silicon materials.

While inorganic materials yield higher efficiency and functionality, they are measurably harder to print unless they can be converted into a soluble form. As a result, hybrid printed electronics have emerged which combine organic materials with inorganic materials. Recent examples include dye sensitized titania photovoltaics and silicon nano-materials combined with organic transistors.

3.1.4 Inorganic Transistors

There are five major applications seeking to exploit the potential of inorganic compounds, notably those based on zinc oxide. Applications include RFID tagging, large area substrate displays, smart packaging devices, intelligent photonics with optical processing circuitry, and disposable electronics such as batteries. Numerous other materials include amorphous InGaZnO, gallium indium hydroxide nanoclusters and silicon nanoparticles ink.

Researchers at the Georgia Institute of Technology have developed a new type of three-dimensional photovoltaic system using zinc oxide nanostructures grown on optical fibers and coated with dye-sensitized solar cell materials. The approach could allow PV systems to be hidden from view and located away from traditional locations such as rooftops. The optical fiber would conduct sunlight into a building's walls where the nanostructures would convert it to electricity.

Leading industrial organizations such as Matsushita, Eastman Kodak, LG Electronics and Hewlett Packard are doing major R&D work which involves UV light emitting transistors and UV sensors that can be printed. Although zinc oxide can be modified from semi-metal to semiconductor and dielectric, it is traditionally seen as an n-type semiconductor. However, printable p-type zinc oxide devices are now emerging.

Several years ago DARPA announced a printed electronics amplifier with integrated sensors (chemical as well as mechanical) and printed antenna circuits. The Agency is seeking to create a new class of disposable devices that are low energy and low cost. The organization has over 60 different programs underway involving electro-chromatic displays, specialty lighting, general illumination and smart circuits printed on paper.

Printable inorganic compounds, notably those based on zinc oxide, have excellent semiconducting properties while gallium arsenide and CIGS are excellent semiconductor inorganic formulations for PV. To this end, Samsung, LG Chemicals, Solicore and CEA Liten are developing applications for laminar batteries. Similarly, ASK, Poly-Flex, Sun Chemical and other companies are developing inorganic conductors and integrated sensors for RFID memory, logic and antenna devices. Nanotubes and nanowires are being printed for PV, semiconductors, nano-lasers, and nano-rod piezo power applications.

3.1.5 Printable Electronics

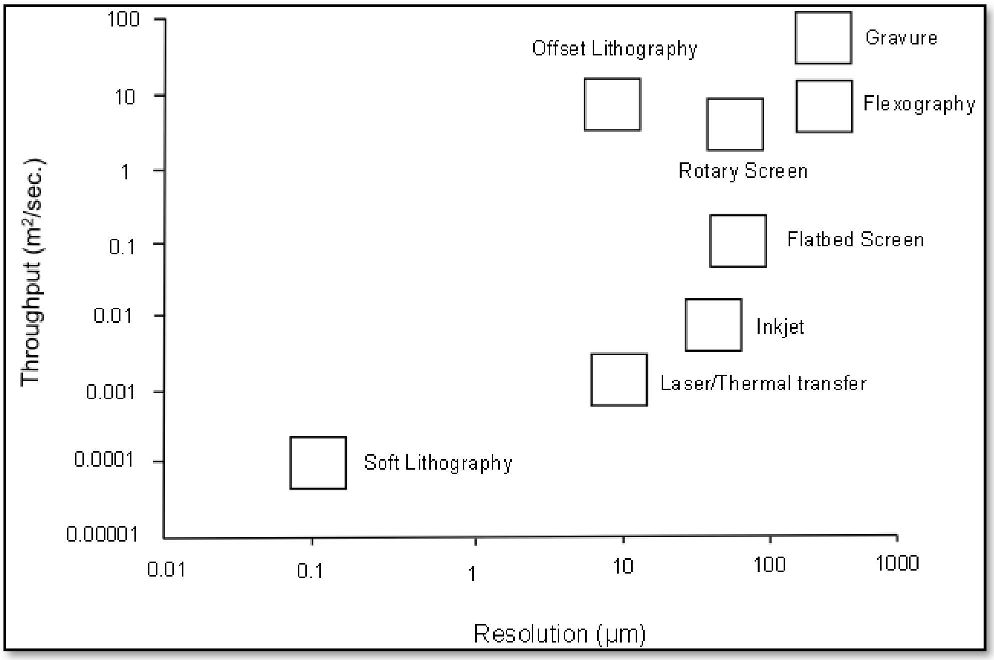
In conventional silicon microelectronics, patterning is done using photolithography (not to be confused with offset lithography discussed later), which is a subtractive iterative process. The active material is deposited initially over the entire area, and selected areas of it are removed. Although the technology is very high resolution and well established, photolithography is very complex, time consuming, and costly. It requires extremely expensive equipment, involves many precise steps, and is only suitable for patterning small areas. Photolithography is not generally compatible with organic electronic materials or flexible substrates, although its subtractive process is sometimes used in manufacturing applications. The harsh conditions required for dissolving resists (high temperatures and damaging chemical reactions), etching the underlying layers, and removing the photoresist can destroy the activity of most organic electronic materials.

The inherent appeal of printable electronics is the possibility of using conventional printing manufacturing processes (printing presses can produce large areas of media—up to hundreds of meters per minute—very quickly and inexpensively) to deposit conducting, semiconducting, and insulating materials, thus producing functional devices in high volume economically. The best example of this to date is the process used by E-Ink which manufactures the electrophoretic displays used in e-readers today. This involves a roll-to-roll plastic substrate with electronic microcapsules being deposited by an inkjet printer technology (discussed further in Chapters 4 & 5).

Organic semiconductors are highly dependent upon the deposition conditions and can be influenced by many factors, including solvent, concentration, deposition technique, deposition temperature, surface treatment, surface roughness, etc. Moreover, environmental conditions can also be a positive factor, as some organic semiconductors have ambient air stability and don't require encapsulation or an inert environment to maintain their performance.

The three main considerations for determining which printing process to use in making organic electronics are quality of process, throughput resolution, and cost. Printing processes with the highest resolution capability are also generally those with the lowest throughput (for example, techniques having a throughput >1 m^2/second are thought to be "high-volume" printing processes). The highest volume printing processes are highly desirable to enable the lowest cost production. Figure 3-1 compares throughput versus resolution for different printing processes.

Figure 3-1 Throughput vs. Resolution for Different Printing Processes



The printing processes selected for printable electronics are determined by various factors. One key factor is the materials to be used in the circuit, such as conductive inks, plastic substrates, and the viscoelastic properties of the materials being deposited. Another is the feature sizes (lateral resolution, ink thickness, surface uniformity) required by the device. Process throughput can vary by only a few millimeters per second (traditional ink-jet speeds) or up to 10 meters per second for high-velocity newspaper printing and naturally is dependant on both cost and quality. The ability to print individual circuits on demand through a continuous process has proven elusive, given the current costs of materials and throughput.

3.2 Printed Electronics Manufacturing Equipment

The Printing Industry of America states that in 2011, the industrial and specialty printing market comprised $82.8 billion in revenue. This was devoted almost entirely to graphics printing as required by commercial newspaper and magazine printing, forms/labels/tags, greeting cards, specialty printing, packaging printing and trade services. Table 3-1 below summarizes the US industrial printer market by application and printing technology for 2011.

Table 3-1 – Summary of US Industrial Printers by Application and Technology, 2011

Printing by Application	Rev. ($B)	Percent		Printing by Technology	Rev. ($B)	Percent
Commercial	56.1	67.8%		Lithographic	21.5	26.0%
Packaging	13.5	16.3%		Gravure	15.7	19.0%
Form/label/tag	5.2	6.3%		Flexographic	14.1	17.0%
Trade services	4.1	5.0%		Inkjet	12.4	15.0%
Specialty	3.4	4.1%		Screen	9.9	12.0%
Greeting cards	0.3	0.4%		Letterpress	6.6	8.0%
Other (PE)	0.2	0.1%		Other	2.5	3.0%
Total	**82.8**	**100%**		**Total**	**82.8**	**100%**

Source: PIA, NVR

It is generally agreed by leading industry participants that screen printing technology dominates the manufacturing of PE devices. This is because it has excelled in the printed circuit board (PCB) industry by laying circuit tracks with silver and copper pastes on the bare PCB. Screen technology has the advantage of being able to layer thick traces (something becoming less important with the new super-conductive nano materials) and is a proven technology. Less successful but emerging is the latest industrial inkjet technology, which is non-contact and capable of extremely precise deposition and high resolutions, and multiple layers (not without time delays). Other traditional printing technologies such as flexography, gravure, and off-set lithography are similarly employed because of their throughput speed, low cost per square foot, and comparable resolutions and feature sizes on wide scale formats. The continuous roll-to-roll production of these print technologies definitely holds promise for very high speed and low-cost PE OLED displays, PV thin films and logic/memory layers. Indeed, there are indications that a mix of print technologies will be necessary in the future to fulfill the most advanced PE product applications, integrating print and deposition technologies.

Inkjet technology has been gaining market share each year as a result of its higher margin for technical improvement (a digital versus an analog technology). This capability holds strong potential for PE applications because, even though inkjet is currently slower and more expensive than roll-to-roll processes, it is increasingly competitive if gang arrays of inkjet nozzles are put in a production line. Traditional wide-format roll-to-roll technologies perform better for mature applications that can leverage their process speed, accuracy and ultimate low cost on a per unit/inch basis.

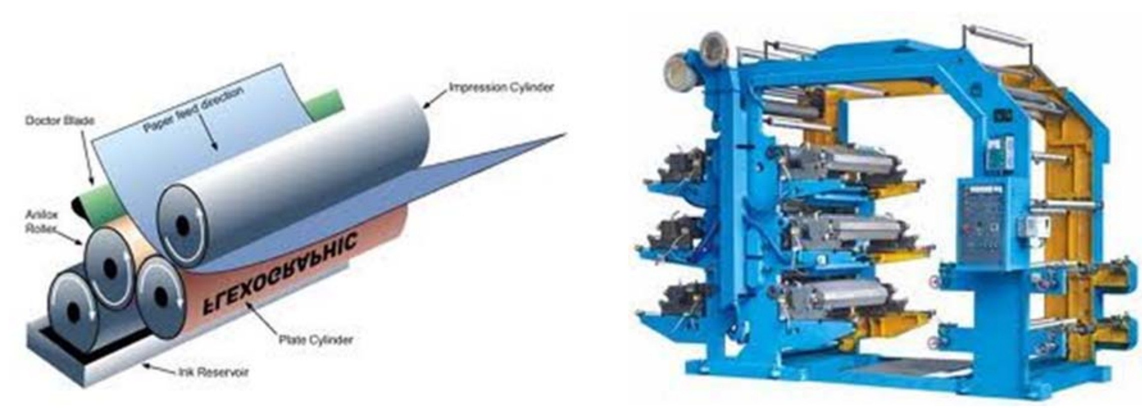
The five most common printing process technologies (flexography, gravure, inkjet, off-set lithography, and screen printing) accounted for an estimated 98 percent of the economic output in the domestic printing industry in 2011 in the US. Flexo, gravure and off-set are relatively similar roll-to-roll technologies with only slight differences in the application of inks and imprint surfaces. Screen print technology stands out in its ability to apply thick pastes and a variety of patterning resolution, as well as having been perfected for many years in mature applications. Inkjet technology has the advantage of being a noncontact technology that can be extremely high resolution and digital in content (thus, application and scale can be adjusted to the substrate), but is comparatively slow in throughput/curing time despite performance improvements with every year.

The following sections provide a more detailed discussion of leading PE print technologies:

3.2.1 Flexography

Flexography (often abbreviated to flexo) is a form of printing process which utilizes a flexible relief plate. It is essentially a modern version of letterpress which can be used for printing on almost any type of substrate, including plastic, metallic films, cellophane, and paper. Also, it is widely used for printing on the non-porous substrates required for various types of food packaging and is well suited for printing large areas of solid color (think supermarket items). Its broadest application concerns commercial printing needs in the food, beverages, and healthcare industries. Figure 3-2 provides an illustration and image of flexographic printing.

Figure 3-2 - Flexographic Print Technology



The advantages of flexography are that it is very high volume, the master plates are easy and inexpensive to make, and it can accommodate low-viscosity inks, so the process can be formulated from functional organic materials or particulate suspensions. The printing process is conformal and tolerant of substrate abnormalities (e.g., deformation). The disadvantages concern its limited resolution capability and dependence on the cells in the anilox roll (the edges tend to form a halo around certain printed features). Finally, some combinations of plate material and solvents may cause the printing plate material to swell or change its viscoelastic properties.

Examples of PE applications utilizing flexographic printers include flexible circuits where a single fluid is applied and situations where the substrate cannot be affected by heat changing its shape or chemical composition, such as plastic electronic displays. Commercial graphics applications are widely adopted and include advertising print, label and wrapper printing, office and legal printing and book printing. In addition, flexographic printing is starting to gain acceptance with transparent conductor grids and other nano-particle-dispersion conductor applications with an interesting play in seed-layer flexo print and copper electroplate.

In a normal implementation, flexographic printing involves two rolls in which ink is transferred from a pan via a fountain roll to an anilox roll. A chambered doctor blade controls the amount of ink that gets placed on the anilox roll and transferred to the printing plate.

Flexographic printing is frequently used for printing on plastic, foil, acetate film, brown paper, and other materials used in packaging. Flexography uses flexible printing plates made of rubber or plastic in which the inked plates with a slightly raised image are rotated on a cylinder that transfers the image to the substrate. Flexography uses fast-drying inks, is a high-speed print process, can print on many types of absorbent and nonabsorbent materials, and can print continuous patterns (such as for gift wrap and wallpaper).

3.2.2 Gravure

Rotogravure (gravure for short) is a type of intaglio printing process; that is, it involves engraving the image onto an image carrier. In gravure printing, the image is engraved onto a cylinder because, like flexography and offset lithography, it uses a rotary printing press. It has been the dominant technology of newspaper photo features, including commercial printing of magazines, postcards, and corrugated (cardboard) product packaging. Figure 3-3 provides an illustration and image of gravure printing.

Figure 3-3 - Gravure Print Technology

Gravure printing is the process by which ink is applied to the entirety of an engraved gravure cylinder, after which thin steel "doctor blades" scrape off excess ink and the ink remaining in the recessed cells of the cylinder is transferred to the substrate. Gravure printing is particularly well suited for multicolor printing, and also makes high-speed, large-volume printing possible, so it is employed for printing magazines as well as the plastic film packaging used for food products and pharmaceuticals.

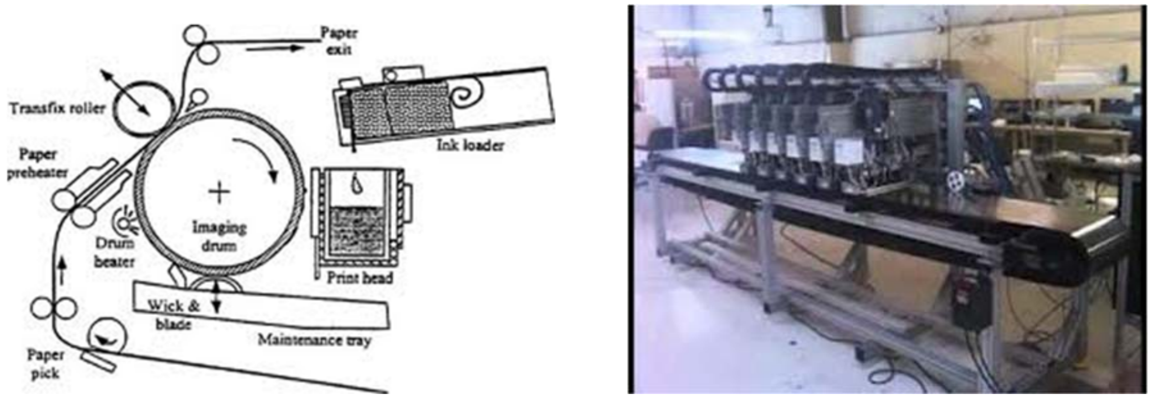
A derivative of gravure printing is gravure offset printing, more commonly known as pad printing. In pad printing, there is an intermediate step between inking the plate and transferring the ink to the substrate (hence offset). The advantages of gravure printing are its high throughput rate, the ability to place different amounts of ink in different areas, and the capability of using low-viscosity particulates. Disadvantages are the need for substrates to be smooth and the high cost of making printing plates.

An example of PE applications utilizing gravure printing technology today are thin films for non-volatile memory and logic circuits such as those manufactured by ThinFilm Electronics, Inc., a PE company headquartered in Oslo, Norway. The company utilizes a gravure print technology of its partner InkTec, Ltd., based in South Korea, to manufacture its memory and logic devices via very precise thin film layers that create memory and more recently logic devices for games, toys and various product packages that integrate sensor devices.

3.2.3 Inkjet

Inkjet printing is a computer printing technology that creates a digital image by propelling droplets of ink onto a substrate. Inkjet printers are the most commonly used type of consumer printer (along with laser printers – a roll-to-roll technology) for personal documents. Commercial brands are now being developed for many printed electronics applications, although they are quite expensive according to customers. Figure 3-4 provides an illustration and image of inkjet printing.

Figure 3-4 - Inkjet Print Technology

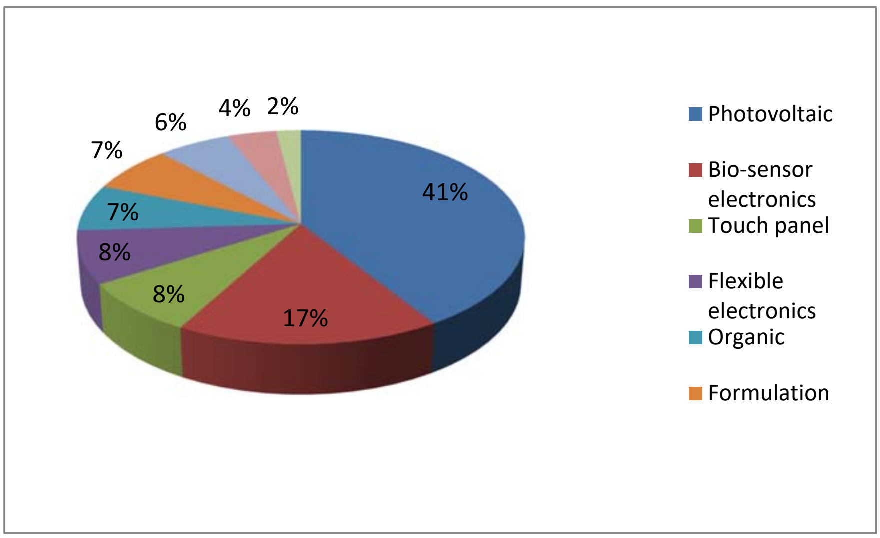


Inkjet printing is particularly good for the deposition of small amounts of materials that have specific electrical or structural functionalities onto well-defined locations on a substrate. The materials deposited can be soluble liquids, dispersions of small (nano-sized) particles, melts, or blends. The main advantages of inkjet printing are the ability to change what is printed without making a new printing plate and the ability to print variable digital patterns. As a result, inkjet printing can achieve excellent resolution, uses a wide range of ink types (conductive, hot melted wax, solder, biomaterials, etc.), is receptive to on-the-fly error correction (e.g., on flexible substrates), uses small amounts of materials that involve little waste, can build up layers, and is a "clean" noncontact technology. The disadvantages are that it has fairly slow throughput, is sensitive to substrate variations, has problems with ink spreading ("coffee stain" effects), and has limited printing speeds and print head solvent compatibility (jetting reliability issues).

The challenge is controlling the interaction between droplets and substrate. Piezo heads do fail as droplet forming is intrinsically unreliable. These fundamental aspects are overlooked and largely not appreciated by other inkjet protagonists. Another problem can occur if the substrate being printed on is flexible, leading to dimensional deformities and, over large areas, misalignment problems, layer-to layer registration errors, and, ultimately, device failures. Often, organic materials are susceptible to high mechanical shears resulting from the piezoelectric print heads or the high temperatures in thermal ink-jet heads. Finally, there are challenges in achieving uniformity and fidelity of the drop placement of the ink from the inkjet head, which can lead to irregular spreading of the edges and the rise of unwanted satellites.

Perhaps the most criticized aspect of inkjet printing is its slow material throughput, although this is changing. Inkjet printing, though continuous in nature, is comparatively slow and limited in its size and format. If RFID and OLED device applications reach the volumes and cost equations being projected by some, it seems likely that conventional lithographic or gravure printing technologies will emerge as more suitably cost effective for the production of OTFT and other devices. Figure 3-5 below summarizes inkjet printer applications for PE in 2012.

Figure 3-5 – Industrial Inkjet Printer Applications for Printed Electronics, 2012



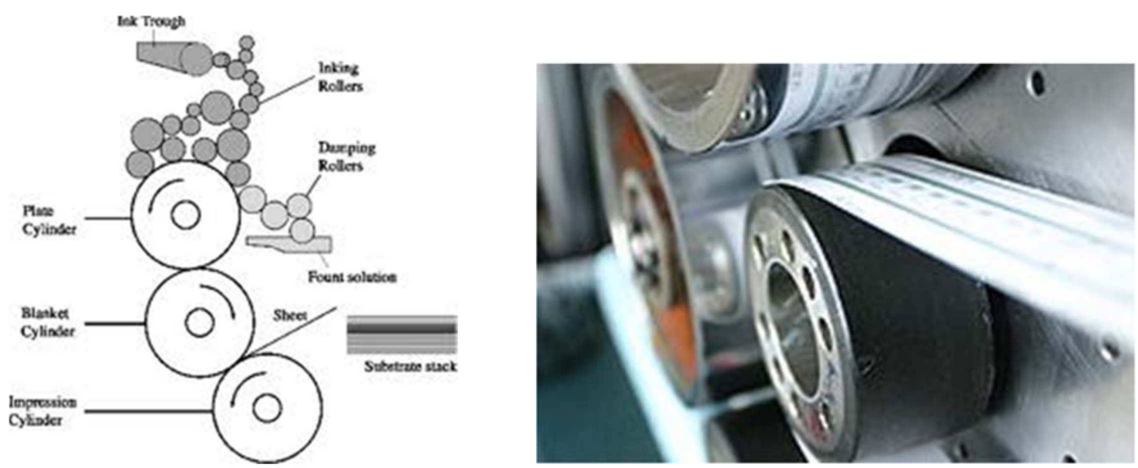
The industrial inkjet supplier market is constrained due to the technical challenges involved in manufacturing the inkjet head nozzles for precision ink placement. Some of the pure play leading suppliers of inkjet print heads (which is where most of the intellectual property resides) are Fujifilm Dimatix, Ceradrop and Xaar. Large OEM inkjet system suppliers include Canon, Epson, HP, Konica Minolta, and Oce.

Overall, the ability to make instant changes in the layering, size, shape, and depth of a pattern makes inkjet a preferred technology for polymer thin-film printable electronics. Significantly, because inkjet printing equipment is usually smaller and often considerably less expensive than conventional printing equipment, it is better suited to the needs, variability, and integration requirements of printable electronics designs.

3.2.4 Off-Set Lithography

Offset lithography printing is a commonly used printing technique in which the inked image is transferred (or "offset") from a plate to a rubber blanket, then to the printing surface. When used in combination with the lithographic process, which is based on the repulsion of oil and water, the offset technique employs a flat (planographic) image carrier on which the image to be printed obtains ink from ink rollers, while the non-printing area attracts a water-based film, keeping the non-printing areas ink-free. Figure 3-6 provides an illustration and image of offset lithography printing.

Figure 3-6 – Offset Lithography Print Technology



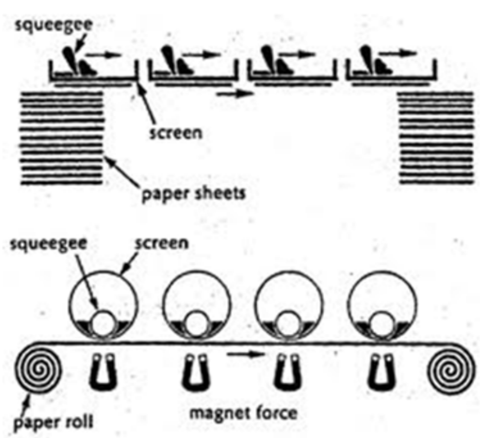
It is probably the most common printing process, and works on differences in the surface energy of the printing plate, so that the ink sticks to the image areas of the plate. The term offset comes from the fact that the ink is transferred from the plate to an intermediate roll and then to the substrate. The intermediate roll is known as the offset cylinder. Advantages include high volume throughput capability, good edge definition, and thin ink layers, which are good for particulates. Disadvantages are thin inks that make electrical conductivity difficult, and the use of an aqueous (water-based) fountain solution, which is often not good for polymers.

Offset lithograhy is similar to flexo and gravure in so far as it is printing of thin films for PE. Yet, because R&D today is mainly focused on graphic or commerical printing, we do not see significant innovations emerging for this technology for PE, although it is clearly possible. The most promising applications involve flexible organic displays, logic/memory and PV layers where single thin-film deposition is needed without excessive curing or sintering.

3.2.5 Screen Printing

Historically called silk-screen printing, screen printing is a slightly more elaborate version of stencil or mask printing. Although not normally considered a high-volume printing process, the volume can be increased considerably by using rotary screen printing. The advantages and disadvantages are similar to those of offset lithography. Figure 3-7 provides an illustration and image of screen printing technology.

Figure 3-7 – Screen Printing Technology

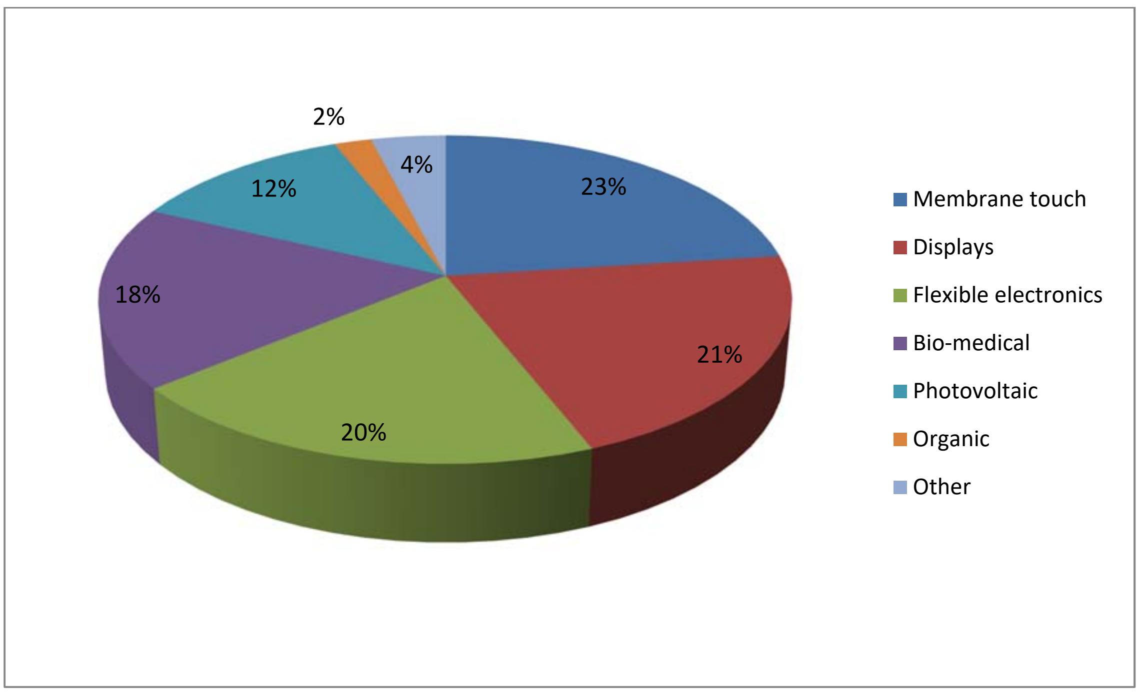


Screen printing is a printing technique that uses a woven mesh to support an ink-blocking stencil. The attached stencil forms open areas of mesh that transfer ink or other printable materials which can be pressed through the mesh as a sharp-edged image onto a substrate. A fill blade or squeegee is moved across the screen stencil, forcing or pumping ink into the mesh openings for transfer by capillary action during the squeegee stroke. A number of screens (more than one) can be used to produce a multicolored, and/or layered image.

Examples of PE applications utilizing screen printers mainly involve the production of printed circuit boards, where a mask is applied to direct a metal (copper, silver or other) circuit path on a bare board with attached components, or in applications that require thick layers of materials such as OLEDs/EL displays, batteries/PV technology, membranes/touch panels, sensors and biomedical glucose test strips. A disadvantage of screen print technology is its limitation to applications of more than one meter square (which is the largest area that can be covered using a silk screen) and manufacturing turn-around time (throughput/curing).

Screen printing is clearly the most established technology today for manufacturing PE products in a wide variety of applications. Chris Walker, Vice President of Business Development for Preco, Inc., headquartered in Lenexa, Kansas, believes that screen printers hold a competitive edge for PE, at least for now. "Our experience is that customers need to apply additive and subtractive coating technologies depending on product application, which may involve laser scribing and etching to refine the circuit paths. This same technology is also pervasive in smart phones today where several layers of material must be coated on glass for the touch sensitive displays as well as in most membrane switch products. Our screen technology is able to refine the conductive and resistive qualities by layer thicknesses to achieve extremely high film accuracy and repeatability." While other print technologies such as inkjet certainly are encroaching, Walker believes that existing screen technology today best meets the needs of the customer applications with which his company is currently engaged. Figure 3-8 summarizes the leading PE applications for Preco's screen printing technology in 2012.

Figure 3-8 – Summary of PE Screen Printer Technology Applications, 2012



3.2.6 Substrates

The development of new and versatile substrates is essential to printable electronics. Many different types of materials are under investigation, including paper, glass, plastic, polymer films, and metallic foils. Ideally, these substrates will be readily bendable and rollable and able to accommodate different types of integral technologies, such as LCDs and OLEDs, electrochromic and electrophoretic inks, and various printable logic devices and power sources.

Printed electronics allows the use of flexible substrates, which lowers production costs and allows fabrication of mechanically flexible circuits. While inkjet and screen printing typically imprint rigid substrates like glass and silicon, mass-printing methods almost exclusively use flexible foil and paper. Poly(ethylene terephthalate)-foil (PET) is a common choice, due to its low cost and higher temperature stability. Poly(ethylene naphthalate)- (PEN) and poly(imide)-foil (PI) are alternatives. Paper's low costs and manifold applications make it an attractive substrate, however its high roughness and large absorbency make it problematic for electronics.

Some of the key challenges for substrates in PE applications include:

- Low shrinkage
- Low co-efficient of thermal expansion
- Upper temperature for processing
- Surface smoothness
- Solvent/moisture resistance
- Modulus, strength and rigidity
- Commercial availability and supply consistency

Researchers at General Electric Plastics created a plastic-substrate system that they claim will lead to more flexible, lighter, more durable OLED-based displays. It is believed that this will be less costly to build than those based on glass substrates because it combines a high-temperature Lexan polycarbonate film with a transparent coating that protects the display from oxygen and moisture. Looking to the future, GE says the system should be amenable to high-volume manufacturing processes, so that costs can be reduced.

The Department of Defense is especially interested in developing plastic substrates for the deployment of ultra-thin yet flexible screens as standard equipment for the Pentagon's "information warrior" of the next century. With plastic displays, soldiers could hang satellite navigation system displays on their belts or keep electronic maps rolled up in a back pocket.

Currently, TFTs for active-matrix displays are manufactured onto a rigid glass substrate in a process that involves baking glass sheets at temperatures of up to 600°C. However, a team of Lawrence

Livermore researchers is now showing how TFTs can be manufactured on top of thin, flexible plastic sheets instead of glass by keeping manufacturing temperatures at or below 100°C. The plastic substrate project, now in its third year, is funded by the DARPA's High-Definition Systems Program, which sponsors development of new display concepts that address the issues of lighter weight, improved ruggedness, lower power, higher resolution, and easier use.

3.2.7 E-Paper and Displays

Electronic ink displays using electronic paper or e-paper are a display technology designed to mimic the appearance of ordinary ink on paper. Unlike a conventional flat panel display, which uses a backlight to illuminate its pixels, electronic paper reflects light like ordinary paper and is capable of holding text and images indefinitely without drawing electricity, while allowing the image to be changed later.

To build e-paper, several different technologies exist, some using plastic substrate and electronics so that the display is flexible. E-paper is considered more comfortable to read than conventional displays. This is due to the stable image, which does not need to be refreshed constantly, the wider viewing angle, and the fact that it reflects ambient light rather than emitting its own light. An e-paper display can be read in direct sunlight without the image fading. Lightweight and durable, e-paper can currently provide only a monochrome display (i.e., black on white). The contrast ratio in available displays as of 2008 might be described as similar to that of newspaper, though newly-developed implementations are slightly better. There is ongoing competition among manufacturers to provide full-color capability.

Applications include electronic pricing labels in retail shops, and general signage, time tables at bus stations, electronic billboards, the mobile phone Motorola FONE F3, and e-Readers capable of displaying digital versions of books and e-paper magazines. Electronic paper should not be confused with digital paper, which is a pad to create handwritten digital documents with a digital pen.

Most electronic inks have suffered from comparatively low conductivities. Higher conductivities have been achieved from thicker, screen-printed silver pastes, although these materials inevitably require a high temperature sintering stage to achieve optimum conductivities, which naturally limits the choice of substrate materials. Inkjet printing of printed circuit boards has not generally been possible using metal particle inks since the particle size and tendency to agglomerate seriously impacts the reliability of the printing process. New developments exploiting metal nanoparticles in inks have opened the door to inkjet printing, but the thin layers produced and the need for sintering still limit the usefulness of the process.

There is a process, however, that provides a means of separating the additive patterning and substrate adhesion from the conductivity requirements of the printed features. Conductive Inkjet

Technology has developed a process in which a catalytic ink is printed on the substrate and UV cured to provide a rapidly processed and adherent base layer. The layer itself is non-conducting but acts as a catalyst for the electroless deposition of metal layers.

3.2.8 Summary

While printer technology is pivotal to the growth of the PE market, it is unresolved which method will dominate or enable this industry to realize its potential. Indeed, it will likely be a mix of traditional and evolving print technologies depending on the application. According to Darrell Etter, a Customer Support Engineer with FujiFilm Dimatix in Santa Clara, CA, "The PE industry cannot progress with just one process. In some cases, inkjet is the best solution, but in others screen technology will still be used." This is corroborated by Andrew Ferber, Co-Chairman of leading PE firm T-Ink, headquarted in New York, NY, who notes, "As of today there is no primary printing method we use. We did begin with traditional screen printing but have developed inks and systems for most any type of printing and its variations from offset, gravure, flex, inkjet...frankly, you name it – and we have inks that we have designed. We have also designed specific systems that are complementary to most any type of equipment."

Rich Morris, owner of Saxby Business Development and consultant to Si-Cal and PChem, points out that there are good reasons for this. "Screen technology is mature and relatively cheap for applications like diagnostic test, such as blood glucose strips, EKG and iontophoresis drug delivery because of its ability to deposit thicker film layers with good deposition consistency. Yet, inkjet can be very precise and thin, and has important applications in PV, OLEDs and bio-sensor electronics, although it can be quite expensive to achieve these ends due to the multiple inkjet head arrays needed to ensure redundancy for high volume production."

With the emergence of nanoparticles and improvements in decreasing the drop size on conductive polymers, ink-jets are able to print a wide variety of devices, including capacitors, inductors, resistors, and transistors. With the development of multiple print heads, hybrid printing of electronic components of 3-D structures has been achieved, improving performance and integration. Finally, ink-jet printing has achieved sufficient speed and throughput to compete with conventional printing methods. Furthermore, ink-jet printing has turnaround times that conventional printing cannot hope to reach.

It is evident that there are a wide variety of print technologies driving the emerging PE market. Table 3-2 summarizes the pros and cons of print technology in a matrix by performance attributes as it applies to the current PE market, according to our field research.

Table 3-2 – Summary of PE Print Technologies by Performance Feature, 2012

Print Method	Throughput	Curing Time	Ink Resolution	Ink Viscosity	Best Applications	Pros	Cons
Flexography	150,000 feet/hour	10s of seconds	< 1-6µm	50-300 CPS	RFID, PV, OLED/OPV, membrane, smart packaging	Large formats, inexpensive, simple process, range of substrates.	Halo effect, can change viscoelastic properties of substrates, set up cost
Gravure	175,000 feet/hour	10s of seconds	4-18µm	50-200 CPS	RFID, memory/logic	Large formats, high quality, ability to place low-viscosity particulants, variable thickness	Expensive, high cost of printing plates and tooling, requires smooth substrates
Inkjet	Dependant on layer thickness	Very High	7-20µm	Very Low	RFID, OLEDs, PV	Little waste, precise deposition, multiple layers of materials, expanding formats, wide variety of inks	Lack of functional inks, sensitive to substrate variations, coffee stain effect, jetting reliability issues
Offset Lithography	180,000 feet/hour	High	0.2-0.75µm	Low	RFID, PV	Large formats, range of substrates	Water based solutions not good for polymers, thin inks making conductivity difficult
Screen	4500 feet/hour	High	20-60µm	10,000 - 50,000 CPS Thick	RFID, PCB, Medical sensors, Diagnostic test strips, Membrane Touch switches, Automotive heaters/sensors.	Variety of material, thick patterning/ proven technology	Limited in size and resolution, slower than R2R graphics

Chapter 4 – Printed Electronics Materials Market

4.1 Conductive Inks

It can be said without much exaggeration that the conductive inks and thin films that make up the PE market are the elixirs behind its success. This certainly has been the case with conductive membrane switches, photovoltiac (PV) films and electropheric displays. But the PE materials market is surprisingly dominated by one material – silver, in the form of silver paste (or flakes of micron size) and silver chloride – which accounts for up to 65 percent of the market today according to industry sources. Other materials that are also in use include di-electric insulating thin films, as well as conducting carbon/graphite compounds, and in limited cases gold, copper and aluminum. Exotic nanoparticles have emerged over the last several years, but nearly all have proven to be costly and none to date have been applied to volume applications. Table 4-1 summarizes the current worldwide PE materials market for 2012.

Table 4-1 Worldwide PE Materials Market by Product, 2012

Conductive Inks	Rev. ($M)	Percent
Silver flake	1,868	57%
Di-electric/insulator	721	22%
Silver chloride	262	8%
Carbon/graphene	197	6%
Copper/gold/platinum	98	3%
Carbon nanotube/silver/copper nanowire	33	1%
Other	98	3%
Total	**3,278**	**100%**

The excitement in the PE market and its demand for thin film materials have spawned a rush to invest and develop newer materials and patterning processes such as can be seen in companies like Kovio, Plextronics, PolyIC and Soligie. These materials seem to receive the most press, yet our investigations have demonstrated that the applications are still years away from being implemented on a volume basis. The majority of materials and processes are still in R&D and few companies are manufacturing any PE applications profitably.

Looking back over the last 30 years there have been many successful, albeit mundane, PE commercial applications such as membrane touch switches, battery testers, biosensors, electroluminescent lamps, and RFID antennas. Most of these have been the result of applying polymer thick film (PTF) ink (now more commonly known as a functional printed ink) on rigid circuit boards or flexible substrates via screen printing technology. Silver is preferred because of its good conductivity, performance stability, resistance to oxidization, malleability, relatively affordable cost, low curing temperature (< 150 °C) and high volume manufacturability.

The basic elements of any functionally conductive ink are the powder (considered the active element), resin (providing the glue for the powder and substrate), and solvent (to control the rheology chemistry). The polymer binder, when combined with the conductive and solvent phases, is a liquid that can be "printed" onto polyester film, forming flexible printed circuits. After printing, the solvent is evaporated out of the mixture, leaving a stable conductive pattern on the flexible substrate.

While the conductive inks can be applied by almost any printing technology, it appears that screen printers are the application of choice followed somewhat distantly by inkjet printing, litho/flexographic and related roll-to-roll methods as discussed in our previous article. Recall from Chapter 3 that screen printing accounted for approximately 85 percent of all new PE applications compared to roughly 14 percent for inkjet (the remaining one percent is allocated to other printing technologies).

Printing electronics by additive methods can be much more efficient than traditional semiconductor subtractive methods (deposition and removal) in terms of cost and process time. For example, the production of a traditional LCD screen is normally composed of two pieces of glass with liquid crystal material in the middle, polarizers on both surfaces as well as a backlight, diffuser and reflector. In the case of an electrophoretic display, only one piece of glass is required at the bottom, along with a plastic covering film, minus the backlight, diffuser, and polarizers. The result is an equivalently functional display that is about half the thickness as a reflective LCD and a fraction of the thickness of a backlit LCD (and significantly less costly). Additionally, the EP display is much lighter and consumes 1/80th the power in most applications compared to LCD. (The black/white E Ink ePaper display for the Kindle/Nook can last up to one or more months on a single charge because it is an image persistent technology, providing up to 90% power saving, whereas a similar sized backlit LCD display might only last a few hours.) Finally, given that there is less rigid material, the EP display is inherently more reliable and infinitely more rugged as there is no crystal chemistry to be broken or degrading circuit failures.

For many people today the notion of printable electronics is synonymous with the printing of conductive or metallic inks, invariably for circuit paths, contact switches and closures. Different materials distinguish themselves by their conductivity, particle size, curing conditions, availability and cost. Compared to silver-based materials, copper is a low-cost option and offers high conductivity in its bulk form. Turning copper into inks has however been a challenge, primarily due to oxidization effects which are accelerated under warm and humid conditions. Oxidization turns copper into an insulator.

While some use copper rather than silver to reduce cost, others are progressing carbon nanotubes (CNT) and graphene as viable alternatives to Indium Tin Oxide (ITO), especially for transparent conductive films. One of the more interesting companies to emerge from this field is Liquid X Printed Metals, a start-up founded by the former CEO of Cambridge Display Technology, Dr. David Fyfe. Liquid X is embedded within Carnegie Mellon University in Pittsburgh, Pennsylvania, and is focused on manufacturing functional metallic inks which, unlike other metallic conductive inks, contain actual metal atoms, not nanoparticles or metal flakes. This improves the processing parameters by offering high conductivity, low conversion temperatures, short processing times and thin layers of deposition. The low temperature processing allows a wide range of substrates to be used including fibrous materials such as paper and gauze, as well as flexible, organic material such as plastics which can be deposited via inkjet, slot die, flexography, offset, and gravure printing.

While Liquid X's materials are exotic, they aren't expected to sell more than several liters of the ink, and when compared to silver flake, which today is sold in metrics tons, will hardly move the needle in the world of PE. As a result of the dominance of silver paste, there is one application that far outscales any other in size for PE materials according to industry participants. It concerns the PV solar cell market which requires the patterning of bus bar lines in crystalline silicon PV cells. According to industry sources, the silver paste PV market accounted for an estimated $1.5 billion of material in 2012 in which bus bar circuit paths connected over 10 million solar cells into 300,000 PV panels. The bus bars laid down by screen printers are estimated to account for 86% of all silver usage today, followed distantly by membrane switches, bio-medical test strips, displays and other flexible and textile applications. All indications are that the PV market will continue to grow in terms of gigawatt capacity, yet the amount of silver paste usage will decrease as part of ongoing cost reductions. Table 4-2 summarizes the current worldwide PE conductive inks market by application for 2012.

Table 4-2 - Worldwide PE Conductive Inks Market by Application, 2012

PE Conductive Ink Applications	Rev. ($M)	Percent
Consumer electronics	274	8.4%
Displays	364	11.1%
Medical	123	3.8%
Packaging	6	0.2%
PCBs	210	6.4%
Photovoltaics	2,196	67.0%
RFID	23	0.7%
Security/Safety	20	0.6%
Smart cards	13	0.4%
Textiles	11	0.3%
Transportation	21	0.6%
Other	17	0.5%
Total	**3,278**	**100.0%**

Kevin Chen is the Chief Marketing Officer for Applied Materials' solar cell manufacturing division (Energy and Environmental Solutions) and is the reported leader for screen printing technology that prints bus bar lines onto solar cells. In order to drive down costs, the company has developed technology to reduce the line width by essentially stacking or increasing the vertical height of the line. The narrower lines use less silver and allow more sun absorption for the solar cell. According to Chen the use of silver paste accounts for approximately 20 percent of the cell's production. Leading silver paste suppliers include DuPont, Dow Chemical, Henkel, BASF, Heraeus, Ferro, Asahi Kasei ITOCHU and Sun Chemical.

For the last several years, there has been strong interest in flexible PV substrates that utilize more exotic solar thin-film materials such as CIGS (copper indium gallium selenide) and CdTe (cadium telluride) that can be printed on to a surface (plastic, roof tile, glass, etc.). Global Solar Energy was one of the first companies to develop a production process to print this material on to plastic, but the costs of this technology could not keep pace with crystalline silicon, despite the higher conversion efficiency. Currently, the amount of R&D being invested in crystalline silicon vastly exceeds the R&D being invested in thin films so that the industry momentum and infrastructure is behind crystalline silicon, making it the technology of choice for solar PV.

The application of functionally conductive inks has penetrated a number of industries. In a recent paper authored by four employees of DuPont Microcircuit Materials titled "Advances in Conductive Inks across Multiple Applications and Deposition Platforms," the authors state that, "Historically, automotive and military/defense were the key markets for DuPont products in the 1980s, largely due to the high reliability requirements of Hybrid ICs on ceramic substrates. Those applications still exist today, but over the past 10 years we have seen displays and photovoltaics become major areas of focus for our business. The resulting increase in volume and batch size demands has led us to further expand our global manufacturing operations, and this has positioned us well to succeed as the next generation of market segments emerge."

4.2 Conductive Films

Transparent conducting films (TCFs) are optically transparent and electrically conductive in thin layers. TCFs for photovoltaic applications have been fabricated from both inorganic and organic materials and are mainly used in displays, some solar applications and touch screen modules. It has been stated in the literature that as much as 93 percent of the market is derived from Indium Tin Oxide (ITO). Unfortunately, TCFs do not fit the definition of PE material because they are applied by using a chemical vapor deposition process, electron beam evaporation, and physical vapor deposition, not a traditional inkjet printed or roll-to-roll technology. While it is a significant market given its product applications (wireless mobility products), it does not, strictly speaking, fit the definition of a PE material.

Transparent conducting films act as a window for light to pass through to the active material beneath (where carrier generation occurs), as an ohmic contact for carrier transport out of the photovoltaic, and can also act as transparent carrier for surface mount devices used between laminated glass or light transmissive composites. Transparent materials possess bandgaps with energies corresponding to wavelengths which are shorter than the visible range of 380 nm to 750 nm. As such, photons with energies below the bandgap are not collected by these materials and thus visible light passes through. However, applications such as photovoltaics may require an even broader bandgap to avoid unwanted absorption of the solar spectra.

Indium tin oxide is one of the most widely used transparent conducting oxides because of its two chief properties, its electrical conductivity and optical transparency, as well as the ease with which it can be deposited as a thin film. As with all transparent conducting films, a compromise must be made between conductivity and transparency, since increasing the thickness and increasing the concentration of charge carriers will increase the material's conductivity, but decrease its transparency.

While ITO is ostensibly a thin film, it is most commonly deposited on surfaces by electron beam evaporation, physical vapor deposition, or a range of sputter deposition techniques, not via any printing technology utilized by PE.

4.3 Microcapsules

Is it a thin film, or is it an inorganic or composite material? The microcapsules that make up the optical component of a film used in electronic paper displays for E Ink are certainly unique. The so-called ink is coated onto a sheet of plastic film that is laminated to a layer of circuitry. Each microcapsule contains positively charged white particles and negatively charged black particles suspended in a clear fluid. When a positive or negative electric field is applied, corresponding particles move to the top of the microcapsule where they become visible to the user. This makes the surface appear white or black at that spot. The circuitry forms a pattern of pixels that can then be controlled by a display driver. A finishing laminate is applied to a protective surface, which could be glass, plastic, fabric and even paper, and completes a functional display.

E Ink's displays also support a variety of solutions for touch. These solutions include inductive touch sensors, resistive sensors, capacitive sensors, or infrared sensors. The result is a rugged, low power display device that is easy on the eye due to its non-emissive nature. E Ink has been so successful commercializing this technology that it holds an estimated 90% of the electrophoretic display market found in e-readers, yet its technology has been designed into signs, wrist-watches, smart cards, toll booth transceivers, and membrane keyboards. The company licenses its technology to other companies or sells its film material to third party companies like Pervasive Displays, Motion Display, Neolux, LG and others.

E Ink was purchased in 2009 by Prime View International (now E Ink Holdings) which in turn is owned by YFY Paper Mfg. Co., headquartered in Taipei, Taiwan. The original company was founded in 1997 and is still located in Cambridge, Massachusetts, where it operates as a printed electronics company and South Hadley, MA, where other production operations take place. E Ink USA manufactures its microcapsules and coats them using a roll-to-roll process on a plastic substrate approximately 1 meter in width but nearly endless in length (videos show rolls approximately 1000 meters long).

From here the display technology is shipped to YangZhou, China, where another subsidiary of YFY named Transcend Optronics packages the modules with a TFT or plastic back plane and related driver/controller/SOC chips. After this, the completed modules can be integrated into one of many e-book final products such as the Kindle or Nook—usually produced by a third party or contract manufacturer such as Foxconn or Flextronics. In a practical sense, the company is separated by its core technology and IP residing in the U.S., and its manufacturing and final assembly operations performed in low-wage China. Because of its dominance in the electronic paper display market, E Ink today describes itself as a display company, as defined by its microcapsule technology, rather than a PE company.

4.4 Organic/Inorganic Transistors, Polymers, et al

There has been much written and spoken about the development and potential of the latest organic and inorganic transistors and related electronics over the last several years. To date, most have stayed within the R&D laboratories with the exception of some printed transistor circuits, flexible OLED technology, electronic paper/displays and other thin films. The preferred printing technology is screen printing such as flexographic for polymer transistor circuits and related new materials, although traditional lithographic, gravure, and, more recently, spin coating technologies have been used on bar codes.

The primary goal of making organic transistors and integrated devices is to create products that are functional, inexpensive, and printable on demand. Organic thin-film circuits can take the place of silicon circuits in applications that require short turnaround times, flexibility (not only for nonbrittle materials but also for variable configurations), and basic performance. Perhaps of more interest is that these materials can be rendered into a liquid form and applied at room temperature and atmospheric pressure, and thus are ideal for printable formats. A new breed of low-cost electronics is emerging that can easily and quickly be applied via conventional ink-jet technologies at minimal cost. Over the last few years we have seen new applications coming from companies like Thin Film, PolyIC, Soligie and others. To date, Thin Film has produced several functional products for the toy game and perishable food packaging industries (discussed in more depth in our final article).

Inorganic materials and composites form a class of conductors with vastly better conductance and cost, and are ideal for producing superior printed laminar batteries, large electrophoretic, electroluminescent, and electrochromic displays, and solar cells. Although these materials yield higher efficiency and functionality, they are demonstrably harder to print unless in soluble form. As a result, hybrid printed electronics such as these have not replaced the mainstream in terms of product evolution.

4.5 Nanoparticles

Sun Chemical is another leading supplier of PE inks and one of the world's largest producers of graphic inks (its inks and coatings products are sold under the Sun Chemical, Kohl & Madden, US Ink, and Coates brands). The Electronic Materials Group develops inks for the PV market including crystalline, thin film, and organic technologies. The company has substantial investments in advanced metallization materials and barrier technology along with advanced materials, including transparent conductors, graphite and silver inks. Moreover, the company has a digital inkjet program, based in the UK, for dispensing electronics.

Plextronics, a Pittsburg, PA based company, is focused on developing new solution-processed inks for OLED displays and lighting, including solvent-based hole injection layer and hole transport layer inks which are designed to deliver improved performance with today's leading light emitting technologies via high throughput manufacturing. Similarly, Creative Materials has developed many formulations of conductive inks that contain a lower percentage of silver while maintaining very high conductivity, according to the company.

Toyochem Co., Ltd., based in Chuo-Ku, Japan, is focused on PV, RFID antennas and displays, according to Syunsuke Nomura, Marketing Group of the Printed Electronics Dept. Moreover, ITO is used to produce transparent conductive materials through a conventional photolithographic process to form various coating layers that will reduce production costs. This market is expected to expand if the performance properties for coated/transparent conductive inks improve to a level that meets market requirements. This will naturally come down to a solution between the thinnest lines and production yields and costs. While screen printing is the most production friendly process on the market today, emerging inkjet nozzle and dispensing may displace screen printing, at least in terms of cost and performance. Yet ultra-fine circuit patterning (line widths around 50µm) by screen printing, in addition to throughput improvements and productivity yields, has given rise to competitive solutions between the competing technologies. The printing methods being deployed today are capable of performance levels that have only been achieved by conventional photolithography and etching methods in the past.

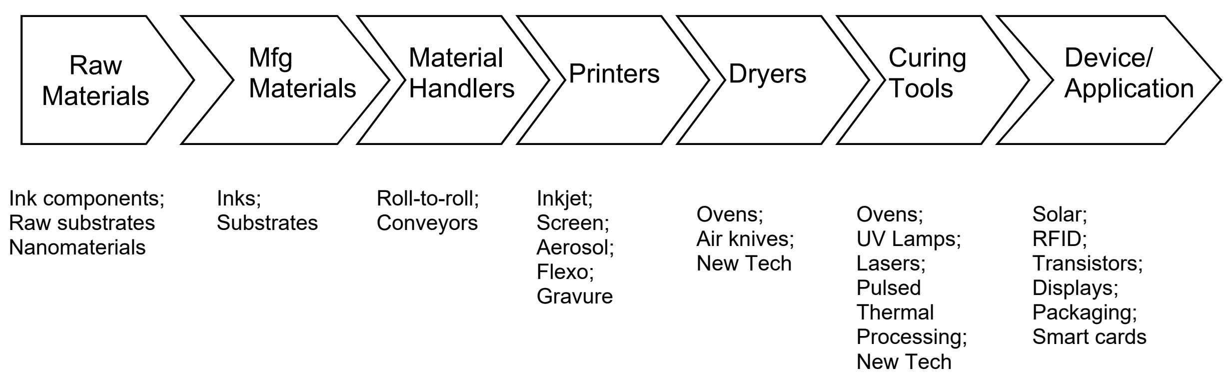
Chapter 5 - Printed Electronics Market Applications

The market for printed electronics continues to grow, albeit not at the rate many had predicted. The barrier to exponential growth seems to be the inability of suppliers to lower costs so that mass-production manufacturing can be adopted and necessary demand can be generated. This is the classical economic dilemma with disruptive technologies when highly competitive and traditional alternatives exist that continue to innovate at similar or at least equitable rates.

As in the semiconductor market that preceded it, specific applications are leading to acceptance of printed electronics, yet they are only niche markets to date. Some applications remain more promising than others, yet overall printed electronics has had little impact in replacing existing applications and has made only incremental progress in creating new ones. This is not to understate the spectacular new technologies coming out of R&D, as addressed in the last chapter, but no "killer application" has emerged to truly disrupt the traditional market.

The following sections in this chapter examine the most promising markets for printed electronics, first by vertical sector and then by application-specific products. This methodology allows readers to consider the manufacturing supply chain, production, and potential distribution trends that will impact the emergence of products within the printed electronics market. Figure 5-1 summarizes the PE manufacturing supply chain for 2012.

Figure 5-1 PE Manufacturing Supply Chain, 2012



In 2003, the world saw the first mass printing of a single transistor. In 2006, the first electronic circuit—a ring oscillator comprising 14 transistors—generated in a mass printing process was presented by Printed Systems in cooperation with BASF and Lucent Technologies. Ring oscillators are basic components of more complex circuits and are used in the production of a clock signal.

The ring oscillator is produced in a process that combines offset, gravure, and flexographic printing. Plastic molecules are very accurately printed in ultra-thin layers one above the other. The interesting thing about this type of production is that the circuits are printed at a rate of up to 0.8 meters per second, a whole new dimension of production speed.

With this kind of production, millionfold print runs are possible. The circuits are produced at a rate that traditional silicon electronics producers can only imagine: this printing technique is between 10,000 and 100,000 times faster than traditional chip production. Using a fast printing press, a chip factory's annual output could be produced in a good hour.

A prime example of the innovation potential of printed electronics is the most recent development of PolyIC: high-resolution, conductive structures on transparent film that are produced in a roll-to-roll production process. These conductive structures can be used as an alternative to ITO (Indium Tin Oxide) films in display, touch sensor or electric heating element applications.

One of the most compelling aspects of large-area flexible electronics is that they can be produced using high-volume, low-cost, and roll-to-roll (R2R) processes. Several factors are driving the growth of this market segment:

- Availability of higher-performance materials — functional inks — that are solution-processable (organic and inorganic) and provide intrinsic bulk electrical, thermal, chemical, or optical properties;
- Commercialization of large-area processing equipment compatible with functional inks;
- Development of large-area, lower-cost manufacturing processes leveraging R2R equipment infrastructure;
- Growing demand for renewable energy systems, low-cost sensors, low-power and highly efficient lighting arrays, low-frequency wireless devices, innovative signage, and flexible displays.

There are three areas that must be addressed to improve the cost/performance value of printed electronics: functional inks, processing platforms, and in-line characterization tools. Contract manufacturers are bringing to market PE solutions for a variety of different product applications. The following sections examine the leading market areas for PE today.

5.1 Worldwide Contract Manufacturing Market

For the last twenty years, the generic term “contract manufacturing” (CM) has been identified almost solely with a very specific niche within the overall durable goods market—that of electronics equipment. This is ironic, as the notion of “contract manufacturing” could be applied to any industry segment (aerospace, appliances, automotive, construction, etc.) that manufactures finished goods, yet over the last few years it has been exclusively linked to the electronics—specifically the high-tech electronics—market segment. As the electronics manufacturing industry has evolved over the years, the term “electronics manufacturing services” (EMS) is used to refer both to the overall industry and a specific class of subcontractor.

The current report focuses on emerging opportunities for CM in PE, yet it is necessary to put this in perspective by stating the entire market for EMS, of which PE is a subset. The total EMS market experienced continuous growth in the fifteen years prior to 2001, when it then underwent a two-year slump and shakeout. In 2003, the market began to recover and grew strongly up to 2009 when it experienced another slump. Since then, the market has rebounded and continues apace with each successive year. With the entry of low-cost original design manufacturers (ODMs) – a CM that specializes in the assembly of specific products such as computers or mobile phones, yet has its own brand of products – the market has become increasingly competitive.

The worldwide CM market expanded significantly in 2011, increasing nearly 12 percent in revenue to exceed $413 billion. Whereas most industry observers expected modest growth, no one anticipated this strong a market, which was driven by the continued demand for smart phones and new mobility devices (iPhones, iPads, and e readers). The largest beneficiary of this growth was Foxconn, the dominant subcontractor of these devices for a variety of key OEM companies. So long as Apple continues its spectacular growth in revenue, as most analysts predict, Foxconn will continue to be lifted by this company’s rising tide.

Table 5-1 summarizes the worldwide market for electronics assembly by manufacturing supplier from 2006 to 2011. Table 5-2 summarizes the market for electronics assembly by market segment and Table 5-3 summarizes the worldwide market for electronics assembly by manufacturing supplier and geographic region for 2011. The majority of CMs produce their products in the low-cost APAC region.

Table 5-1 Worldwide Electronics Assembly Market by Manufacturing Supplier, 2006-2011

Revenue ($M)	2006	2007	2008	2009	2010	2011	CAGR
OEM	700,132	697,430	669,687	562,523	601,569	644,412	-1.6%
ODM	61,152	85,838	94,816	100,133	147,518	160,237	21.2%
EMS	161,648	175,459	199,179	169,560	223,220	252,516	9.3%
Total	**922,932**	**958,728**	**963,683**	**832,216**	**972,307**	**1,057,165**	**2.8%**
Percent Change	13.9%	3.9%	13.5%	-14.9%	16.8%	8.7%	
OEM	75.9%	72.7%	69.5%	67.6%	61.9%	61.0%	
ODM	6.6%	9.0%	9.8%	12.0%	15.2%	15.2%	
EMS	17.5%	18.3%	20.7%	20.4%	23.0%	23.9%	
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	

Table 5-2 Worldwide Electronics Assembly Market by Supplier and Market Segment, 2011

Total Assembly ($M)	EMS	ODMs	OEM	Total	Percent
Communications	85,218	33,137	209,282	327,638	31.0%
Computer	70,698	96,119	72,747	239,564	22.7%
Consumer	44,365	25,844	138,528	208,737	19.7%
Industrial	21,280	1,747	72,258	95,285	9.0%
Medical	14,867	582	38,739	54,187	5.1%
Automotive	7,488	2,706	62,543	72,736	6.9%
Aviation/Defense/Other	8,600	103	50,315	59,018	5.6%
Total	**252,516**	**160,237**	**644,412**	**1,057,165**	**100.0%**

Table 5-3 Worldwide Electronics Assembly Market by Supplier and Geographic Region, 2011

Total Assembly ($M)	EMS	ODM	OEM	Total	Percent
Americas	64,981	6,803	268,439	340,223	32.2%
EMEA	46,632	3,046	287,679	337,357	31.9%
APAC	140,903	150,388	88,294	379,585	35.9%
Total	**252,516**	**160,237**	**644,412**	**1,057,165**	**100.0%**

5.2 Consumer Electronics

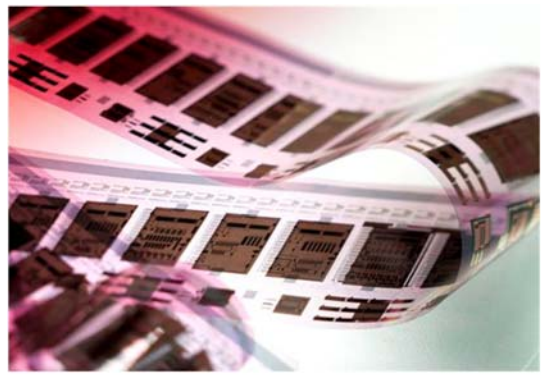
The consumer electronics industry comprises a large array of products, but for PE these fall into two main categories: membrane switches and toys/games and related electrical devices. Appliance control panels make extensive use of membrane switches as seen in microwave ovens, washers, dryers, toasters, exercise equipment, in addition to the timers, rheostats and potentiometer controls embedded in these products. Nobody is really sure how many PE membrane switches are being made today but input from industry participants estimates it to be close to $500 million in revenue annually, worldwide.

Perhaps the most innovative company in the PE market is T-Ink, which has numerous customers such as Fisher-Price, Hasbro, Nickelodeon, Playtex and MacDonalds that use PE for electronic labelling, interactive wall art/posters and game tray liners. Nintendo and Essential Reality both have developed virtual reality glove products by using PE sensor and interactive technology. PragmatIC has demonstrated functional printed electronics on greeting cards that, when opened, reveal a flashing image of a fireworks display. Similarly, it claims its technology can be used for animated branding of product logos and labels that flash or change color when touched or placed near an RF device.

Thin Film Electronics is a Norwegian-based company that has been working for years in developing printed memories and logic for a variety of applications. Thin Film is the first company to use a roll-to-roll printing process, thus making the production of thin-film memories potentially very inexpensive. The company is pioneering the design and integration of multiple functions such as logic, memory, battery power, plus one or more sensing elements (e.g., time, temperature, pressure or chemical change).

Active devices have been used in power generation in batteries. Although batteries generally use inorganic materials for the anodes and cathodes, organic materials are important for both electrolyte and separator materials. Printed batteries are now being used in products as diverse as power sources for RFID and cosmetic applications. Much work is being carried out on organic semiconductors in photovoltaic cells and battery storage. The vision is to have cheap, lightweight, flexible, and energy-efficient power production from solar-generated energy. Although the efficiencies of inorganic semiconductors are still greater than those of their organic counterparts, organic semiconductors may lend themselves better to high-volume, larger-area, and lower-cost manufacturing processes. Figure 5-2 shows examples of PE applications for consumer electronics in 2012.

Figure 5-2 Examples of PE Applications for Consumer Electronics, 2012



Printed logic © PolyIC GmbH&Co.KG

5.3 Displays and Lighting

PE display technology is comprised of OLEDs (organic light emitting diodes) and their derivatives, EL (electroluminescent), and electrophoretic technology popularized by E-Ink technology in e-readers. Most of these technologies are printed on flexible substrates (OLEDs can be formed by both printing and vapor deposition), and while there has been significant investment by companies such as Samsung, Sharp and others, it has not yet reached the level of commercialization needed to replace conventional LCD technology (E-Ink is the exception). This is analogous to the PV industry (previously discussed) in which the R&D dollars invested in conventional silicon crystalline technology far outweighs the latest thin films, thus making them uncompetitive from a cost and performance perspective. Such systems can be used in television screens, computer monitors, small, portable system screens such as cell phones and PDAs, watches, advertising, information, and indication. OLEDs can also be used in light sources for general space illumination, and large-area light-emitting elements. OLEDs typically emit less light per area than inorganic solid-state-based LEDs, which are usually designed for use as point light sources.

In the context of displays, OLEDs have a significant advantage over traditional liquid crystal displays (LCDs) in that they do not require a backlight to function. Thus, they can display deep black levels, draw far less power, and can be much thinner and lighter than an LCD panel. OLED displays also naturally achieve a much higher contrast ratio than LCD screens, which use cold cathode fluorescent lamp (CCFL) backlights. The fact that OLED displays can be printed onto flexible substrates opens the door to new applications such as roll-up displays or even displays embedded in clothing.

The biggest technical problem still to be overcome is the limited lifetime of the organic materials. In particular, blue OLEDs typically have lifetimes of around 5,000 hours when used for flat panel displays, which is lower than the typical lifetimes of LCD or plasma technology. However, recent experimentation has shown that it is possible to swap the chemical component for a phosphorescent one, if the subtle differences in energy transitions are accounted for, resulting in lifetimes of up to 20,000 hours for blue phosphorescent OLEDs (PHOLEDs).

The commercial development of OLED technology is also constrained by patents held by Eastman Kodak and other firms, requiring other companies to acquire a license. Samsung has licensed OLED technology from Kodak and has demonstrated a 40-inch OLED display. It is currently the market leader and has invested hundreds of millions of dollars in infrastructure for mass production since 2005 (both active matrix with amorphous silicon backplanes) and has shipped over a million units since that time.

Marketers and their advertising and packaging companies are eager for printed digital displays and attention-grabbing packaging, which could be a huge business eventually, though customer wish lists still seem far beyond what printed technology can currently deliver. Eric Penot, digital media director at JCDecaux has been quoted as saying, “We desperately need printed electronics products for displays.” The company is eager for giant low-energy, high-contrast, flexible digital screens to replace LCDs that can last outdoors for 10 years and be cost competitive with conventional displays.

Leading suppliers of PE displays include Universal Display, which shipped approximately $80 million in display product technology in 2012, although it is not known to what extent OLED display and lighting products were made via organic vapor jet printing or organic vapor deposition. eMagin is another leading supplier of OLEDs for the military, medical and industrial sectors. Samsung is purportedly the largest OLED manufacturer in the world in order to supply its vast array of consumer electronics products. Based on our look at the PE display market (OLEDs and electrophoretic), we are estimating the market to be approximately $500 million annually, worldwide.

Currently, electrophoretic displays represent the largest market opportunity for PE displays, with E-Ink accounting for almost $300 million in revenue for e-readers in 2012. The OLED market is still in development with companies like Samsung and others attempting to commercialize these printed devices on flexible substrates for a variety of consumer products. While OLEDs hold strong potential, they cannot match the R&D investment in traditional LCD display technology prevalent in nearly all consumer electronics devices. OLEDs have been forecast for high revenue growth for many years, yet it seems inevitable that they will never be able to match the economic cost model of LCDs.

5.3.1 Technical Issues

The production of OLED electronics relies heavily on semiconductor manufacturing technology to ensure its efficacy. For example, electrical conductivity between the OLED transport layers must be maintained to obtain high brightness output at low levels of power. Therefore, a doping technology is employed as part of the vacuum deposition process. The doping material must be robust enough to resist cross-contamination and cannot diffuse over time, as that would degrade the light-generating efficiency.

A new class of OTFTs can be fabricated on polymer substrates at room temperature, resulting in a unique operation at very low voltage. This technology enables production of large-area, lightweight, low-cost flexible electronics with high impact resistance. This technology could have a huge impact on the display industry by reducing fabrication costs.

OLEDs fall into two general categories: active matrix (AM) and passive matrix (PM). PM OLEDs are formed by creating an array of OLED pixels connected by intersecting anode and cathode conductors arranged in rows and columns. Electrical power is passed through selected pixels by applying a voltage to the corresponding rows and columns from the drivers attached to each. An external controller circuit provides the necessary input power, video data signal, and multiplex switches.

AM OLEDs have an integrated electronic backplane as the substrate that uses at least two thin film transistors (TFTs) to control the on current at each OLED cell or pixel. The transistor circuits retain the state (on/off) and level (intensity) information programmed by the display electronics. Therefore, the light output of every pixel is controlled continuously, in contrast to PM OLED displays, which are pulsed with high currents just once per refresh cycle.

Compared with PM OLEDs, AM OLEDs fabricated on flexible plastic substrates have these advantages:

- Thinner and lighter weight
- Less susceptible to breakage, which allows the arrays to be rolled for transportation and storage and formed in unique ways
- Lower power, highly rugged, superior image quality, and low cost compared with current LCD displays

AM OLED displays provide the same video-rate performance as their PM OLED counterparts, but they consume significantly less power. This advantage makes AM OLEDs well suited for portable electronics, where power consumption is critical to battery life.

Capacitive touchscreens

Over the last several years, the use of touchscreens in electronics products has become increasingly popular. Most touchscreens today can be controlled through simple or multi-touch gestures via a stylus or one or more fingers (for example zooming the text size or a photo image). Touchscreens now play a prominent role in computers, mobile phones, video games, PDAs and satellite navigation devices. Historically, the touchscreens are made by a wide array of after-market system integrators, and not by display manufacturers. Recently, however, display manufacturers have begun to integrate touchscreens into the fundamental design of their products.

Several technologies are used in touchscreens but the most popular is a capacitive touchscreen panel consisting of an insulator such as glass, coated with a transparent conductor such as indium tin oxide (ITO). As the human body is also an electrical conductor, touching the surface of the screen results in a distortion of the screen's electrostatic field, measurable as a change in capacitance. The location is then sent to the controller for processing.

Companies like Samsung have built capacitors inside their AM-OLED displays, creating a more direct contact with the content being displayed and enabling taps and gestures to be even more responsive. The assembly of the touchscreen today uses a vapor deposition coating technology (including sputter deposition and electron beam evaporation), however, because of high cost and limited supply of indium, the fragility and lack of flexibility of ITO layers, and the costly layer deposition requiring a vacuum, alternatives are being sought in the PE industry. Carbon nanotube conductive coatings are a prospective replacement along with films of graphene, thin metal films and conductive polymers. Other, inorganic alternatives include aluminum, gallium or indium—doped zinc oxide.

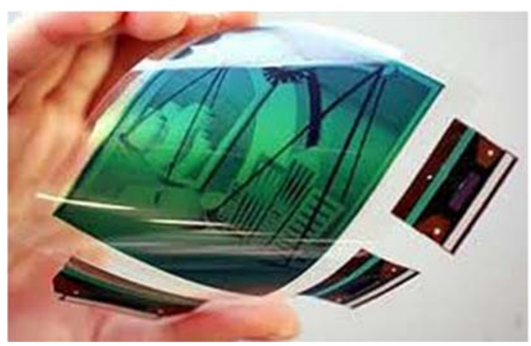
5.3.2 Display Applications

OLED displays are used in applications ranging from low-end MP3 players to laptops and televisions; however, the majority of applications fall into a class of e-readers found in consumer electronics. Wireless device manufacturers are attracted by OLED technology's low power consumption and video qualities.

Although traditional liquid crystal display (LCD) technology still dominates the marketplace of display applications, there is incipient demand for printed OLED displays in a variety of product application areas. The rationale behind this kind of display technology is that it can ostensibly be printed (via screen printer or inkjet) and is potentially cheaper to manufacture than LCD displays. However, leading OLED manufacturers such as Samsung and LG have recently lost confidence in the technology. The main reason is the low yield which can be as small as 10 percent, or as high as 30 percent (requiring extra electronics), according to DisplaySearch. Apparently, the glass frit bond process (sometimes called "frit encapsulation"), introduces fragilities that reduce each finished panel's effective lifespan—to what degree, the manufacturers can only guess. In addition, prices for 55" OLED TV screens are in the region of $10,000 per unit, nearly five times the cost of a full HD LCD TV today. The clear benefit of the Ultra HD LCD TV has forced the leading OLED manufacturers to delay mass production until they can calculate the success of their investment. This won't be done until 2014 at the earliest.

The area where printed OLEDs can excel is with flexible substrates, but this appears to be a novelty and seemingly expensive version of e-paper (albeit in color), of which the applications are limited. Figure 5-3 illustrates two possible examples of flexible OLED displays in 2012. Also, customers are demanding flexible substrates and lighting options that have better mechanical stability than traditional technologies can provide, so the potential to replace existing lighting and display technology seems to be high. Figure 5-3 illustrates two possible examples of flexible OLED displays in 2012.

Figure 5-3 – Examples of Flexible Electrophoretic and OLED PE Displays, 2012



The ultimate goal of employing printed display technology is the ability to manufacture products using a continuous process. Once this has been perfected and costs minimized, OLEDs could replace traditional display technology in a few application areas. Table 5-4 summarizes the leading product applications for OLED displays in 2012 in terms of units, ASP, and revenue.

Table 5-4 - Potential Applications for PE Electrophoretic and OLED Displays, 2012

PE Display Applications	Units (M)	ASP ($)	Rev. ($M)	Percent
E-Readers	37.0	7.80	289	58.2%
OLED TV	0.1	180.00	18	3.6%
Mobile phones	4.0	9.90	40	8.0%
Car audio	2.0	23.00	46	9.3%
Industrial	1.5	12.00	18	3.6%
Notebooks	0.2	150.00	30	6.0%
MP3	2.0	5.10	10	2.1%
Video camera	1.6	11.80	19	3.8%
Games	1.1	9.40	10	2.1%
Printers	1.8	7.50	14	2.7%
Others	2.0	1.44	3	0.6%
Total	**53.3**	**9.31**	**496**	**100%**

Source: DisplaySearch and NVR Estimates

The vast majority of OLEDs manufactured today are low resolution and are not created by printing, but rather by vapor deposition processes and etching. They also use small-molecule chemistries, rather than the polymers that dominate the literature on printed organic electronics. Examples of other polymer displays include household appliances such as shavers, handheld medical devices and analyzers, and even industrial circuit analyzers and professional light/sound mixers.

High-brightness OLEDs may become commercially viable light sources for large areas. Europeans are now cooperating to investigate lighting alternatives that combine high brightness (1,000 cd/m^2) and high efficiency (50 lm/W, comparable to energy-saving bulbs) with extended life spans (10,000 hours like fluorescent tubes) and the color ambiance of a light bulb. A secondary aim is to design a flat light source with a large, uniformly diffuse emitting surface, based on durable, lightweight substrates so thin they will be transparent and, ultimately, flexible.

5.3.3 Non-Emissive Displays

Electronic paper, also sometimes called e-paper or electronic ink, is a display technology designed to imitate the appearance of regular ink on paper. Unlike a conventional flat panel display, which uses a backlight to illuminate its pixels, electronic paper reflects light like ordinary paper and is capable of holding text and images indefinitely without drawing electricity or using processor power, while allowing the paper to be changed. The technology underlying electronic paper is electrophoretic and is associated with printed electronics mostly because it differs so much in its manufacturing from widespread LCD flat panel technology, although it is not necessarily printed in the same sense that OLED technology can be printed (it is a layered technology). Regardless, it is included as part of the printed electronics display market due to its uniqueness and application.

The sudden surge in popularity of e-readers such as Amazon's Kindle and Barnes & Noble's Nook was one of the big surprises of 2009. According to our estimates based on field research, approximately 20 million e-readers were sold in 2011, and this increased to 37 million in 2012, depending on the definition of an e-reader (recently blurred with the introduction of the Apple "Mini" in 2012). The essential difference between e-readers and tablets is that the e-reader is a reading and shopping device, whereas the tablet (and upstream iterations thereof) is a computational device with embedded reading and shopping features, yet primarily an imitation of notebook functionality (therefore shipments and revenue projected by industry pundits will disagree depending on definition).

The core PE technology behind e-readers is electrophoretic display technology, which is produced by printing microcapsule material on a plastic substrate (E-Ink is the leading supplier). E-reader end-user consumption is expected to be fueled by the rising popularity of Amazons' Kindle, Barnes & Noble's Nook, and the increase in digital content and applications available in many foreign languages. As e-readers experience more increased competition from tablet devices, the average assembly value growth rate will converge. It remains to be seen if the increasing capabilities of e-readers will make them a more attractive alternative to tablets, but based on an assessment of the worldwide market, we predict a significant market disruption.

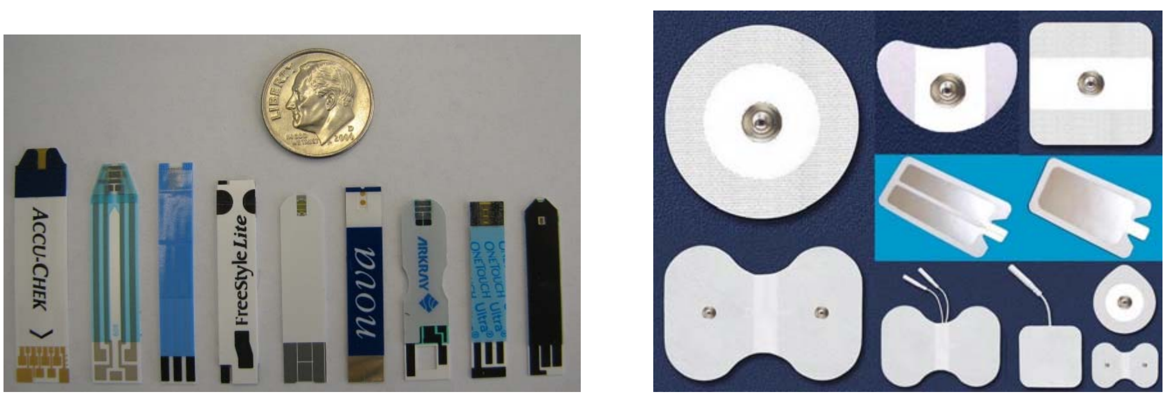
There are several other promising technologies for e-readers such as those being developed by Liquavista, Mirasol (a QUALCOMM company), Pixtronix, Fujitsu, Philips, and Pixel Qi. These products render color displays that can handle video at low power consumption without backlighting. However, they all are relatively expensive and are not in mass production. In the meantime, variants of LCD technology continue to improve performance in the areas of viewing angles, handling fast motion, power consumption, thin panel size, and, most important of all, low cost. R&D engineers have repeatedly shown that they can make LCD technology competitive if the market demands it.

5.4 Medical

Our field research interviews consistently found medical and bio-sensor applications to be one of the most promising markets for PE. Many suppliers were engaged in providing test strips for blood glucose monitoring, disposable defibrillator pads and medical electrodes for EKG and EEG. Contract manufacturers such as GSI Technologies and Si-Cal were optimistic about business opportunities in these areas and projected strong business growth over the next several years for cost and performance reasons. While the medical PE market is relatively small at this time (approximately $250 million annually, worldwide), it is one of the fastest growing application areas.

Diagnostic test strips manufactured by printed technology really stand to lower the cost of these and other disposable devices. Combined with sensor technology (chemical analysis, temperature, pressure, displacement, humidity, moisture, vibration and biological information), new devices can be developed using PE manufacturing, increasingly at low cost. Fields yet to be explored include toxins, nutrients, pheromones and proteins in the environment and living species. Figure 5-4 illustrates two possible examples of medical sensor strips in 2012.

Figure 5-4 – Examples of Medical PE Sensor Applications, 2012



5.5 Packaging

Packaging has long held strong potential for PE but only recently has penetration occurred. Hallmark was an early adopter of adding light and sound to its greeting cards as was AGI with its interactive DVD packaging. Kellogg's is starting to add lighting to its cereal boxes and Talking T-Shirts brings characters and products to life on its apparel. PE packaging is very embryonic and currently represents a market of only $10 million today, worldwide, although the growth is expected to be quite rapid over the next several years.

Active packaging can be defined as a package that changes the condition of packaged food to extend shelf life or improve food safety or sensory properties, while maintaining the quality of the packed food. Certain applications have been described as "oxygen scavenging", prompting efforts to develop enzyme-containing coatings that can be applied in existing processes at the paper/board producer or converter (printer) level. To this end, active packaging can be used to reduce food waste through time-temperature indicators (TTIs), freshness indicators, oxygen indicators, leak indicators, and carbon dioxide indicators.

In July, 2012, Thin Film announced a contract to provide a printed electronics module that integrates several functions into an application that monitors environmental conditions on perishable food and medical products. The customer is Bemis, Inc., a $5 billion food and beverage packaging company, and the division is Shield Pack, a manufacturer of flex film packaging for dry and liquid applications that is based in West Monroe, Louisiana. The cost of the new smart package has not been disclosed but it needs to be for applications that can be made for as little as $0.10 per package (Bemis has packaging solutions today that range from pennies to $25). Traditional sensor technologies that provide this kind of capability for specialty foods can cost in excess of several dollars a unit and spokesmen for Bemis believe the low-cost goal can be met. Ultimately, Bemis wants to bring this technology in-house as it sees it as a platform for a number of its environmentally sensitive packages. First production quantities are expected by the end of 2014. Figure 5-5 illustrates two possible examples of PE packaging applications for 2012.

Figure 5-5 – Examples of PE Packaging Applications, 2012

5.5.1 Technical Issues

It has long been recognized that attractive packaging is essential to the sales success of many consumer products. Supermarket shelves and retail displays are full of examples that have benefited from improving their attractiveness, such as hair treatment products in bright green spherical containers, setting lotions for youngsters in loud colors, toothbrushes with webbed feet and toothpaste boxes with children's motifs. The beauty industry in particular relies on original and fresh ways to advertise its products in the retail environment.

Over the next several years, an emerging packaged display industry is expected to begin using a print process utilizing conductive and insulating plastics. Printed electronics companies will be able to apply soluble materials via a printing press process to a foil. The process produces a wafer-thin electronic circuit or display that can be seen in daylight and is thus much easier to read than most traditionally illuminated displays. These displays consume very small amounts of energy—as little as 1.5 volts is required to activate them.

Though it sounds futuristic, conductive chemicals are being developed that can change color under the influence of an electrical field. As part of the product packaging, a network of filigree electrodes can be printed on the underside of an electrically conductive plastic foil that serves both as cover plate and backplane electrode. In this way, a flexible, paper-thin display can be created. Unlike the OLED displays discussed in the previous section, intelligent packaging displays are tiny color films imprinted on items such as beverage cans and food and beauty product labels. Combining them with OTFT circuitry will allow for such entertainment as small interactive games on the back of cereal boxes.

However, there is more to intelligent packaging than making attention-getting displays. Manufacturers interested in maintaining freshness and quality are looking to smart packaging to give indications of age and temperature. Smart labels are being deployed that can show the relative freshness of a product by a change in color. Because many products are temperature sensitive, time and temperature indicators (TTIs) are finding increasing use in supply chains. Additionally, intelligent packaging is being designed to detect biocontamination. Nevertheless, providing cost-effective antipathogen packaging that can detect more than one kind of pathogen is currently a major challenge, albeit one that has attracted the attention of a few firms.

Authentication issues are important in a wide variety of industries, from food and beverages to chemicals, pharmaceuticals and cosmetics. They affect any manufacturer concerned about tampering or contamination and are a major influence on smart packaging. For example, in the pharmaceutical industry, authentication is required in clinical trials, in which compliance and reliable data are critical to accuracy. Pharmaceutical companies must then record and track the progress of a product through every transfer by wholesalers and repackagers, up to the final sale or use of the drug.

Alarmed by the increasing cases of fake Viagra, Pfizer announced in January 2009 that it would use RFID tags on all Viagra bottles in the United States to authenticate the products. Meanwhile, TTI labels are already being used on medicine packs that indicate, through a chemical reaction, whether a product has experienced debilitating heat. However, the TTI labels used heretofore on vaccine vials have not proven accurate. In contrast, RFID-based indicators, produced so far in low volumes for trials and evaluations, have proved accurate and can also indicate damage from shock or freezing.

"Smart" in packaging is a broad term that covers a number of functions, depending on the product being packaged, whether food, beverages, pharmaceuticals, household products, or others. Examples of current and future functional "smartness" would be in packages that:

- Retain integrity and actively prevent food spoilage (shelf life)
- Enhance product attributes (look, taste, flavor, aroma, etc.)
- Respond actively to changes in product or package environment
- Communicate product information, product history, or condition to users
- Assist with opening and indicate seal integrity
- Confirm product authenticity, and act to counter theft

There is an important distinction between package functions that are smart or intelligent, and those that become active in response to a triggering event, for example, filling, exposure to UV, or release of pressure. Some smart packaging already exists commercially and many other active and intelligent packaging concepts are under development, as illustrated in Table 5-5.

Table 5-5 Examples of Intelligent Packaging Under Development

Active Apps	Intelligent Applications
Oxygen scavenging	Time-temperature history
Anti-microbial/moisture absorbing	Microbial growth indicators
Ethylene scavenging	Light protection (photochromic)
Heating/cooling	Physical shock indicators
Odor and flavor absorbing/releasing	Leakage, microbial spoilage indicating

In intelligent packaging, the package function switches on and off in response to changing external or internal conditions, and can include communication to the customer or end user about the status of the product. A simple definition of intelligent packaging is "packaging that senses and informs." An example of this definition can be found in the "smart home of the future" scenario, in which intelligent labeling will be capable of communicating directly to the customer via thin-film devices providing sound and visual information in response to touch, motion, or some other means of scanning or activation. Another example is drug delivery systems in smart packaging that will be programmed to communicate patient information back to health care centers.

5.5.2 Packaging/Label Applications

Consumer and societal factors are likely to drive the adoption of smart packaging in the future. Consumers increasingly need to know what ingredients or components are in a product and how the product should be stored and used. Voice-activated safety and disposal instructions on household and pharmaceutical products will be used to tell the consumer how the product should be disposed of after consumption—information that can be directly used in the recycling industry to help sort packaging materials from waste streams.

In 2012, the global consumer packaging market was estimated to be almost $500 billion, with growth expected at around 4–5 percent per annum over the next several years. Mature markets in North America and Western Europe are expected to show moderate year-to-year increases, while developing markets will exhibit above-average growth rates. Food and beverage packaging are the two largest segments, accounting for more than two-thirds of the revenue total. Table 5-6 summarizes the worldwide packaging market by industry in terms of units, ASP, and revenue for 2012.

Table 5-6 - Worldwide Packaging Market by Industry, 2012

Industry	Units (B)	ASP ($)	Rev. ($B)	Percent (%)
Food	9,346	0.022	206	42
Beverages	5,272	0.026	137	28
Pharmaceutical	2,856	0.012	34	7
Beauty	1,088	0.027	29	6
Other	5,548	0.015	83	17
Total	**24,110**	**0.020**	**490**	**100%**

Source: Pira Intl. and NVR estimates

Plastic packaging accounts for almost 40 percent of world output and is growing faster than any other packaging material. Its growth is mainly attributable to advances in material properties, resulting in replacement of existing packages and development of new applications. Glass producers have achieved growth by creating lightweight, decorated containers with premium appeal. Metal, meanwhile, has seen strong performance in beverage applications corresponding to increased consumption of packaged soft drinks and beer. At the same time, metal has also experienced moderate growth in food and general applications. Table 5-7 summarizes the worldwide packaging market by material in terms of units, ASP, and revenue for 2012.

Table 5-7 Worldwide Packaging Market by Material, 2012

Package Material	Units (B)	ASP ($)	Rev. ($B)	Percent (%)
Metal	2,128	0.023	49	10
Glass	1,399	0.028	39	8
Paper & Board	11,297	0.013	147	30
Plastics	13,831	0.026	191	39
Other	4,546	0.014	64	13
Total	**24,110**	**0.020**	**490**	**100%**

Source: Pira Intl. and NVR estimates

Cost issues will probably mean that early adoptions of smart packaging are likely to be for noncommodity products, such as pharmaceuticals, health and beauty products, and items that play a part in lifestyle and leisure activities. A further consideration is the need for education to reassure consumers of package safety and to ensure against incorrect operation and mistrust of smart technology. The successful adoption of smart packaging concepts in the future must create advantages for the whole of the supply chain.

Leading consumer packaging companies continue to consolidate market positions through acquisitions and mergers and by focusing their operations. In a world of brand globalization, the ability to support customers in different regions, to establish economies of scale, and to offer a range of packaging systems or materials are just a few of the requirements for becoming a global packaging player. However, the industry remains fragmented; the top ten consumer packaging companies still have only around a 15 percent share of the global consumer packaging market.

The smart label and intelligent packaging industry remains embryonic because of its innovative technology and relatively high cost. The current market is estimated to account for only a fraction of a percent of the total packaging market, although it carries an ASP nearly 50 times that found in traditional packaging. E Ink leads this industry as a result of more than $120 million in investments from such leading OEMs as Sony, Philips, Intel, Motorola, and Toppan Printing. Over the next several years, the average cost per unit is expected to drop considerably and thus drive unit volumes up. Most new packaging technology will be applied to new product introductions and also to novelty items.

5.6 Photovoltiacs (PV)

Photovoltaics (PV) refers to a subsegment of the energy industry that is dominated by solar cells and electricity generation. PV cells are electricity-producing devices made with traditional semiconductor materials. The cells come in many sizes and shapes—from smaller than a postage stamp to several inches across. Cells are often connected to form PV modules that may be up to several feet long and a few feet wide, although recently PV cells have been offered in a continuous form on various substrates. Modules can be combined and connected to form PV arrays of different sizes and power output abilities.

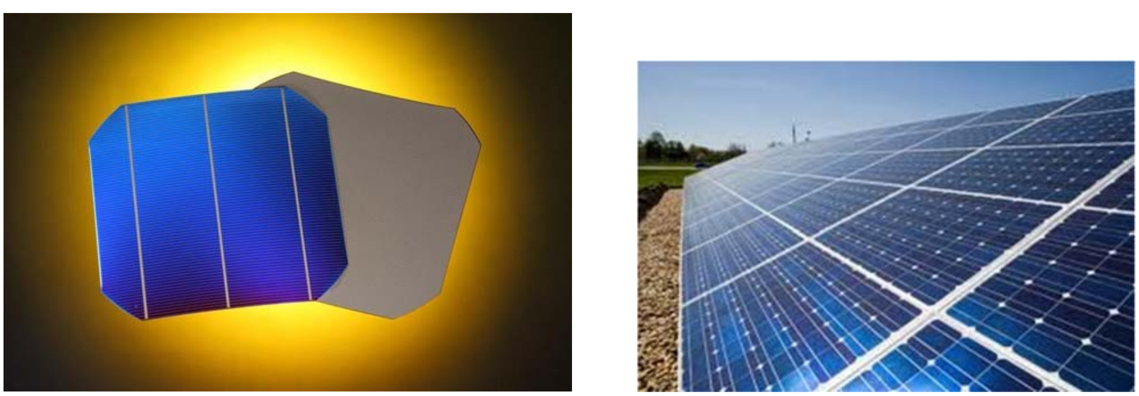
PV cells can be made of many different semiconductors, but crystalline silicon was the material used in the earliest successful PV devices and is still the most widely used material today. Using this technology the energy of absorbed light is transferred to electrons in the atoms of the PV cell. With their newfound energy, these electrons escape from their normal positions in the atoms of the semiconductor PV material and become part of the electrical flow, or current, in an electrical circuit. A special electrical property of the PV cell—called a "built-in electric field"—provides the force, or voltage, needed to drive the current through an external ''load,'' such as a light bulb.

Solar cells can be made from three types of photovoltaic materials—crystalline silicon, polysilicon, and thin films. Crystalline silicon (c-Si) is the most pervasive and efficient, with expensive laboratory cells having achieved efficiencies as high as 24.7 percent, whereas commercial cells typically have efficiencies of less than 16 percent. Researchers continue to explore highly versatile techniques—such as plasma processing, which can etch surfaces, deposit dielectric coatings, and passivate surface and bulk defects—to form high-efficiency cell structures using manufacturing procedures.

The PE application of PV is mundane – that is because it involves the patterning of circuit paths between the crystalline solar cell and the conventional storage electronics – a production step involving screen printing layering on traditional semiconductor cell development. As a result, the rising tide of the PV market will lift the PE silver paste market, as unglamorous as it may be. PE assembly based on current worldwide demand of 32 gigawatts of PV production (approximately 160 million panels shipped in 2012) accounts for approximately $2.1 billion in PE assembly revenue according to our estimates.

The remaining PV technologies seem to hold the true potential. Advanced thin-film PV materials will be applied to flexible substrates for potentially transformational applications on things like plastic substrates and roofing tiles or substrates, yet this technology is currently unaffordable in most conditions except for wearable and mobile applications. Sadly, conventional crystal-silicon technology has proven to be more cost-effective for the mass market of PV solar energy generation. Figure 5-6 illustrates two possible examples of PE PV applications in 2012.

Figure 5-6 – Examples of PE PV Applications, 2012



The market for traditional (nonprinted) PV modules is quite large—estimated to be over $14 billion in assembly value in 2012—and has grown rapidly over the last decade due to subsidies given by governments worldwide. Table 5-8 summarizes the PV market by gigawatt capacity installed, average watts per PV panel, total panels shipped, the average panel assembly cost and total panel assembly value for 2012.

Table 5-8 Worldwide PV Module Assembly Market, 2012

Capacity Installed (GW)	32
Ave. Watts per Panel (W)	200
Total Panel Shipped	160,000,000
Average Panel Assembly Cost ($)	90
Total Panel Assembly Value ($B)	**14.4**

5.6.1 Technical Issues

The materials most suitable to printable electronics are thin films of special materials such as amorphous silicon (a-Si), copper indium diselenide (CIS) and its alloys, and cadmium telluride (CdTe). Researchers are working to improve efficiencies of commercial modules to levels above 10 percent (and incrementally, toward 15 percent) as well as to ensure outdoor operational reliability with robust packages. Photovoltaic research involves studying new materials and controlling technical details such as doping profiles, morphology, short-range order, stoichiometry, and process uniformity.

Whereas conventional silicon and thin-film materials have dominated the solar cell industry to date, solar cells derived from nanomaterials seem poised to foster tremendous advancements in the industry. Nanotechnology-engineered materials, while displaying superior properties such as high strength and flexibility, can also be oriented so as to trap energy more efficiently than conventional materials. Emerging silicon photovoltaic technologies include the FLATCON technology being developed by Concentrix Solar and the emitter wrap-through (EWT) solar cells being developed by Advent Solar. While FLATCON uses a Fresnel lens to efficiently concentrate light on the solar cell, and thereby finds potential applications in grid networks for remote locations, the EWT solar cell is basically a back contact solar cell that achieves up to 22 percent efficiency in power conversion.

Sharp Corporation has achieved what the company says is the world's highest solar cell conversion efficiency of 35.8 percent using a triple-junction compound solar cell. Since 2000, Sharp has been advancing research and development on a triple-junction compound solar cell that achieves high conversion efficiency by stacking three photo-absorption layers. To boost the efficiency of triple-junction compound solar cells, it is important to improve the crystallinity (the regularity of the atomic arrangement) in each photo-absorption layer (top, middle, and bottom). It is also crucial that the solar cell be composed of materials that can maximize the effective use of solar energy. The key to solving this problem was to form the bottom layer from InGaAs (indium gallium arsenide), a material with high light-utilization efficiency. However, the process to make high-quality InGaAs with high crystallinity was difficult. Sharp has now succeeded in forming an InGaAs layer with high crystallinity by using its proprietary technology for forming layers.

One of the latest thin-film photovoltaic materials is copper indium gallium selenide (CIGS), which has become the preferred choice of many manufacturers. This is largely on account of its higher efficiency and greater environmental friendliness compared with the competitive technology, cadmium telluride films. California-based Miasole Corporation has developed several novel CIGS modules and Austin, Texas-based HelioVolt has developed a field-assisted simultaneous synthesis and transfer (FASST) process that has produced noteworthy low-cost yet efficient solar cell modules.

5.6.2 PV Market Applications

The PV power generation market can be divided into two primary market areas, on grid and off grid. One can further organize the market into residential, commercial, and utility uses. Because most PV products are not attractive from a financial point of view (that is, the cost to develop PV electricity is much higher than that of the traditional methods of coal, gas, and nuclear), the current market is a niche one in which users are willing to pay higher prices to accomplish some altruistic goal (environmental, social independence, philosophical). However, the cost gap between conventional energy and innovative PV solutions is rapidly narrowing as the efficiency of PV materials increases.

The market potential for PV systems is greatest in the remote areas of the world, particularly in villages without access to grid electricity. A number of PV systems have been sold to provide residential power in remote regions of China, India, and Africa. Around the world, there are more than 100,000 off-grid residential PV systems, including tens of thousands of vacation homes in Scandinavia. These systems, typically from one module to one kilowatt, comprise the PV modules, batteries, charge controllers, and assorted loads (lights, radio/TV, and refrigerators).

In developing economies, there are hundreds of thousands of villages that currently have no access to electric power or that use diesel generators, which are expensive to fuel and maintain. PV village power systems provide electricity for domestic, community, or industrial activities. PV systems can replace hand pumps or large engine-powered water pumping systems. In many pumping systems, no batteries are required, as the pumped water can be stored.

Photovoltaic systems have been used to power satellites and space probes since the Vanguard 1 launch in 1958. The critical issues in space power systems are weight and reliability: weight, because of the high cost of boosting equipment into space; and reliability, because servicing a system is difficult and expensive. On the other end of the spectrum, consumer products (calculators, etc.) use very small amorphous silicon PV devices to provide the power necessary for their operations.

Thin-film battery technology represents a revolution in energy storage. In contrast to conventional lithium cells found in the mass market, thin-film cells are being fabricated with a thickness of about 5µ—thinner than a sheet of Saran wrap. But with a decrease in size, a trade-off has to be made somewhere in the device's performance. Typical capacity of solid-state, thin-film batteries averages from a fraction to a few milliamp hours, and critics contend that in a direct comparison, these systems provide less capacity than that of their conventional and liquid- or gel-based counterparts. Nevertheless, the flexibility afforded by these microbatteries with regard to number of recharges, temperature range (critical to SMT reflow assembly), pulse capability, shelf life, and small form factor helps these products excel in niche markets.

The vast majority of current solid-state batteries can be manufactured onto most substrates such as ceramics, plastics, metals, and semiconductors. Using deposition processes on thin metal foils would facilitate the move to faster manufacturing techniques such as roll-to-roll manufacturing, which would print thin-film batteries onto giant rolls of a flexible substrate material. This technique would improve the throughput and yields of flexible applications, as well as their time to market.

Thin film batteries are being applied to printed circuit boards through a process of lamination, according to Schweizer Electronics AG, of Schramberg, Germany, which has patented such a process. The result is an application with the potential to replace supercapacitors and backup power devices in today's computers. Perhaps most important, the batteries have been tested and have survived up to ten solder reflows without any degradation, according to experts. However, to generate the yields necessary to drive products such as cell phones, notebook computers, and portable digital assistants, these microbatteries will have to be stacked or placed in very large arrays to provide enough current capacity. This market is essentially embryonic today but is expected to grow and attract a number of suppliers in the next few years, at which time a forecast will be developed.

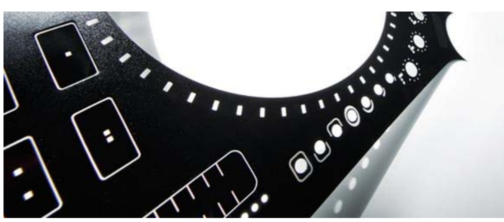
5.7 Printed Circuit Boards (PCBs)

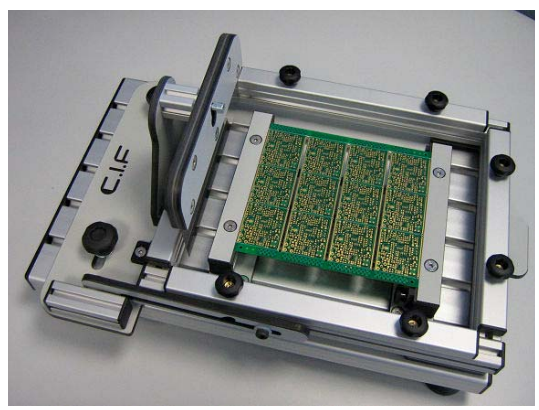
Printed circuit boards (PCBs) have almost entirely been dominated by traditional surface mount technology (SMT), manufacturing technology for tracing and mounting semiconductor components on to bare circuit boards, as well as conductive fillings with silver ink for through-hole components. In these situations, photoimages and lettering are screen printed onto the circuit boards (both flat bed or vertical double-side). The coatings are then oven-dried, UV imaged, aqueous developed and finally oven cured.

Manufacturers use standard screen printing technology to lay circuit paths on to the PCBs or use peelable solder masks instead of tape. Etching technology is still involved but the essential manufacturing step is to print on to the board (green resin substrate), which can be single or multi-layered. The opportunity lies in reducing the layer depth and increasing the circuit complexity via PE patterning technologies – and ultimately replacing the PCB with thin films.

The market for thin-film PCBs and active components (such as logic or memory) sums up the large market potential for PE, crossing all market applications discussed in this report. T-Ink has shown that there is demand for replacement PE solutions in automotive, medical, and consumer electronics and in broad battery/logic/memory/sensor applications for a great many products. Competing against this is the vast investment in the perfection of standard circuit board technology, which today involves multi-layering assembly methods with integrated ICs that have driven costs to the lowest possible margin. The question remains whether PE technology can supersede current electronics assembly methods, which represent over a one trillion dollar industry today. The answer is probably yes, but the scale is not clear. Currently, we estimate the market for PE in PCB assembly to be slightly over $400 million worldwide – hardly the smallest fraction of the total assembly value. Yet for many suppliers like T-Ink, E Ink, Thin Film Electronics, Kovio and others, it is a market worth pursuing. Figure 5-7 illustrates two possible examples of PE for PCB applications in 2012.

Figure 5-7 – Examples of PE for PCB Applications, 2012





5.8 Radio Frequency Identification (RFID)

RFID (radio frequency identification) was once touted as a high-growth market for PE, but recent advances in low-tech materials (specifically thin-film metals and even aluminum foil as a replacement for printed antennas) have resulted in this market stagnating over the last few years. The emergence of printable RFID tags has been widely predicted starting in 2009 when Kovio released the first commercially available device. Whereas this device could hardly be categorized as complex (under 1,000 transistors), it heralded a potentially radical change to the industry in terms of cost, performance, and volume.

The RFID market is composed of two primary components: readers and tags (or cards). Readers embed the software and services necessary to complete the entire functional system. The elements work together through a noncontact radio transmission technology that communicates wirelessly between the reader and the tag/receiver.

The tag is composed of an integrated circuit and an antenna, which can be passive, active, or hybrid. Active tags contain their own power or battery, whereas passive tags are powered by the reader. Hybrid or battery-assisted passive (BAP) tags require an external power source to turn on, but have significantly higher forward link capability, providing greater read range.

The reader and tag communicate via an RF magnetic field that emanates from the reader by means of a transmitting antenna, typically in the form of a coil. The magnetic field serves as a "carrier" of power from the reader to the RFID card or tag. When a card or tag is brought into the magnetic field produced by the reader, the converted energy powers the IC. This enables the transmission of the IC's memory contents in the form of an electromagnetic signal to the reader via the tag's antenna.

RFID tags do not require contact with the reader, nor do they require the line of sight that bar-code technologies rely upon. As a result, RFID has the potential to replace bar codes by improving visibility of inventory in near real time, and materially changing how inventory is managed in warehouses, in transit, in distribution centers, and even on store shelves and checkout counters.

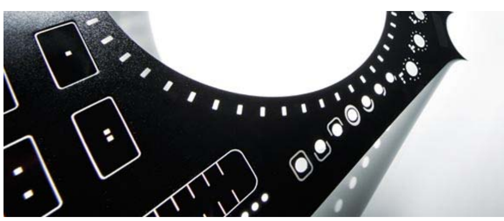
RFID requires a fairly complex circuit that follows a standard communications protocol which can require circuit logic of up to 10,000 transistors – far beyond what is possible today via PE. Current solutions are being purchased by retailers at an average of 10 cents per device (involving an antenna stuck to a shirt within a store, for example). Anything that can be done to lower the cost of the technology would be considered disruptive to the current solution. RFID has the theoretical potential to create devices that could lower the cost of current solutions, but the technology has not yet been developed according to Wayne Baker, Senior Director of RFID Consumables at Checkpoint Systems, Inc., a supplier of RFID solutions to retail and commercial businesses. Baker states that the current PE technology is not sufficiently robust, low in cost, or small in size to compete with traditional solutions. Checkpoint's current technology uses a photoresist and etching process to manufacture its RFID antennas.

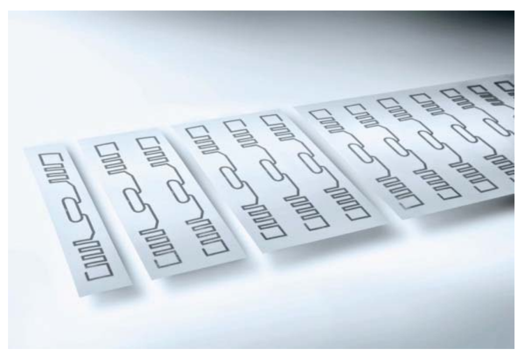
In January, 2012, INSIDE Secure announced that its family of NFC solutions can now be used to interact with the Kovio RF Barcode wireless tag, an affordable NFC tag solution based on Kovio's printed silicon technology platform. Mobile devices powered by INSIDE's MicroRead and SecuRead NFC hardware and Open NFC protocol stack can now make it possible for brands, retailers, advertisers, mobile operators, and retail system integrators to provide instantaneous, personalized and contextual experiences to everyone who purchases, uses or interacts with everyday consumer goods.

Kovio is one of the few firms that produces a "printed silicon-based ink" RFID solution. While highly innovative, it is not clear if the manufacturing cost is competitive with traditional solutions. In November, 2012, the company announced a new category of Electronic Article Surveillance (EAS) tags for the retail and fashion industry that can be invisibly embedded into clothing and other products and deactivated permanently at point of sale.

DuPont Microcircuit Materials continues to develop its technology along with start-up companies like Soligie, but today no mass production applications have emerged, although opportunities for RFID transponders may soon appear. Contract manufacturers like GSI Technologies and Si-Cal have been reported to be engaged in RFID projects using PE technology, however the total market is estimated to be no more than $20 million in revenue worldwide in 2012. Figure 5-8 illustrates two possible examples of PE for RFID applications in 2012.

Figure 5-8 – Examples of PE for RFID Applications, 2012





5.8.1 Technical Issues

Operating frequency is a critical factor for the type of RFID system. These frequencies include high frequency (850–950 MHz and 2.4–5 GHz), intermediate frequency (10–15 MHz), and low frequency (100–500 kHz). Overall, high-frequency RFID systems are more suitable for applications requiring a longer read range such as toll-collection systems and railroad car and intermodal container tracking. Intermediate-frequency RFID systems are just now beginning to emerge with the use of smart cards in financial transaction processing. Low-frequency systems are used for applications requiring shorter read ranges. These include access control, work in process tracking, and asset management.

Low-frequency (LF: 125–134.2 kHz and 140–148.5 kHz) (LowFID) tags and high-frequency (HF: 13.56 MHz) (HighFID) tags can be used globally without a license. Ultra-high-frequency (UHF: 868–928 MHz) (Ultra-HighFID or UHFID) tags cannot be used globally as there is no single global standard. In North America, UHF can be used unlicensed for 902–928 MHz (±13 MHz from the 915 MHz center frequency), but restrictions exist for transmission power. In Europe, RFID and other low-power radio applications are regulated by ETSI recommendations, allowing RFID operation with somewhat complex band restrictions from 865–868 MHz.

As frequency increases, tag and reader costs increase too. Tags at 125-kHz operating frequency have ICs costing cents; 2.4-GHz tag ICs cost several dollars. Similarly, higher frequencies increase the passive read range and also increase the speed at which the device can operate; these longer ranges are measured in yards and miles. Lower frequency tags in the 125-kHz and 13.56-MHz range have read ranges measured in inches and feet.

Read range, or the maximum distance from the reader at which a card or tag may be read, is generally a function of the antenna size within the reader and/or the tag for a given operating frequency. Larger readers and/or larger tags usually have greater read ranges.

5.8.2 RFID Market Applications

RFID has benefits similar to other automatic identification technologies such as barcodes, in that it can expand the ability to collect data automatically and electronically. Moreover, RFID devices are immune to dirty, oily, wet, or harsh environments and, because they have no moving parts, rarely need maintenance. The technology is ideal for confidential identification of people or assets because it is easy to protect from corruption. Finally, RFID is fast, communicating in milliseconds, and can tolerate temperature extremes from –40°C to 200°C.

Printed electronics is expected to impact the low end of the market first in terms of performance and cost. Because active devices involve battery power and a greater number of transistors and functions, currently they are difficult to integrate into printed electronics technology, despite the progress made by adding antennas, amplifiers, and sensors into a single device. Whereas the overall RFID market is expected to be driven by traditional passive and active tags used in financial services (smart cards), government (passports), automotive (car door openers), and military applications, printed electronics can be expected to replace some existing passive applications (national ID cards, fobs, ticket sales) and drive the emergence of new ones, most notably item-level tracking of consumer goods and general asset management tracking.

Printed RFID tags currently exhibit some technical drawbacks in that their electrical properties cannot compete with those of inorganic materials. The charge carriers in the polymers travel more slowly, with the result that a printed RFID tag will have a shorter transmission range than a conventional one. Moreover, polymers tend to react more sensitively to moisture and UV light. To remedy this, researchers at the Fraunhofer Institute of Integrated Systems and Device Technology IISB in Erlangen claim to have developed a process line in which electronic devices can be printed from inorganic materials using an inkjet similar to that in any office printer. The researchers used ink made of nanoparticles and added a stabilizer so that the particles could be easily processed and did not clump together.

In October 2009, Xerox announced that it had perfected a method for printing a silver metallic ink, at essentially room temperature, using a desktop printer. The method, Xerox claims, can produce fine lines suitable for electronic circuits. The Xerox process prints three layers: a semiconductive layer, a conductive layer, and a dielectric. Whereas the initial samples were produced using a desktop printer, Xerox envisions the technology eventually being used in continuous roll applications.

The most significant aspect of this new technology is that it is applicable to a wide range of consumer products, such as games, e-readers, signage, flexible keyboards, and computers. The applicability of the technology to consumer products provides a real incentive to companies to further develop the technology—with RFID benefits being almost secondary.

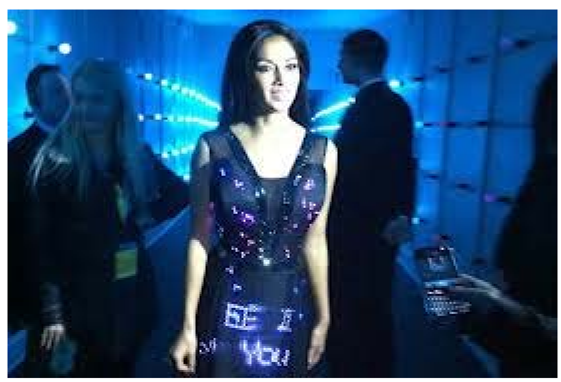
Packaging manufacturers will be among the first to explore the use of printed RFID tags. If only three layers of ink are actually required, the presses currently used could easily turn out RFID tags in huge volumes. Current high-quality multicolor presses can have eight or more "stations" (units that print a specific ink color), so even if a few more layers are required, they could be accommodated with existing equipment. Obviously, registration (the exact alignment of the substrate as it moves from one station to the next) would be critical. A potential downside is that printed tags will be easier to counterfeit, as they will not need to be produced in an advanced chip foundry.

5.9 Textiles/Clothing

An application that is gaining attention is textiles or smart clothing, which uses PE production technology to manufacture clothes or materials that sense and react to environmental conditions or stimuli. Current applications seem focused on printing flexible conductors onto fabrics for use as heaters and biometric inks, which respond and record movement and vital functions. The PE conductors are machine washable and printed directly on the textile. Manufacturers such as Sears, Andrew Marc, Burton, Thermologic, Aklimate and the US Army Air Crew all have conductive inks incorporated into their fabrics to control heat, sounds, light and a wide array of sensors.

T-Ink is one of the leading innovators for PE in wearable fabrics. Various athletic and military customers have expressed interest in the sensing and heating technology that PE offers. This is a growing field and should experience rapid expansion over the next several years as practical and affordable applications are developed. Heated car seats (embedded PE heating wires in the fabric) is one of the most promising areas for development. At present, this market is quite small (estimated to be approximately $20 million in revenue, worldwide), but could easily multiply once the transportation industry begins to adopt this solution. Figure 5-9 illustrates two possible examples of PE for textiles/clothing applications in 2012.

Figure 5-9 – Examples of PE for Textile/Clothing Applications, 2012



5.10 Transportation

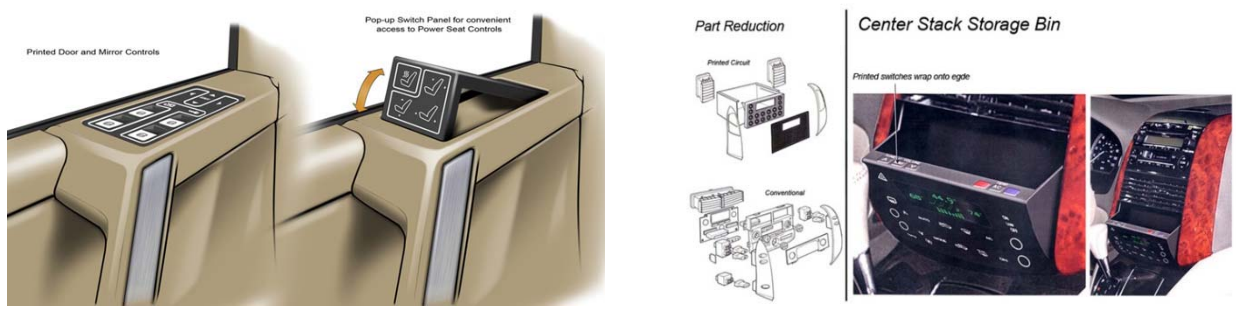
Finally, one of the most exciting and overlooked applications for PE has emerged in the automotive and aerospace industries, primarily as a result of reducing the size and weight (in some cases of between 30%-70% per part) of legacy systems. Boeing has stated that there are billion-dollar cost-saving opportunities for every percent reduction in physical weight on their airplanes and sees a huge potential for using light, integrated printed wiring to replace the heavy cable bundles that fill the floor and ceilings of the plane.

Applications include InMold overhead control panels, keyless entry systems, heated seating and steering wheels, and wiring replacement on aeroplane and automobiles. While this market is estimated to be approximately $20 million in worldwide PE revenue in 2012, it could easily be one of the highest growth markets if adopted by the transportation industry.

Boeing already uses printed electronics for the bird detector sensor on its 747s. It also seeks sensors to monitor structural stress and condition and tags to authenticate Boeing parts to stop the multibillion dollar market in counterfeit replacement parts. But reliability demands are extreme – components have to survive 20 years in extremely harsh conditions, including everything from regular lightning strikes to soaking in hydraulic fluid capable of dissolving screwdriver handles.

The military is using the technology for sensors to detect explosive devices and gather the results of weapon tests. It is putting flexible sensors in helicopter skin to feed the pilot real-time information on where the craft is hit and how badly. Explosive or energetic inks allow small, flexible detonators, meaning room for more intelligence and more firepower within the weapon. Sensors attached to ammunition boxes track storage and shipping conditions so users can tell if the equipment will work before having to rely on it in the field, and if one round fails they won't have to condemn the whole lot. A printed antenna on the helmet replaces the old wire antenna sticking up from the soldier's back pack, and makes him less of a target. Figure 5-10 illustrates two possible examples of PE for transportation applications in 2012.

Figure 5-10 – Examples of PE for Transportation Applications, 2012



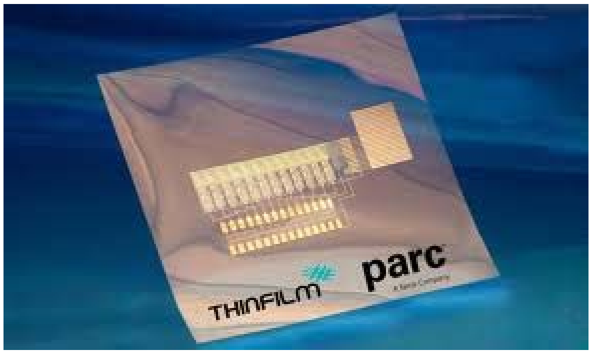
5.11 Other

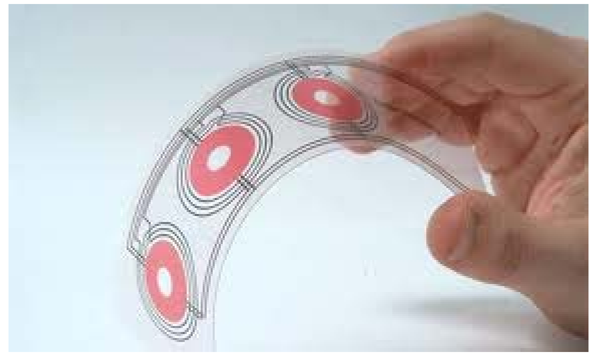
Printed electronics is making significant strides in the field of printable sensors which integrate printed electronics with sensor input data (such as optical, pressure, humidity, chemical/electrochemical, biomaterials, etc. detection). These sensors work by changing their resistance upon exposure to a wide variety of conditions, including organic vapors, water, methanol, ethanol, chloroform, methylene chloride, as well as acids (HCl, acetic acid) and bases (ammonia). Integrating such functionality onto a new product offers potential in low manufacturing costs and integration.

Such sensors can be printed on a variety of substrates, including paper and plastic, and show different performance on the different substrates. In some cases, enormous changes (> 300X) in resistance can be observed. For example, some of these sensors respond to changes in humidity almost as fast as commercial humidity sensors. Optical profilometry and SEM can be used to analyze the surface and interface structure of the sensors.

In December, 2012, Thin Film Electronics announced the first proof-of-concept prototype of an integrated printed electronic tag based on rewritable memory. The printed electronic label, consisting of printed memory, sensor and logic, detects that critical temperature thresholds have been exceeded and records data digitally for later retrieval and display. Such labels can deliver item-level tracking of quality data for goods such as pharmaceuticals and perishable foods. The Thin Film integrated system shows how low-cost, disposable printed electronic technology will provide information about product history based on data stored in Thin Film Memory. An example of the prototype is presented below in Figure 5-11 which also illustrates another example of PE in 2012.

Figure 5-11 – Example of PE for Other Applications, 2012





American Express engaged T-Ink to explore a solution for security fraud without changing how current credit cards are used. The company developed a unique card interface printed directly on the face of the credit card to activate the card by user pin. Printable security features in smart cards and other official documents (including passports) have been talked about for years, but there exist only a few pilot projects in development.

Sensors, batteries, logic and memory devices are positively emerging opportunities for PE over the next 5-10 years. Typical applications involve devices that require power, temperature, pressure, weight, vibration, acceleration and chemical composition (including accompanying logic and memory) embedded into the design of light-weight and inexpensive devices. For example, the sensor industry has been migrating toward smaller and less costly devices that utilize semiconductors in their functionality (e.g., accelerometers in automotive air bags). Start-up companies like Cymbet, Enfucell, Excellatron, Infinite Power Solutions, and Solicore have developed innovative solutions via PE technologies. Thin Film, PragmatIC Printing and T-Ink are developing PE devices that integrate logic, memory and sometimes a power source into a single solution. The current market for these solutions is certainly less than $50 million in revenue worldwide, as summarized in the next table, but represent very high potential for the future as manufacturing processes are perfected.

5.12 PE Market Summary

The market for printed electronic assembly is still very much in its infancy after more than 10 years, but certain areas are slowly becoming established. Right now it hardly moves the needle as a measurable market compared with the current size of the traditional IC market that it will replace.

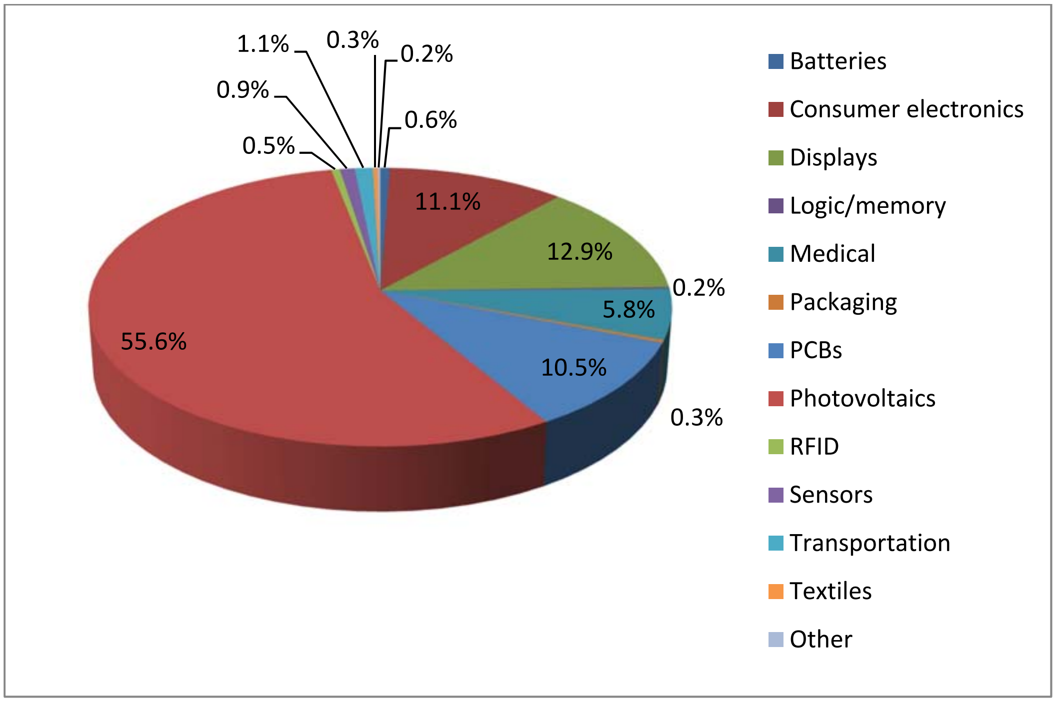
In conclusion, we would say that the definition of printed electronics is too limited today. While it clearly represents high opportunity in many product areas, the process of "printing" is not superior to "deposition", as used in semiconductor manufacturing. In fact, PE roll-to-roll printing is technically inferior to vapor deposition, though it appears to have a higher potential for products with short turn-around time and customization. PE might appear to be more natural and efficient, but when all of the costs and production steps are taken into account, it is not clear if it is the most cost-effective solution in all cases. Scott White of PragmatIC Printing states it best when he says, "Viable approaches will use a combination of different technologies (both printing and otherwise), each optimized to achieve the desired form factor, functionality and cost structure for a particular component of the 'printed electronics' solution. These technologies should be chosen based on the end result (which is what the customer ultimately cares about), not based on a religious view that any particular type of printing is best."

Table 5-9 and Figure 5-12 summarize the current PE market in terms of revenue worldwide by application area for 2012.

Table 5-9 Worldwide PE Assembly Market by Application, 2012

PE Application	Rev. ($M)	Percent
Batteries	23	0.6%
Consumer electronics	426	11.1%
Displays	496	12.9%
Logic/memory	8	0.2%
Medical	223	5.8%
Packaging	12	0.3%
PCBs	402	10.5%
Photovoltaics	2,133	55.6%
RFID	21	0.5%
Sensors	36	0.9%
Transportation	43	1.1%
Textiles	12	0.3%
Other	6	0.2%
Total	**3,840**	**100%**

Figure 5-12 - Worldwide PE Assembly Market by Application, 2012



Chapter 6 – Printed Electronics Market Forecasts

The future market for PE has been over-hyped in forecasts for many years now. Yet, based on our field research, it seems clear that there are very strong application areas emerging today as identified in Chapter 5. It is hard not to be optimistic of high-technology electronics developments for two reasons: first, radically new technology does have the power to displace and sometimes eliminate conventional product technologies (think electronic internet replacing printed yellow pages or email replacing physical mail), and second, low-growth markets rarely get much attention. This can result in a conflict of interest between consumers and publishers of market research data, who naturally tend to exaggerate the true picture of emerging technologies. Most people within the market research industry know this, yet few will freely admit it. It is our hope that we can maintain a cautious and realistic perspective.

The PE market initially captured the imagination of the electronics industry, as it seems to be a fresh alternative to the intense and expensive path of semiconductor component manufacturing. Printing electronic devices can be cheaper in certain circumstances, as well as quicker and more practical than IC manufacturing (soldering of components on printed circuit boards is by nature labor-intensive). Yet, high technology product markets rarely achieve the growth rates forecast by industry pundits. Computer tablets are definitely on track to set the record in hardware growth, although we only have three years of data to compare. Smart phones didn't get a boost beyond a 20% CAGR until the iPhone arrived. Once we were able to get reliable data, it was clear that Notebooks have only averaged 10% CAGR. Video console games fared a little better as did MP3 players, yet estimating how fast the PE market will expand is nothing but a subjective guess. We are predicting a CAGR growth rate of nearly 20% annually for all applications – an attractive achievement for an emerging market.

This last point of growth rates needs to be discussed further. We are aware of past market research reports that forecast the future PE market eight, ten and even twenty years hence. Of course, this can be nothing but pure speculation designed to promote the sales of a given report. NVR has been forecasting electronics assembly markets for many years and has established five-year growth estimates because this is a window of time which has good predictability – and has proven to be reasonable over time. There are simply too many market variables and possibilities of technical development for a market such as PE to be forecast beyond a five year window, therefore our estimates may appear less optimistic than those quoted by other pundits in the industry. With each year, our research contributes better information and more accurate market numbers –so long as we stay within a reasonable forecast visibility period. With this in mind, we have examined up to 40 unique PE applications in this chapter, and their associated forecasts, which we hope will be useful for marketing executives and strategic planners.

6.1 Worldwide Contract Manufacturing Market, 2011-2016

EMS services accounted for 39 percent of all electronic product assembly in 2011 (approximately the same percent as in 2010). The growth of the CM industry has been led by strong demand for smart phones and notebooks/tablets and the rebound in CAPEX (capital equipment expenditures) spending across the industrial and transportation sectors. As a result, the automotive and semiconductor industries recovered significantly, and contributed to the growth of the overall CM industry. Slight consolidation of the EMS industry took place (e.g., Elcoteq went out of business), but most CM companies were expanded into new markets with advanced services.

The CM industry should continue producing good financial performance in ensuing years if there is not another downturn (which normally comes after a large inventory buildup of the kind that now appears to be in process). ODMs are benefiting significantly from the continued growth of the computer and low-end mobile phone industries, but there is only moderate growth forecast for the future. ODMs focus on commodity markets—a winning formula to date, except that these markets eventually decay over time.

Table 6-1 presents a summary forecast for the worldwide revenue growth of the EMS and OEM assembly markets from 2011 to 2016. ODMs should underperform EMS companies over the forecast period as a result of their riskier business model, which relies on giving preference to branded and low-end computer, communications, and consumer products. This is because ODMs are usually better able to streamline their production methods and create economies of scale through the concentration of components and vertical integration, but ultimately all profits get driven to the margin over time. Because EMS firms manufacture a wider range of products, and can leverage their operations in different ways, it is believed that they will experience a slightly higher growth rate over the forecast period.

Table 6-1 Worldwide Electronics Assembly Market by Manufacturing Supplier, 2011-2016

Revenue ($M)	2011	2012	2013	2014	2015	2016	CAGR
OEM	644,412	679,850	705,001	747,464	780,389	819,017	4.9%
ODM	160,237	175,266	191,651	210,772	231,220	252,779	9.5%
EMS	252,516	276,433	302,841	333,629	366,338	401,487	9.7%
Total	**1,057,165**	**1,131,548**	**1,199,493**	**1,291,864**	**1,377,946**	**1,473,283**	**6.9%**
Percent Change	8.7%	7.0%	6.0%	7.7%	6.7%	6.9%	
OEM	61.0%	60.1%	58.8%	57.9%	56.6%	55.6%	
ODM	15.2%	15.5%	16.0%	16.3%	16.8%	17.2%	
EMS	23.9%	24.4%	25.2%	25.8%	26.6%	27.3%	

The ODM business model has its risks and rewards, as many OEMs have discovered. The tendency to copy existing products and capture intellectual property (as evidenced by the ongoing lawsuits between companies like Apple, Samsung, and HTC) remains high, although for commodity products most ODMs provide their own IP advances and pass them on to their customers. Unlike most ODMs, EMS companies do not manufacture their own private label products to compete with their customers' products. EMS firms do offer ODM design services, rapid product turnaround, and deployment in segments where ODMs have competitive advantage (computers, cell phones, low-end networking equipment, and consumer electronics), but do not have this conflict of interest. However, most ODMs take precautions to avoid competing directly with their customers in the marketplace by creating firewalls between their OEM operations and their CM activities. This limits their potential growth.

Table 6-2 Worldwide Electronics Assembly Market by Supplier and Market Segment, 2011-2016

Total Assembly ($M)	2011	2012	2013	2014	2015	2016	CAGR
Communications	327,638	352,103	374,502	405,556	433,507	465,155	7.3%
Computer	239,564	257,987	275,399	296,802	316,960	340,149	7.3%
Consumer	208,737	226,688	242,463	261,098	277,628	297,493	7.3%
Industrial	95,285	99,819	100,747	106,941	112,764	118,583	4.5%
Medical	54,187	55,019	57,991	61,887	66,526	69,017	5.0%
Automotive	72,736	79,087	85,598	91,230	96,293	100,898	6.8%
Aviation/Defense/ Other	59,018	60,845	62,792	68,350	74,269	81,988	6.8%
Total	**1,057,165**	**1,131,548**	**1,199,493**	**1,291,864**	**1,377,946**	**1,473,283**	**6.9%**

Table 6-2 summarizes the total market for electronics products by manufacturing source and market segment from 2011 to 2016. It is clear that a large proportion of manufacturing is still being completed by OEMs in-house—largely among Japanese, Korean, and Chinese electronics companies, but also to some degree among the leading American and European OEMs. Yet these percentages are shifting as competition continues to emphasize cost reductions, making it increasingly difficult for OEMs to manufacture in-house competitively. EMS suppliers are better at velocity manufacturing because they have perfected their production processes and can achieve higher utilization and throughput on their equipment. However, not all electronic products are ideal for outsourcing, particularly those that are low in volume, high in complexity, or have product liability concerns. Not surprisingly, an increasing percentage of high-volume products have become commodified and thus are best suited for contract manufacturing.

For the last ten years, ODMs have been primarily niche suppliers, most notably in the computer motherboard market. For the last five years, these suppliers have increased their design skills and have branched out into communications and consumer electronics products, capturing increasing numbers of assembly contracts traditionally held by EMS companies. This is due to their operational cost structure, which is very low because it is almost exclusively Asian, and so ODMs tend to concentrate on products that are sold in high volumes and are price-sensitive. When valuable product IP exists (such as in the medical or aerospace industries), most OEM customers opt to outsource to an EMS firm to avoid the risk of these products being reverse-engineered and sold as competitive knock-offs.

OEM assembly of electronic products is expected to decline to slightly more than half of all assembly in 2016. The EMS percentage of the total available assembly market is expected to increase to around 27 percent, while the ODM percentage will grow to approximately 17 percent of the total assembly market. The trend to outsource will have its greatest impact on the computer and communications industries, in which almost 60 percent of communications products will be outsourced by 2016. A substantially smaller percentage of consumer, industrial, medical, and transportation products will be outsourced because many of these products are either captive to in-house manufacturing or are not readily outsourceable. In many cases, such as medical and aerospace, only the PCB assemblies are outsourced to CM suppliers, and the OEM completes the final box assemblies (usually due to product liability concerns).

Both EMS firms and ODMs today are capable of completely manufacturing increasingly complex products. Advanced computer and communications switching products require very sophisticated manufacturing technology that is no longer maintained by OEMs. By using EMS subcontractors, OEMs have lost the ability to manufacture their hardware products in-house and their livelihood is increasingly dependent on their EMS partners. This trend is similar to that in the automotive industry, in which electronics OEMs are using subcontractors extensively to manufacture components and subsystems, while performing final product integration.

ODMs have taken a slightly different approach of focusing on a single product area (such as computer motherboards, cell phones, digital TVs, or cameras). OEMs like this model because their investment is minimal and they only have to give the ODM a general specification, from which a finished product will be delivered carrying the OEM's private label. EMS firms have not offered this vertical kind of manufacturing service, although they increasingly tout ODM-like services (for example, Foxconn, Flextronics, Jabil, and Sanmina-SCI do this). EMS firms prefer to remain product independent by making a wide range of designs and assemblies, and do not assume liability for excess material. Hence, each business model has its attractive features and associated risks for the OEM.

Outsourcing provides the most leverage of equipment and economies of scale among products that are high in volume or that are easily assembled via automation. This capability is ideal for products in the computer, communications, consumer, and instrumentation industries, which have sensitive time-to-market needs. EMS suppliers become profitable when they are able to fully utilize their manufacturing equipment by leveraging it across multiple customers and in some cases achieving equipment utilization rates of 95 percent or higher.

6.2 PE for Consumer Electronics, 2012-2017

PE in consumer electronics is not new, but it has been generating a lot of attention and new participants since the mid-2000s, while some of the more traditional applications such as keyboards, appliances, battery testers, electroluminescent lamps, and biosensors date back to the 1970s. The consumer electronics market is comprised of a large array of products, which for PE has fallen into two main categories: membrane switches and memory/logic/battery and sensor solutions for the toys, games and appliances in this segment. Membrane switches use thin-film conductor and dielectric inks to form a mechanical switch that can be built into an appliance or into a computer keyboard. Silver inks are screen printed onto two polyester film layers separated by a spacer layer, and when physically depressed, the two silver traces make a connection and close a circuit.

The assembly market for home appliances by leading supplier and their geographic regions of manufacturing can be found within Table 6-2, under the Consumer Electronics category and the "Other" market segment. These products are part of the consumer electronics market and account for $27 billion in assembly revenue in 2011. Of course, membrane switches are a very small part of this total, as defined in Table 6-4, yet over the next five years they are expected to expand by almost three times within the overall appliance industry, as they have been shown to be very cost-effective solutions compared to mechancial switch designs. That growth rate is high not only because membrane switches will replace mechanical ones, but because new PE applications in memory, sensor and battery functions will be integrated over the next several years. This is made clear by suppliers like T-Ink, which has experienced significant success with customers such as Fisher-Price, Hasbro, Nickelodeon, Playtex and MacDonalds in end consumer products.

Table 6-3 summarizes the leading appliance supplier assembly revenue worldwide and their manufacturing regions for 2011. Table 6-4 summarizes our market forecast for PE membrane switches and other functionality products to be used in consumer products, between 2012 and 2017.

Table 6-3 Worldwide Appliance Assembly Market by Leading Supplier and Region ($M), 2011

Appliance Companies	Total	Americas	EMEA	APAC
Midea	1,970	-	-	1,970
Tatung	1,456	-	-	1,456
LG Electronics	1,050	210	210	630
Whirlpool	660	495	132	33
Electrolux	657	263	328	66
Bosch Group	596	107	370	119
Hisense	528	-	-	528
General Electric	478	239	96	143
Samsung	471	-	-	471

Vestel	393	-	393	-
Arcelik	353	-	353	-
Haier Electronics	324	-	-	324
TCL	321	-	-	321
Panasonic	279	28	28	223
Sanyo Electric	252	-	-	252
Casio	235	-	-	235
SVA	192	-	-	192
Mitsubishi Electric	188	13	15	160
Sharp	160	-	-	160
Toshiba	114	11	11	91
Hitachi	114	-	-	114
Pioneer	58	-	-	58
Yamaha	53	-	-	53
Olympus	51	-	-	51
Radio Shack	35	-	-	35
Top Consumer	10,987	1,366	1,936	7,685
Others	16,211	2,016	2,856	11,339
Percent	**59.6%**	12.4%	17.6%	69.9%
Assembly Revenue	**27,198**	**3,382**	**4,792**	**19,024**

Table 6-4 Worldwide PE Appliance Assembly Market by Application ($M), 2012-2017

Consumer Products	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**CAGR**
Membrane switches	425.8	478.8	543.4	620.4	711.6	820.8	14.0%
Memory/sensors/ battery	0.21	0.45	0.98	1.87	3.4	5.7	93.1%
Assembly Revenue	**426.0**	**479.3**	**544.4**	**622.3**	**715.0**	**826.5**	**14.2%**

6.3 PE for Displays and Lighting, 2012-2017

There are three types of display technology that are considered to be part of the PE industry: electroluminescent, electrophoretic and OLEDs. Unfortunately, the only technology of these three that has proven to be successful has been the electrophoretic displays, as popularized by E-Ink in e-readers. E-readers are a fast growing market with the latest generation of devices coming out of Amazon, Barnes&Noble and recently Google. One new market segment is targeting children's educational and entertainment devices that use the e-reader technology platform but customize the content.

For reasons previously discussed, the success of EL and OLED display products has been limited for technical production reasons, and are not foreseen to replace or be used by OEM companies to any significant extent over the next few years. This has not occurred for lack of trying. Despite huge investments from giant companies like Samsung, LG and Sony, EL and OLED technology has not been able to displace the far more successful and dominant LCD technology, which has proven to be more cost-effective over the years. Thus, the alternative technologies have been relegated to niche solutions. Wireless device manufacturers are still attracted by OLED and EL technologies for their low power consumption and video capability qualities.

Although traditional LCD technology still dominates the display applications marketplace, there is incipient demand for printed OLED displays in a variety of niche product applications. The rationale behind this preferred display technology is that it can be printed via screen printer or inkjet, and is cheaper to manufacture than LCD displays. Yet, this has not proven to be the case. Leading OLED manufacturers have recently lost confidence in the technology due to its low yields, according to DisplaySearch. The earliest period these display technologies can hope to gain traction is 2014. Table 6-5 summarizes the worldwide market for PE display and lighting assembly by application from 2012 - 2017.

Table 6-5 Worldwide PE Display and Lighting Assembly Market by Application ($M), 2012-2017

Displays and Lighting	2012	2013	2014	2015	2016	2017	CAGR
E-Readers	289	341.9	406.8	478.0	558.4	649.4	17.6%
Mobile phones	40	44.2	48.3	52.4	56.5	60.3	8.6%
Car audio	46	49.0	52.8	57.2	62.4	68.4	8.3%
MP3	10	10.8	11.5	12.2	12.9	13.5	6.2%
Video camera	19	20.6	22.4	24.4	26.5	28.9	8.7%

General lighting	-	0.1	0.1	0.1	0.2	0.2	5.3%
Other	92.0	94.9	98.9	104.0	109.7	116.2	4.8%
Assembly Revenue	**496.0**	**561.5**	**640.9**	**728.3**	**826.5**	**936.9**	**13.6%**

6.4 PE for Medical Products, 2012-2017

Our research field interviews consistently found medical and bio-sensor applications to be one of the most promising markets for PE. Many EMS suppliers were engaged in providing test strips for blood glucose monitoring, disposable defibrillator pads and medical electrodes for EKG and EEG testing. Companies such as GSI Technologies and Si-Cal were optimistic about the business opportunities in these areas and projected strong business growth over the next several years due to cost and performance features. While the medical PE market is relatively small at this time, it is expected to grow very positively for test and measurement applications.

Diagnostic test strips manufactured by printed technology stand to dramatically lower cost on these and other disposible devices. Blood glucose sensors are commonly manufactured by screen printing technology of silver, carbon, and silver chloride among large scale manufacturers. Other biosensor applications include iontophoretic drug delivery – a non-invasive technique where a small current is used to deliver drugs through the skin. Advantages include controlled and continuous low-dosage delivery of medication directly to the treatment area, relatively pain free, and with better patient compliance.

The integrated ability of sensor technology (such as chemical analysis, temperature, pressure, displacement, humidity, moisture, vibration and biological information) is be developed using PE manufacturing technology, supposedly on an integrated basis. New fields yet to be explored include toxins, nutrients, pheromones and proteins in the environment and living species.

Table 6-6 summarizes the leading medical suppliers worldwide and their manufacturing regions for 2011. Table 6-7 summarizes the market forecast for PE medical solutions between 2012 and 2017.

Table 6-6 Worldwide Medical Assembly Market by Leading Supplier and Region ($M), 2011

Medical Companies	Prod. Total	Americas	EMEA	APAC
Siemens Healthcare	2,446	734	1,223	489
GE Healthcare	1,639	819	328	492
Philips Medical	1,272	318	763	191
Fujitsu	1,184	59	59	1,066
Fresenius	1,099	879	220	-
Olympus	1,081	-	-	1,081
Hitachi	1,009	50	50	908
Toshiba	812	-	-	812
Johnson & Johnson	774	387	155	232
Medtronic	626	376	156	94
Becton Dickinson	561	280	196	84
Baxter	548	219	164	164
3M Healthcare	523	261	131	131
Beckman Coulter	473	237	142	95
Canon	470	-	-	470
Novartis	456	137	228	91
Varian Medical	421	210	126	84
Agilent	417	125	83	208
Covidien	400	240	80	80
Thermo Fisher	394	118	79	197
Others	37,585	14,573	4,240	18,772
Total Revenue	**54,187**	**20,023**	**8,424**	**25,741**

Table 6-7 Worldwide PE Medical Assembly Market by Application($M), 2012-2017

Medical Products	2012	2013	2014	2015	2016	2017	CAGR
Blood glucose, EKG, EEC	222.9	291.1	364.2	439.2	507.7	581.3	21.1%
Other medical	0.11	0.22	0.43	0.77	1.30	2.08	79.6%
Assembly Revenue	**223.0**	**291.2**	**364.3**	**439.4**	**507.9**	**581.6**	**21.1%**

6.5 PE for Packaging, 2012-2017

PE technology for packaging has been emerging over the last several years. Thin Film continues to lead the field in developing packaging and labeling solutions, such as an integrated printed electronic tag based on rewritable memory. Its latest PE label, consisting of printed memory, sensor and logic functions, detects if critical temperature thresholds have been exceeded and records data digitally for later retrieval and display. Such labels can deliver item-level tracking of quality data for goods such as pharmaceutical drugs and perishable foods. The Thin Film solution shows how low-cost, disposable printed electronics technology can provide information about product history based printed memory technology at affordable cost.

Most of this kind of technology is referred to as active packaging, and measures changes in the condition of packaged food in order to extend shelf-life or improve food safety while maintaining the quality of the packed food. Companies such as T-Ink and GSI Technologies seek to integrate PE or traditional electronics into the packaging of foods, beverages, pharmaceutical and beauty products. ThinFilm's packaging customer, Bemis Inc., is breaking new ground in this sector which is only starting to realize its potential. Suppliers of beauty products are exploring animation in packaging involving lighting and retail incentive solutions. Table 6-8 summarizes the market for PE in packaging solutions by product application, from 2012-2017.

Table 6-8 Worldwide PE Packaging Assembly Market by Application ($M), 2012-2017

Packaging	2012	2013	2014	2015	2016	2017	CAGR
Food	6.48	9.7	16.4	29.9	61.3	135.4	83.7%
Beverages	0.2	0.5	1.0	1.9	3.5	5.4	80.9%
Pharmaceutical	3.8	5.6	9.3	13.9	19.3	24.9	45.3%
Beauty	0.4	0.6	1.2	2.7	5.0	7.4	82.9%
Other packaging	1.1	1.4	2.1	3.2	5.3	9.2	53.5%
Assembly Revenue	**12.0**	**17.8**	**30.0**	**51.6**	**94.3**	**182.3**	**72.3%**

6.6 PE for Photovoltiacs (PV) , 2012-2017

There was a time when thin-film PV solar cells were thought to lead the marketplace in terms of electrical efficiency and cost, yet, some of the most advanced materials such as CIGS, a-Si, CdTe, and Organic (Dye Conversion) have not been able to keep pace with the cost-per-watt electrical generation capability of traditional silicon, thus these technologies continue to be niche developments in R&D. Regardless, it is believed that these new thin films will find a home in emerging markets, such as flexible substrates for mobile and remote applications of the kind found in the military and recreational industries.

This leaves us with the conventional market of silicon solar cells that employ a method of depositioning light-sensitive receptors on a hard substrate such as metal or glass. This has nothing to do with PE, but electrical connector traces (referred to as bus bars) are still necessary to carry the electrical current to the required inverters and storage devices. For various mechanical reasons, the preferred print technology appears to be screen printers that have been dominant for many years.

The market for PE in PV will continued to be driven by the rising tide of silicon PV technology. This remains a healthy market so long as costs continue to drop and governments continue to provide investment subsidies for interested countries. It's a market that remains healthy for the moment but it could be displaced with innovations by thin films.

Table 6-9 summarizes the leading solar OEMs in terms of PV assembly production by manufacturing region for 2011. Table 6-10 summarizes the total market for PE in PV bus bar assemblies from 2012-2017. Bear in mind that the high growth rate of thin film PE solutions is due to a very low assembly base in 2012.

Table 6-9 Worldwide PV Assembly Market by Leading Supplier and Manufacturing Region ($M), 2011

PV Companies	Prod. Total	Americas	EMEA	APAC
LDK	1,167	-	-	1,167
First Solar	1,109	111	843	155
SunTech Power	864	86	631	147
Q-Cells	757	-	757	-
SunPower	750	218	488	45
Trina Solar	599	84	461	54
Canadian Solar	540	135	135	270
SolarWorld	537	16	477	43
Gamesa	451	135	271	45
Fronius International	291	29	221	41
AREVA	275	-	275	-
Solon SE	271	-	271	-

China Sunergy	191	-	77	115
Power-One	185	37	93	56
GE Industrial	185	74	37	74
Tokyo Electron	148	-	-	148
BP Solar	128	41	49	38
Hitachi	126	10	10	106
Mitsubishi	114	-	-	114
Others	3,652	404	1,967	1,280
Total Assembly Revenue	**12,342**	**1,381**	**7,063**	**3,899**

Table 6-10 Worldwide PV Assembly Market for PE by Application ($M), 2012-2017

Solar PV	2012	2013	2014	2015	2016	2017	CAGR
Bus bars	2,133.2	2,459.6	2,806.4	3,196.5	3,596.1	4,034.8	13.6%
Thin Films	0.11	0.27	0.49	0.77	1.30	2.08	81.2%
Assembly Revenue	**2,133.4**	**2,459.9**	**2,806.9**	**3,197.3**	**3,597.4**	**4,036.9**	**13.6%**

6.7 PE for Printed Circuit Boards (PCBs) , 2012-2017

PE silver flake and other conductor materials have been used in the construction of PCBs since the 1990s. The most common applications are to provide EMI/RF Shielding, to fabricate low-voltage circuitry, to create a temporary and removable silver "plating link," and to plug vias with a thermally and electrically conductive material that is plateable. In almost all cases, the patterning is done via screen or stencil printing of a silver or silver-coated copper conductor. New materials development is ongoing for use by the PCB fabricators, but one general limitation is the limited screen/stencil printing infrastructure and expertise within the board shops.

The PE market for PCB assemblies is growing according to numerous industry participants interviewed in the field. This is because screen printing of circuit paths and inventory information cannot be achieved by any other printing means once the PCB has been cast. Additional trace patterns and production identification is necessary after the fact. Therefore, growth in demand for PE assembly will come after the the fabrication of the initial PCB and usually to supplement design changes of the

PCB. Therefore, the market will likely only grow in parallel with the overall PCB assembly market. Table 6-11 summarizes the worldwide PCB assembly market for PE by application, 2012-2017.

Table 6-11 Worldwide PCB Assembly Market for PE by Application ($M), 2012-2017

PCB Assembly	2012	2013	2014	2015	2016	2017	CAGR
Automotive	55.9	59.6	63.5	67.7	72.2	76.9	6.6%
Communications	52.7	58.4	64.8	71.8	79.7	88.3	10.9%
Computer	86.0	94.3	103.3	113.3	124.1	136.0	9.6%
Consumer	42.2	46.2	50.6	55.4	60.7	66.4	9.5%
Industrial	65.5	70.5	75.9	81.6	87.8	94.5	7.6%
Medical	49.8	53.8	58.0	62.6	67.6	72.9	7.9%
Aerospace/Other Transportation	49.8	52.5	55.4	58.4	61.5	64.8	5.4%
Total Revenue	**402.0**	**435.3**	**471.5**	**510.8**	**553.5**	**600.0**	**8.3%**

6.8 PE for Radio Frequency Identification (RFID) 2012-2017

RFID Systems are typically comprised of a primary antenna, a transceiver, and a transponder with a passive antenna. A lot has been predicted about how the future of PE will include the printing of transistors to replace the RFID chip and chip assembly. If/when this occurs cheaply enough, the addressable opportunity is huge. However, for now, the PE portion is limited to the antenna and in some cases the chip-containing strap. Even then, the silver cost of the printed antenna has permitted other technologies such as etched copper and aluminum foil to satisfy the low cost requirements. Table 6-12 summarizes the worldwide RFID market by component for 2012.

Table 6-12 Worldwide RFID Market by Component ($B), 2012

RFID ($B)	2012	Percent
Tags: Passive	3.13	40.8%
Tags: Active	0.42	5.5%
Interrogators	1.92	25.0%
Networking	2.2	28.7%
Total	**7.67**	**100%**

Source: IDTechEx

RFID systems have proven to be particularly difficult to replace by PE solutions. While theoretically possible, in most cases traditional silicon technology has proved sufficient and the latest designs appear to be more competitive. This doesn't mean that PE for RFID is dead, rather we think that the ability to integrate multiple functional activities (memory, logic, battery, sensors, etc.) will eventually prevail, albeit not at a rate that will displace conventional electronics. Table 6-13 summarizes the worldwide RFID assembly market for PE by application from 2012-2017.

Table 6-13 Worldwide RFID Assembly Market for PE by Application ($M), 2012-2017

RFID	2012	2013	2014	2015	2016	2017	CAGR
Antennas	20.4	21.5	22.9	24.9	27.5	30.6	8.5%
Memory/sensors/ battery	0.10	0.14	0.19	0.25	0.31	0.38	27.4%
Assembly Rev. ($M)	**20.5**	**21.6**	**23.1**	**25.2**	**27.8**	**31.0**	**8.6%**

6.9 PE for Textiles/Clothing, 2012-2017

The current market for PE applications in textiles and clothing seems focused on printing flexible conductors into fabrics for use as heaters or other biometric electronic applications. The need for heating is by far the most attractive and practical application of smart fabrics, although developers are touting the benefits of biometric measurement for sports, extreme competitions and scientific exploration. The field of embedding advanced electronic components onto textile fibers is sometimes called fibertronics.

In many cases, the PE conductors are machine washable, and can be combined with other functionality to create solutions for comfort and aesthetics (such as electrical generation and lighting). E-textiles embed classical electronic devices such as conducting wires, integrated circuits, LEDs, and conventional batteries into textile fibers. Some examples are touch buttons that are constructed completely in textile forms by using conducting textile weaves, which are then connected to devices such as music players or LEDs mounted on woven conducting fiber networks to form displays. Customers include leading sports apparel manufacturers (Adidias, Nike, Puma, etc.), the armed forces (Army, Navy, AirForce, Marines, etc.), as well as advanced material producers (BASF, Dow Chemical, DuPont, Mitsui Chemicals, W.L. Gore, etc.). This field is still very embryonic and so only the heating technology application is expected to emerge rapidly over the next five years. Table 6-14 summarizes the worldwide textile assembly market for PE applications from 2012-2017.

Table 6-14 Worldwide Textile Assembly Market for PE by Application($M), 2012-2017

Textiles	2012	2013	2014	2015	2016	2017	CAGR
Biometrics	1.7	1.9	2.1	2.5	3.0	3.8	17.8%
Heating	8.3	9.7	13.1	21.6	39.4	80.7	69.9%
Lighting	0.3	0.3	0.3	0.3	0.4	0.4	11.0%
Sensing	1.0	1.1	1.2	1.4	1.6	1.8	12.2%
Other	0.7	0.8	0.8	0.9	1.0	1.1	8.4%
Total Revenue	**12.0**	**13.7**	**17.6**	**26.7**	**45.3**	**87.8**	**48.9%**

6.10 PE for Transportation, 2012-2017

In the market for PE application development over the next five years, transportation products (which include automotive, aerospace and military applications) are ranked highest. This is because there are two simple but innovative solutions that have emerged for this industry that will have a disruptive impact by cost and function. The practice of embedding heating elements into so many standard seat and cockpit fabric solutions, along with the replacement of conventional wiring coils with printed trace wiring, will vastly improve the current cost, weight and space requirements for OEMs in the automotive and aerospace industries. Companies like T-Ink are just beginning to tap into this, and the explosion of growth over the next five years will be significant.

Although used broadly as a heating element in automotive truck mirrors for years, recent advances in the design and construction of devices containing silver and positive temperature coefficient carbon have led to expanded uses of PE heater technology in automotive/aerospace seating and environmental designs, thus replacing conventional resistive wiring. More important, especially to the aerospace and military manufacturing industries, is the reduction in physical weight of PE trace circuit paths as opposed to coil wired technology, which uses miles of cable and connectors that can now be eliminated through PE technology. The technical advantages in weight and space are a difference of one hundred to one (that is the PE solution is 1/100th that of the conventional solution). The differential in cost when compared to conventional electronics technology has yet to be established, but could be as high as 10-30 percent less than today. Because of these combined advantages, the growth of PE for the transportation industry is expected to be the highest of all market applications from 2012-2017.

In a related application, the advancement of capacitive touch sensors in devices such as smart phones and tablet PCs is leading towards a new group of PE applications that includes in-molded plastics, which by analogy is now being applied to the automotive, aerospace and military industries. By nature, capacitive switches are more reliable than mechanical switches, as there are no moving parts to wear out or fail and the ability to print the controls onto a flat surface, then mold them into the 3D interior portions of appliances and automotive electronics helps reduce the total space and weight of the final device. More than any other industry, PE in transportation is projected to experience the highest growth in assembly revenue (both by replacement and by new innovation) than any other application examined. Table 6-15 summarizes the worldwide transportation market for PE by application, from 2012-2017.

Table 6-15 Worldwide Transportation Assembly Market for PE by Application ($M), 2012-2017

Transportation	2012	2013	2014	2015	2016	2017	CAGR
Control panels	6.8	8.1	9.9	13.4	20.7	40.5	42.9%
Heating	20.8	32.4	60.1	123.2	277.2	637.6	110.6%
Wiring replacement	12.7	26.7	58.3	129.4	304.0	760.0	126.6%
Other	2.7	2.9	3.1	3.4	3.7	4.1	8.4%
Total	**43.0**	**70.1**	**131.4**	**269.3**	**605.6**	**1,442.1**	**101.9%**

6.11 PE for Other General Applications, 2012-2017

The emerging market for PE in general applications is a catch-all for designs that have not been identified previously, or if they have, represent evolving opportunities that exist outside the specific vertical product needs. Clearly, there are many emerging products that require general PE functional capability, which we now define as battery power, logic/processor capability, memory/storage functionality and integrated sensor/detection elements that are specific to the product application. These product areas naturally cross all industry segments, and are not repetitive or redundant to our previous analysis.

In this regard, we want to consider emerging market products and applications that are embedded in today's computer, communications and consumer electronics technology. Because of this, we foresee PE replacement solutions in low-cost consumer communications products such as modems, LANs, and standard telephones. In the consumer market segment, there might be products such as fax machines, flash memory drives, and standalone display functions (printers, copiers, etc.) that could benefit by OLED display technology. Similarly, with consumer electronics, it is possible that MP3/DVD players could benefit from display and memory display/logic technology for the DVD and digital cameras that are so popular today. Finally, the transportation market applications are sure to evolve with new and cheaper in-flight/vehicle OLED or memory devices, whereby lower-cost solutions are found through PE technology. It is impossible to say, but we believe that these emerging market applications will ultimately result in a strong 'other' market that will be realized over the next five years. Table 6-16 summarizes the worldwide market for 'other' PE assembly products by general market application from 2012-2017.

Table 6-16 Worldwide Other Assembly Markets for PE by Application($M), 2012-2017

Other General Applications	2012	2013	2014	2015	2016	2017	CAGR
Batteries	22.5	25.3	28.5	35.8	48.2	70.3	25.6%
Logic/memory	8.3	10.5	15.2	28.1	57.5	120.8	84.3%
Sensors	35.5	40.8	67.4	117.9	212.2	350.1	58.1%
Other Apps	6.0	6.5	7.0	7.5	8.2	9.0	8.4%
Total Revenue	**72.3**	**83.1**	**118.0**	**189.3**	**326.1**	**550.2**	**50.1%**

6.12 PE Market Forecast Summary, 2012-2017

The total market of PE products by individual industry segment is summarized in Table 6-17 for 2012-2017. This represents the conclusion of our extensive field research involving printed electronics over the next five years.

Table 6-17 Worldwide PE Market by Industry Segment ($M), 2012-2017

PE Industry Segment	2012	2013	2014	2015	2016	2017	CAGR
Consumer Products	426	479.3	544.4	622.3	715.0	826.5	14.2%
Displays & Lighting	496.0	561.5	640.9	728.3	826.5	936.9	13.6%
Medical Products	223.0	291.2	364.3	439.4	507.9	581.6	21.1%
Packaging	12.0	17.8	30.0	51.6	94.3	182.3	72.3%
PCBs	402.0	435.3	471.5	510.8	553.5	600.0	8.3%
RFID	20.5	21.6	23.1	25.2	27.8	31.0	8.6%
Solar PV	2,133	2,460	2,807	3,197	3,597	4,037	13.6%
Textiles	12.0	13.7	17.6	26.7	45.3	87.8	48.9%
Transportation	43.0	70.1	131.4	269.3	605.6	1,442.1	101.9%
Other General Apps	72.3	83.1	118.0	189.3	326.1	550.2	50.1%
Total	**3,840**	**4,434**	**5,148**	**6,060**	**7,299**	**9,275**	**19.3%**

The total market of PE products by individual application is summarized in Table 6-18 for 2012-2017. This takes into account all the variables of the PE market by competing and emerging market application, of which we have identified more than 40 different subjects. Table 6-18 summarizes the worldwide PE market by leading market application from 2012-2017.

Table 6-18 - Worldwide PE Assembly Market by Application ($M), 2012-2017

PE Applications	2012	2013	2014	2015	2016	2017	CAGR
Membrane switches	425.8	478.8	543.4	620.4	711.6	820.8	14.0%
Appliance memory/sensor/battery	0.2	0.4	1.0	1.9	3.4	5.7	93.1%
E-reader displays	289.0	341.9	406.8	478.0	558.4	649.4	17.6%
Mobile phone displays	40.0	44.2	48.3	52.4	56.5	60.3	8.6%
Car audio displays	46.0	49.0	52.8	57.2	62.4	68.4	8.3%
MP3 displays	10.0	10.8	11.5	12.2	12.9	13.5	6.2%
Video camera displays	19.0	20.6	22.4	24.4	26.5	28.9	8.7%
General lighting	0.00	0.13	0.13	0.14	0.15	0.16	5.3%
Other displays/lighting	92.0	94.9	98.9	104.0	109.7	116.2	4.8%
Blood glucose, EKG, EEC	222.9	291.1	364.2	439.2	507.7	581.3	21.1%
Other medical	0.11	0.22	0.43	0.77	1.30	2.08	79.6%
Food packaging	6.5	9.7	16.4	29.9	61.3	135.4	83.7%
Beverage packaging	0.2	0.51	1.02	1.94	3.49	5.41	80.9%
Pharmaceutical packaging	3.8	5.6	9.3	13.9	19.3	24.9	45.3%
Beauty packaging	0.4	0.6	1.2	2.7	5.0	7.4	82.9%
Other packaging	1.1	1.4	2.1	3.2	5.3	9.2	53.5%
PV bus bars	2,133	2,460	2,806	3,197	3,596	4,035	13.6%
PV thin films	0.11	0.27	0.49	0.77	1.30	2.08	81.2%
PCB automotive	55.9	59.6	63.5	67.7	72.2	76.9	6.6%
PCB communications	52.7	58.4	64.8	71.8	79.7	88.3	10.9%
PCB computer	86.0	94.3	103.3	113.3	124.1	136.0	9.6%
PCB consumer	42.2	46.2	50.6	55.4	60.7	66.4	9.5%
PCB industrial	65.5	70.5	75.9	81.6	87.8	94.5	7.6%

PCB medical	49.8	53.8	58.0	62.6	67.6	72.9	7.9%
PCB aerospace/other	49.8	52.5	55.4	58.4	61.5	64.8	5.4%
RFID antennas	20.4	21.5	22.9	24.9	27.5	30.6	8.5%
RFID memory/sensors/batteries	0.10	0.14	0.19	0.25	0.31	0.38	27.4%
Textile biometrics	1.7	1.9	2.1	2.5	3.0	3.8	17.8%
Textile heating	8.3	9.7	13.1	21.6	39.4	80.7	69.9%
Textile lighting	0.3	0.3	0.3	0.3	0.4	0.4	11.0%
Textile sensing	1.0	1.1	1.2	1.4	1.6	1.8	12.2%
Other Textiles	0.7	0.8	0.8	0.9	1.0	1.1	8.4%
Transportation control panels	6.8	8.1	9.9	13.4	20.7	40.5	42.9%
Transportation heating	20.8	32.4	60.1	123.2	277.2	637.6	110.6%
Transportation wiring replacement	12.7	26.7	58.3	129.4	304.0	760.0	126.6%
Transportation other	2.7	2.9	3.1	3.4	3.7	4.1	8.4%
General apps batteries	22.5	25.3	28.5	35.8	48.2	70.3	25.6%
General apps memory/logic	8.3	10.5	15.2	28.1	57.5	120.8	84.3%
General apps sensing	35.5	40.8	67.4	117.9	212.2	350.1	58.1%
General apps other	6.0	6.5	7.0	7.5	8.2	9.0	8.4%
Total	**3,840**	**4,434**	**5,148**	**6,061**	**7,301**	**9,277**	**19.3%**

The final table ranks the worldwide PE market by leading application by CAGR growth rate, starting with the highest. As can be seen, the transportation sector (wiring and heating) is expected to lead this industry over the next five years. This is followed by the general memory appliance market for memory/logic/sensor and battery sectors for consumer electronics and other emerging market applications experiencing evolution. The packaging and PV thin film display and markets are also expected to grow strongly over time, followed closely by the medical application segments. Table 6-19 summarizes the worldwide market for PE assembly by CAGR in descending order of growth, for 2012-2017.

Table 6-19 - Worldwide PE Assembly Market by Leading Application CAGR ($M), 2012-2017

PE Applications	2012	2013	2014	2015	2016	2017	CAGR
Transportation wiring replacement	12.7	26.7	58.3	129.4	304.0	760.0	126.6%
Transportation heating	20.8	32.4	60.1	123.2	277.2	637.6	110.6%
Appliance memory/sensor/battery	0.2	0.4	1.0	1.9	3.4	5.7	93.1%
General apps memory/logic	8.3	10.5	15.2	28.1	57.5	120.8	84.3%
Food packaging	6.5	9.7	16.4	29.9	61.3	135.4	83.7%
Beauty packaging	0.4	0.6	1.2	2.7	5.0	7.4	82.9%
PV thin films	0.11	0.27	0.49	0.77	1.30	2.08	81.2%
Beverage packaging	0.2	0.51	1.02	1.94	3.49	5.41	80.9%
Other medical	0.11	0.22	0.43	0.77	1.30	2.08	79.6%
Textile heating	8.3	9.7	13.1	21.6	39.4	80.7	69.9%
General apps sensing	35.5	40.8	67.4	117.9	212.2	350.1	58.1%
Other packaging	1.1	1.4	2.1	3.2	5.3	9.2	53.5%
Pharmaceutical packaging	3.8	5.6	9.3	13.9	19.3	24.9	45.3%
Transportation control panels	6.8	8.1	9.9	13.4	20.7	40.5	42.9%
RFID memory/sensors/batteries	0.10	0.14	0.19	0.25	0.31	0.38	27.4%
General apps batteries	22.5	25.3	28.5	35.8	48.2	70.3	25.6%
Blood glucose, EKG, EEC	222.9	291.1	364.2	439.2	507.7	581.3	21.1%
Textile biometrics	1.7	1.9	2.1	2.5	3.0	3.8	17.8%
E-reader displays	289.0	341.9	406.8	478.0	558.4	649.4	17.6%
Membrane switches	425.8	478.8	543.4	620.4	711.6	820.8	14.0%

PV bus bars	2,133	2,460	2,806	3,197	3,596	4,035	13.6%
Textile sensing	1.0	1.1	1.2	1.4	1.6	1.8	12.2%
Textile lighting	0.3	0.3	0.3	0.3	0.4	0.4	11.0%
PCB communications	52.7	58.4	64.8	71.8	79.7	88.3	10.9%
PCB computer	86.0	94.3	103.3	113.3	124.1	136.0	9.6%
PCB consumer	42.2	46.2	50.6	55.4	60.7	66.4	9.5%
Video camera displays	19.0	20.6	22.4	24.4	26.5	28.9	8.7%
Mobile phone displays	40.0	44.2	48.3	52.4	56.5	60.3	8.6%
RFID antennas	20.4	21.5	22.9	24.9	27.5	30.6	8.5%
Textiles other	0.7	0.8	0.8	0.9	1.0	1.1	8.4%
Transportation other	2.7	2.9	3.1	3.4	3.7	4.1	8.4%
General apps other	6.0	6.5	7.0	7.5	8.2	9.0	8.4%
Car audio displays	46.0	49.0	52.8	57.2	62.4	68.4	8.3%
PCB medical	49.8	53.8	58.0	62.6	67.6	72.9	7.9%
PCB industrial	65.5	70.5	75.9	81.6	87.8	94.5	7.6%
PCB automotive	55.9	59.6	63.5	67.7	72.2	76.9	6.6%
MP3 displays	10.0	10.8	11.5	12.2	12.9	13.5	6.2%
PCB aerospace/other	49.8	52.5	55.4	58.4	61.5	64.8	5.4%
General lighting	0.00	0.13	0.13	0.14	0.15	0.16	5.3%
Other displays/lighting	92.0	94.9	98.9	104.0	109.7	116.2	4.8%
Total	**3,840**	**4,434**	**5,148**	**6,061**	**7,301**	**9,277**	**19.3%**

Chapter 7 – Printed Electronics Company Profiles

Figure 7-1 - PE Market by OEM Supplier, 2012

PE companies are presented in alphabetical order in the next section, however we have summarized the tables for PE participants by industry segment which is defined as follows: 1) equipment companies (OEM manufacturers, equipment providers and various hardware firms); 2) material companies (including raw and chemical materials providers and solution companies such as conductive ink and thin film suppliers: and, 3) integrators that provide finished manufactured products using specialized equipment (contract manufacturers and other). Thus, the following three columns summarize our understanding of the PE market by OEM supplier according to dimension (equipment, material or solution). Table 7-1 summarizes the worldwide market for PE assembly products by assembly market function. Table 7-2 summarizes the PE market by alphabetical listing.

Figure 7-1 - Worldwide PE Supplier Assembly Market by Function, 2012

Equipment Companies	Materials Suppliers	OEM Solution/Integrators
Agfa-Gevaert	3M	Add-Vision
AIXTRON AG	Advanced Nano Products	Ascend Solar
Applied Materials	Agfa-Oracon	AVANCIS
Canon	Applied Nanotech	Aveso
CERADROP	Asahi Glass Co.	Blue Spark
Conductive Inkjet Tech.	Asahi Kasei	Bosch Solar
Dainippon Screen Printing	BASF	Calyxo
DEK Printing Machines	Beneq	Cambridge Display
Dialog Semiconductor, GmbH	Blue Nano	Canadian Solar
FUJIFILM Dimatix	Cabot	China Sunenergy
Fuji Xerox Co., Ltd.	Cambrios	Cymbet
Goss International Americas	Carestream Advanced Materials	Durel
Haiku Tech	Cima Nanotech	E Ink
Hewlett Packard	Corning	eMagin
Hisense	Creative Materials	Energy Conversion Devices
Johnson Laminating/Coating	Dai Nippon Printing	Enfucell
Kammann Machines	DayStar Technologies	EV Group
KIWO	Delta Optoelectronics	Evonik
Konica Minolta	Dow Chemical	Excellatron
Landa Corporation	DuPont Microcircuit Materials	First Solar
MacDermid Printing	Eastman Kodak	Flexcell
MAN Roland	Electric Vinyl, Inc.	Front Edge

Mark Andy, Inc.	Elect. Paper and Tech. Solutions	Frontier Industrial Technology
Merck Millipore	elumin8	Fuji Electric
Midori Mark Co., Ltd.	Ercon	G24 Innovations
MuTracx	Ferro Corp.	Global Solar Energy
NovaCentrix	FUJIFILM Holdings Corporation	GSI Technologies
NXT PLC	Fujikura	Imprint Energy
Ohio Gravure Technologies	Gwent Group	Incubation Alliance
PixDro BV	H. C. Starck	Infinite Power Solutions
Preco, Inc.	Heliatek GmbH	Innovalight
Printcolor Screen Ltd.	Henkel	ISORG
Printechnologics	Heraeus	Kaneka
Roth & Rau	Hitachi Chemical	KSW Microtec AG
Schreiner PrinTronics	Indium Corporation	Liquavista BV
Seiko Epson	Infineon Technologies AG	Memtron Input Components
SiPix Imaging, Inc.	Inktec	Nanosolar
SonoPlot	Intl' Solar Elect. Tech.	NRG Solar
Speedline Technologies	Intrinsiq Materials	Ormet Circuits, Inc.
ST Microelectronics	Kimoto	PARC
Sung An Machinery	Konarka Technologies, Inc.	Parelec
Taiyo Ink Mfg. Co., Ltd.	Kovio	PChem
Thieme GmbH & Co. KG	LG Philips LCD Co., Ltd.	Plastic Logic
Tokyo Electron, Ltd.	Liquid X Printed Metals	Power Paper, Ltd.
Toppan Printing Co., Ltd.	Litrex	PragmatIC Printing
UniJet	Luminous Media, Ltd.	ReneSola, Ltd.
Universal Display Corporation	MEMC Electronic Materials	Semprius
Veeco Instruments	Microvision, Inc.	Sensormatic
Xaar	Mirwec Films	Sharp Corporation
Xerox Corporation	Nanogap	Si-Cal
	NanoInk, Inc.	SMARTRAC
	NanoMas Technologies, Inc.	Solarmer
	Nissan Chemical Industries	Solar Frontier
	Novaled AG	Solexant
	Novalia	Solicore
	Optomec	Sontor GmbH
	ORFID	Sumation Co., Ltd.
	OrganicID	T-Ink, Inc.
	Ormecon GmbH	Terepac
	OSRAM GmbH	Thin Film Electronics
	Plextronics	
	PolyIC GmbH & Co. KG	
	Poly-Ink	
	QUALCOMM MEMS Tech.	
	Samsung Electronics Co., Ltd.	
	Soligie	
	SouthWest NanoTechnologies	
	Sumitomo Chemical Co., Ltd.	
	Sun Chemical	

	Toshiba Mobile Display	
	ToyoChem	
	ULANO	
	Unidym, Inc.	
	Victrex Polymer Solutions	
	Vorbeck Materials	

Figure 7-2 - PE Market by Alphabetic Supplier, 2012

Table 7-2 summarizes the supplier market of PE companies by alphabetical listing.

3M Company

3M is essentially a materials company; it makes everything from Post-it stickers to thin-film electronics materials. The diversified company makes products through six operating segments: Consumer and Office; Display and Graphics; Electro and Communications; Health Care (through 3M Health Care); Industrial and Transportation; and Safety, Security, and Protection Services. Well-known brands include Post-it notes, Scotch tapes, Scotchgard fabric protectors, Scotch-Brite scouring pads, and Filtrete home air filters. 3M has operations in more than 65 countries. About two-thirds of its sales are made outside the US. It sells products directly to users and through numerous wholesalers, retailers, distributors, and dealers worldwide.

As a technology-driven company, 3M continues to make research and development a top priority, investing heftily in new product development efforts. Through significant investments in R&D, sales, and manufacturing, the company ranks among the most innovative companies in the world. It also competes on a global scale and likes to develop, manufacture, hire, and purchase locally in whatever region it is in to get close to its customers. Although 3M tries to keep costs down in response to the uncertainty of global economic conditions, it remains flexible enough to act quickly if opportunities arise.

3M completed nine acquisitions in 2011 that totaled $649 million, including the do-it-yourself unit and professional division of France's GPI Group, a manufacturer and marketer of home improvement products such as tapes, hooks, insulation, and floor protection products. The deal boosts 3M's presence in Western Europe. It also added to its growing Industrial and Transportation segment by acquiring a majority stake in Switzerland-based Winterthur Technology Group, an international supplier of precision grinding technologies that makes grinding tools used in the aircraft, automotive, industrial, and steel industries.

Back in the US, it acquired Florida-based Nida-Core, a manufacturer of structural honeycomb core and fiber-reinforced foam core materials, and Nida-Core's French affiliate, Structiso SARL. The acquisition allows 3M's Engineered Products and Solutions department to build on its composite and engineered materials product portfolio.

In late 2011, the company also agreed to acquire the California-based consumer and office products unit of Avery Dennison for $550 million in cash. The deal, which includes such well-known brands as Avery, Marks-A-Lot, and HI-LITER, will complement 3M's own Consumer and Office segment and expand its global reach. Avery Dennison made about 68% of its total sales from international operations in 2010.

3M is active in the printed electronics market through its raw materials and thin film businesses, which produce tapes and related wallpaper solutions such as posters, patches, and packaging that integrate electronic capabilities into equipment. Applications include oil transportation packaging that detects leaks and contamination.

http://www.mmm.com/

Add-Vision, Inc.

Founded in 1994, Add-Vision, Inc. (AVI) has focused on developing proprietary techniques for low-cost screen-printed light-emitting display systems. During its first seven years, the company focused on creating light-emitting displays using thick film inorganic, alternating-current phosphor electroluminescence (ACPEL, or EL for short) technologies. Add-Vision has extensive commercial experience with EL displays. The EL screen printable displays are phosphor based (ZnS), with a characteristic blue-green emission.

AVI is located in Scotts Valley, California, and is developing a disruptive polymer organic light-emitting diode (P-OLED) display technology. The flexible display technology offers robust display characteristics and can be fabricated using high-speed printing techniques onto flexible substrates. AVI's technology opens the door to P-OLED display manufacturing that is high throughput, large area, Web compatible, and air processable. This technology enables the display of dynamic information and specialty lighting effects in a host of applications that might not be possible using other display technologies.

In late 2001, having a liquidity opportunity, the company sold its ACPEL assets to devote its full resources to LEP technologies. For the past two years, Add-Vision has exclusively focused its nearly 10 years of experience in screen-printed light-emitting displays to pioneer and develop a new generation of technologies for low-cost, screen printed light-emissive displays. The company's technology represents a breakthrough for the commercial viability of LEP technologies in many large vertical markets, including point-of-purchase (POP) displays, gaming and vending machines, electronic signage, and toys.

Add-Vision's business model is a combination of manufacturing and IP licensing models. Add-Vision will sell LEP displays as components to products in targeted markets by working with industry leaders in those market segments. A key attribute of Add-Vision's technology is ease of adoption by existing printing production facilities, making fabless production extremely viable. In addition, Add-Vision will license its IP on a very limited and strategic basis to major companies that can leverage their core technical strengths, infrastructure, and distribution channels to rapidly enter new businesses.

http://www.add-vision.com/

Advanced Nano Products

As a leading company which opens the new era of nanomaterial business in Korea, ANP is manufacturing and supplying the chemically processed nanocrystalline materials and their chemical precursors for coating and powder processing applications.

ANP nano-materials are used in LCD screens, solar batteries and touchscreens. The company exports 90 percent of its products and its customers include global corporations such as 3M Corp.

Agfa-Gevaert

Agfa-Gevaert makes and markets imaging systems for printing, graphic arts, motion picture, and medical imaging processes. Agfa's Graphic unit makes prepress film and printing plates, industrial inkjet printers, and related supplies. It also provides workflow automation, proofing, and digital printing software. Agfa's HealthCare unit offers films, chemicals, software, and printers used in digital radiography and other medical applications. The company's Materials division supplies sound recording and print film to the motion picture market, as well as microfilm and technology used in aerial photography, ID cards, printed circuit boards, and computer displays.

Most of the company's sales are split between its Graphics and HealthCare units; its Materials group, which encompasses Agfa's Specialty Products operations, accounts for more than 6% of sales. Though its other geographic regions have made gains, more than half of its sales still came from Europe in 2010, about twice that of the next closest segment, Asia/Oceania/Africa. To boost sales in the latter region, Agfa has created a joint venture, Agfa Graphics Asia, with Shenzhen Brothers.

In 2010 through its Agfa-Gevaert Graphics unit, the company bought the assets of the Harold M. Pitman Company, a family-owned supplier of prepress, industrial inkjet, press, and packaging printing products. The acquisition significantly expanded the unit's reach in the US printing industry by adding a number of new product lines, including a range of complementary industrial inkjet products, and a large customer base in the US.

Earlier that year the company acquired the assets of Gandi Innovations Holdings, a manufacturer of large-format inkjet systems that was operating under bankruptcy protection, and Insight Agents, a European developer and producer of contrast media used in health care imaging applications.

The acquisition of the Pitman and Gandi assets serves the company's strategy of focusing more on industrial inkjet products, a relatively new segment for Agfa. Industrial inkjets are a leading edge in digital print technologies. They can be used in producing banners, displays, posters, and signs. While the industrial inkjet market shows promise for Agfa, the company is also challenged by increases in the prices of raw materials.

Thanks mainly to strong sales in the company's Graphics division – especially of Pitman products and business for Agfa Graphics Asia – company revenue rose 7% in 2010 compared with 2009.

http://www.agfa.com/

Agfa Orgacon

Agfa Orgacon is a subsidiary of Agfa-Gevaert and has developed a portfolio of proprietary PEDOT/PSS materials produced within the Advanced Coatings & Chemical Business group of Agfa Specialty Products which includes classic films, functional foils and advanced coatings & chemicals. Some examples are films for the motion picture and aerial photography industry, film for the production of printed circuit boards and microfilm. The Functional Foils group makes specialty films for applications in security, print and other industries. Examples are PET-film based materials for smartcards, synthetic papers or solar panels. All Agfa's Research & Development activities related to materials have been centralized in the Agfa Materials Technology Center.

http://www.agfa.com/sp/global/en/internet/main/

AIXTRON SE

AIXTRON is the leading manufacturer of MOCVD (metal-organic chemical vapor deposition) equipment, which chip makers use to produce advanced compound semiconductors for devices such as light-emitting diodes (LEDs), lasers, and fiber-optic components. AIXTRON's systems center on a "planetary reactor," in which multiple wafers revolve while gaseous materials (such as gallium arsenide) are deposited upon them. The company operates in the United Kingdom through Thomas Swan Scientific Equipment and in Sweden through Epigress. AIXTRON gets about 90 percent of its sales outside of Europe.

Aixtron is offering vapor phase deposition of organic and polymer films at low vacuum, which it argues allows better control of film composition and quality. The process uses short flash evaporation to limit thermal stress, and a carrier gas to control delivery of materials from multiple chambers through a close-coupled showerhead to the substrate with precise mixing and dosing, on R2R or G3.5 LCD formats

AIXTRON's customers include AZZURRO Semiconductors, Epitech, Genesis Photonics, Huga Optotech, Novalux, Rainbow Opto, and Showa Denko.

Holger Jürgensen, a company cofounder and deputy chairman of the supervisory board, owns about 9 percent of AIXTRON. Cominvest Asset Management holds around 5 percent of the company.

http://www.aixtron.de/

Applied Materials

Applied Materials is the world's largest maker of semiconductor production equipment. With its acquisition of Applied Films, the company moved into the market for equipment used in making solar power cells. Applied's machines vie for supremacy in many segments of the chip making process, including deposition (layering film on wafers), etching (removing portions of chip material to allow precise construction of circuits), and semiconductor metrology and inspection equipment. About 70% of Applied's sales come from the Asia/Pacific region, with China leading the way at nearly a quarter.

Leading customers for Applied's chip making equipment -- which include Samsung Electronics (12% of sales), Intel (10%), Taiwan Semiconductor Manufacturing Company (10%), Advanced Micro Devices, and Freescale Semiconductor -- are increasingly moving manufacturing plants to countries in Asia where labor costs are lower. In order to be closer to its customers, Applied Materials has established R&D, support, and manufacturing facilities outside the US, with primary offices in China, Germany, India, Israel, Italy, Singapore, South Korea, Switzerland, and Taiwan. The company also outsources certain of its manufacturing and supply chain functions to third parties that are located in the US, India, China, South Korea, and Malaysia, among other countries.

Applied does more than make equipment for manufacturing semiconductors, though its silicon systems group segment is the foundation of the company and its largest segment at 51% of sales. Equipment used to make solar cells is part of the company's energy and environmental solutions segment (19% of sales), which also makes coating systems for flexible electronics and and equipment used to manufacture energy-efficient glass. Applied global services is the company's second largest segment with 23% of sales; that unit makes a range of products that includes spare parts, services, legacy products, and remanufactured equipment, all of which is intended to improve efficiency and lower costs by reducing the environmental impact of its customers' factories. As part of its much smaller display segment (7%), Applied makes equipment used to manufacture liquid-crystal displays (LCDs) for TVs, PCs, touch panels, and video-enabled devices.

As semiconductors are incorporated into more and more products -- from kitchen appliances to cars and TVs -- demand for ever-smaller and more complex chips grows. Just as quickly, chip-making machinery becomes obsolete, which can be good news for Applied's sales. To keep up with the chip industry's constant drive toward smaller circuits, larger wafers, and new technologies such as copper interconnects, Applied relies heavily on R&D efforts. The company spends more than 10% of sales on R&D each year.

Overall sales in fiscal 2011 were up 10% to $10.5 billion, a record for annual sales, and net income increased 105% to $1.9 billion. In spite of a decline in orders for the year, Applied's sales rose on increased investment in c-Si solar equipment and higher spares and refurbished equipment sales. Higher sales and lower operating expenses, offset by increased interest and other expenses and restructuring charges, were responsible for the increase in profits. Geographically sales were up 65% in China.

Applied has used a combination of acquisitions and internal development to bolster its moves into the few areas of chip manufacturing -- such as atomic layer deposition and ion implantation -- where it wasn't already a major player. In 2011 Applied bought Varian Semiconductor Equipment Associates (VSEA) in a transaction valued at about $4.2 billion. Globally, VSEA is the leading manufacturer of ion implantation equipment, used by chip makers to alter the electrical properties of integrated circuits. Combined, the companies offer a broad portfolio of products used in transistor formation, a critical step in making faster and more energy-efficient chips for mobile applications. Ion implant technology also has potential to expand into adjacent markets such as solar, display, and LED components. VSEA operates as a business unit within Applied's Silicon Systems Group.

Applied Materials, Inc. was recognized as the largest supplier of photovoltaic (PV) solar manufacturing equipment in 2011 by VLSIresearch, a market research firm located in Santa Clara, Calif. This is the fourth consecutive year that Applied has been ranked number one in revenue in the PV solar market, and fiscal 2011 represented its third year of achieving more than $1 billion in sales in this market.

As the market leader in PV manufacturing equipment, Applied currently supports over 1,800 solar manufacturing systems including screen printing, precision wafering, ion implantation and thin film deposition equipment at more than 200 customer sites worldwide through its Applied Global Services division.

http://www.appliedmaterials.com/

Applied Nanotech Holdings

Applied Nanotech Holdings, Inc. is a research and commercialization organization focused on solving problems at the molecular level using nanotechnology. The company was founded in 1989, went public in 1993, and is located in Austin, Texas. In 2005, it organized efforts into five divisions each of which has substantial potential: Nanomaterials, Nanoelectronics, Nanosensors, Nanoecology, and our legacy business, CNT Electron Emission.

To accelerate product introductions and secure a portfolio of recurring royalty streams, for specific large opportunities within the divisions, ANI has established dedicated business units for direct commercialization of technology. These business units are small multifunctional groups responsible for all aspects of a particular technology. The initial focus of each of these units is to secure funding to further develop and commercialize the particular technology.

The goal for these business units is to allow us greater input and direct control of product introductions and commercialization, accelerate the payment of running royalties, and to participate further in the value created by the manufacture and sale of products. These business units have the potential to become separate legal entities, such as subsidiaries or joint ventures. Potential partners in these entities include manufacturers, end users, and financial partners. Currently, we have established the following business units:

CarbAl thermal management materials

Technical Inks Printing Solution (TIPS)

CNT reinforced composites

Life Science Sensors - Breath analysis

http://www.appliednanotech.net/

Asahi Glass Co., Ltd.

Asahi Glass Company is the leading maker of flat glass for automotive glass, plasma display panel substrates, and fluorinated resins. Glass for construction, automotive, and other applications accounts for half of Asahi Glass's overall sales. The company's Electronics and Display division makes high-purity silicon carbide and synthetic quartz glass for semiconductors and glass substrates for LCDs, while its Chemicals unit manufactures soda ash, caustic soda, and other specialty chemicals. Subsidiaries include US-based AGC America and French glassmaker Glaverbel.

Although the company is closely tied to the Japanese marketplace, Asahi Glass markets aggressively into China, Southeast Asia, Central Europe, and Russia—all areas where demand for glass products is growing. The company deals with OEMs such as Audi, BMW, Chrysler, and Mercedes-Benz, and with component manufacturers, including Aisin Seiki, Webasto, and ArvinMeritor.

In the field of electronics and energy components, the company offers the latest glass materials and processes, fluorine chemistry, coating technologies, and nanomaterials. It has developed synthetic quartz lens materials for steppers with deep ultraviolet (DUV) laser permeability and durability for manufacturing semiconductors. In so doing, Asahi Glass has formed a joint partnership with SEMATECH, a global consortium of chip manufacturers. The collaborative effort tackles the challenge of producing defect-free mask blanks in the quantities required for high-volume manufacturing. (Mask blanks are the starting material used to make finished masks containing the device pattern for lithographic processes.) All parties seek to benefit by reducing the time from research and development to high-volume manufacturing.

http://www.agc.co.jp/

Asahi Kasei

Asahi Kasei is among Japan's leading chemical companies and operates in six segments. Its chemicals (basic chemicals, plastics, fertilizers) and homes (prefabricated homes) units together account for about three-quarters of Asahi Kasei's sales. The company's fibers unit makes nylon, and its construction materials division makes concrete panels and artificial fish reefs. Asahi Kasei also makes electronic materials and medical products. Roughly two-thirds of its sales are in Japan, though the country hosts substantially all (more than 90%) of its assets.

Asahi Kasei now runs essentially as a holding company with subsidiaries in chemicals, homes (new-home and apartment building construction), fibers, pharmaceutical (pharmaceutical intermediates, artificial kidneys, among other medical products), electronics materials and devices, construction materials, and services and engineering (environmental engineering, personnel staffing, and other more or less random activities).

Revenues for Asahi Kasei dropped slightly (about 8% in 2009) in the two years since a peak in 2007. After a precipitous drop in net income in 2008, the company's bottom line showed a strong recovery the next year. The Japanese economy remained sluggish in 2008, with curtailed capital spending and weak consumer demand. Improved exports helped move net income in the right direction in 2009.

In 2007 the company merged its Chemicals unit with its former Life & Living division. The latter made consumer products, including brand names like Saran Wrap and Ziploc storage bags, as well as flexible packaging products.

The next year saw Asahi Kasei launch a new wastewater recycling business. Its first contract was to build a facility in China, and the company anticipates the unit to become a key growth operation.

http://www.asahi-kasei.co.jp

Ascent Solar Technologies

Ascent Solar Technologies is a development-stage company working on photovoltaic modules for use in consumer applications as well as satellites and spacecraft. The firm aspires to make such gear smaller, lighter, and more flexible than existing solar cells for use in space by utilizing a thin-film absorbing layer on top of a polyimide substrate. The thin-film layer on top of the high-temperature plastic is made up of copper, indium, gallium, and selenium, which is why the technology is called CIGS. Norsk Hydro has a 39% stake in the company.

The CIGS PV module technology is claimed to be superior to existing solar cells because it is produced through a roll-to-roll manufacturing process, much like the way newspapers are printed, rather than like semiconductor fabrication, which is how most solar cells are manufactured. By producing rolls and sheets of PV modules all at once, Ascent Solar asserts it will have a manufacturing advantage over solar cells that have to be produced on silicon substrates in a complicated process.

Ascent Solar completed its 30 MW thin-film production plant and began initial production in mid-2010 (its pilot manufacturing facility began limited production in 2008). The company raised more than $20 million in a subsequent stock offering to fund the building. Previously, it received $5 million from Norsk Hydro in 2009; the Norwegian aluminum company has already invested about $37 million in Ascent Solar and the two companies are working together on developing solar energy products.

The production plant is off to a good start with test orders for its thin-film photovoltaic modules. Samsonite is using the technology for its new line of solar-powered travel gear, and FTL Solar is using it in its line of solar power-generating canopies. Real estate company ProLogis and roofing company Johns Manville are testing Ascent Solar products for rooftop applications. The company also signed an agreement with GlobalWatt to develop a line of retractable solar modules for mobile generators. Outside the US, Ascent Solar signed international distribution agreements with DisaSolar in France, Votum in the Czech Republic, and Radiant Holding in China.

Ascent Solar grew out of ITN Energy Systems, a technology incubator firm involved in several areas of energy research and development. ITN Energy Systems spun off Ascent Solar in 2005 to commercialize its CIGS photovoltaic (PV) module technology; it owns almost 6% of Ascent Solar. ITN Energy Systems in turn is owned by Inica, Inc., and Ascent Solar's retired chairman Mohan Misra is the majority shareholder of Inica. Ascent Solar completed a $16.5 million IPO in 2006.

http://www.ascentsolar.com/

AVANCIS

AVANCIS is a joint venture between Shell and Saint-Gobain that will develop, produce, and market solar power modules based on advanced CIS technology. AVANCIS combines Shell's CIS technology expertise, aided by eight years of commercial manufacturing at its Camarillo plant in California, with Saint-Gobain's global and in-depth knowledge of glass processing and production of building materials.

The first AVANCIS module production facility will be located in Torgau, Germany. The annual capacity of the plant will initially be 20 MW in CIS thin-film modules producing at an efficiency level of 11 percent. The research and development sector of the company, in Munich, Germany, employs 30 staff members.

AVANCIS's new plant will provide 85 new jobs at the new Torgau production site, with another 45 hopefully to be added in 2009. The modules, with their naturally uniform "tinted" black look, offer superior aesthetics and are designed to maximize light-to-electricity conversion, including at low light and with shade and clouds.

www.avancis.de/en/

Aveso, Inc.

Aveso, Inc. is the leading provider of flexible displays suitable for high-volume, cost-sensitive, mass consumer applications. The company's paper-thin, rugged display products are designed for applications where it has been impossible or impractical to integrate displays in the past, due to cost, form factor, or scalability.

Aveso's displays are based on a patented electro-active ink technology that makes it possible to manufacture displays using installed manufacturing capacity and readily available materials. Aveso's low-voltage operation (<1.0V) allows for display drive code to be loaded onto customer-specific silicon or low-cost, general-purpose microprocessors. The displays can also be driven via radio frequency (RF) energy for contactless applications.

A spin-off of The Dow Chemical Company, Aveso was founded in July 2004 with venture capital financing from premier firms ARCH Venture Capital and Frazier Technology Ventures. Dow Chemical funded the original research and development efforts for Aveso's proprietary display technology and remains an investor in the company. The company's name is derived from the Spanish "aviso" or "avisar," meaning to notify, inform, or warn—a link to the critical nature of the information Aveso's displays deliver.

The company's high-contrast, reflective displays can be printed as thin as 25 microns and require less than 1.5V to operate. Aveso's displays are easily integrated into the existing high-speed card and label manufacturing base, and can withstand standard production processes such as hot lamination. Print processes used to produce Aveso displays include screen printing, flexographic, and gravure, depending upon end product application.

http://www.avesodisplays.com/

BASF

BASF is the world's largest chemical company, ahead of Dow and DuPont. It has more than 370 manufacturing facilities and does business worldwide through six business segments: plastics (polymers and polyurethanes), performance products (including dispersions and pigments, adhesives and sealants, personal care and pharma additives, paper chemicals, and lubricant additives), chemicals (plasticizers and solvents), oil and gas exploration and production (through subsidiary Wintershall AG), functional solutions (catalysts, coatings, and construction chemicals), and agricultural products (fungicides, herbicides, insecticides). BASF has divested most of its fertilizer operations.

In early 2012, BASF began a new global business unit, Battery Materials, to integrate its battery materials activities within an operating unit of New Jersey-based subsidiary BASF Catalysts. In moves to become a global leader in the supply of battery materials, the company has made a series of acquisitions and licensing agreements to broaden its coverage of technology, materials, and components to serve cell and battery manufacturers worldwide. It has been licensed by the Argonne National Laboratory in Illinois to commercialize some of its advanced cathode materials, used in hybrid and full-electric vehicles.

Adding to its battery operations again in 2012, BASF acquired Cleveland-based Novolyte Technologies from private equity group Arsenal Capital Partners for an undisclosed price. Novolyte manufactures electrolyte formulations for lithium-ion batteries and other specialty chemicals. It operates sites in the US and China. BASF will continue Novolyte's joint venture with Korean company Foosung, which produces lithium hexafluorophospate, a high-purity specialty salt used in producing lithium-iron battery electrolytes. The electrolytes are key components in lithium-ion batteries for the automotive, consumer, and industrial markets.

BASF Coatings is the paints and coatings division of BASF, and one of the top coatings companies worldwide. The company produces a range of automaker coatings, automotive refinishes, and industrial coatings. It also produces decorative paints for the European and South American markets. BASF Coatings is one of the world’s leading manufacturers of automotive and industrial lacquer. It also ranks among the top three global leaders for automotive OEM coatings. Brand names include Glasurit, R-M, and Salcomix. In industrial coatings, the company focuses on coil, foil, and powder coatings.

http://www.basf.com/

Beneq Oy

Beneq, based in Vantaa Finland, is a supplier of equipment and coating technology for global markets. Beneq develops applications and equipment for cleantech and renewable energy fields, especially in glass, solar and emerging thin-film markets. Coating applications include optics, barriers and passivation layers, as well as energy generation and conservation. Beneq also offers complete coating services. The coating applications of Beneq are based on two enabling nanotechnology platforms: Atomic Layer Deposition (ALD) and aerosol coating (nHALO and nAERO).

Beneq has sales offices in Germany, China, and the United States. Its 36 representative sales offices worldwide bring the company's products to businesses across the globe. Over the past three years, Beneq has exhibited an annual growth of more than 60 percent. In 2011, Beneq posted sales exceeding 18 million euros.

http://www.beneq.com/

Blue Nano

Blue Nano is a manufacturer of high-quality, high-volume nanomaterials with a focus on clean energy and display technologies. The company provides wide-ranging selections of nanomaterials and nano-focused solutions for end-user products in a wide variety of industries, including energy, automotive, electronics, chemical, materials and medical. In particular, it has placed an emphasis on cutting-edge clean energy products for solar cells, lithium ion batteries and a variety of chemical and fuel cell catalysts.

For the solar panel conductive film industry, Blue Nano's proprietary SLR-160 conductive film allows for up to 38% greater efficiency due to light trapping and conductivity gains. The SLR-160 can be applied to most types of solar cells including thin-film photovoltaic, crystalline silicon photovoltaic, and concentrator solar panels. The SLR-160 is deposited onto the emitter surface during normal solar cell manufacturing processes.

For lithium ion battery conductive additives, Blue Nano's BTY-175 is a proprietary blend of carbon nanomaterials designed specifically to extend the life of lithium ion batteries. It features proprietary granular conductive additives to maintain dispersion, increase durability and improve discharge capacity. This plug-and-play additive replaces the use of pure carbon black as the leading anode and cathode material for lithium-ion batteries, offering up to a 4x improvement in durability.

For fuel cell catalysts, Blue Nano's porous catalyst technology increases reactive surface area, minimizing expensive material usage and increasing power density for both fuel cells and other chemical catalysts. Reducing Pt loading by up to 99% and simultaneously increasing the power density by up to 77%, this catalyst far exceeds any current market offering at dramatically lower cost due to lower material and processing costs.

http://www.bluenanoinc.com/

Blue Spark Technologies

Initially launched in 2003 as Thin Battery Technologies, the company's goal was to develop thin, flexible printed batteries built on IP acquired from Eveready Battery Company (now Energizer). The patented IP was the result of years of Eveready knowledge, experience, and research and development.

In the first few years, private investors led by Early Stage Partners made significant investments to further develop, test, and commercialize this revolutionary technology. Its rich IP heritage and a growing portfolio of patents and design innovations enabled Thin Battery Technologies to provide customers with high-volume production of thin printed batteries. Since 2004, over 300,000 of the company's thin printed batteries have been produced and delivered.

Today, Blue Spark Technologies is an early stage company and leading producer of thin, flexible, printed battery solutions. The company makes printed carbon-zinc batteries for OEMs, product design engineers, and system integrators in a wide range of industry applications including food and beverage, pharmaceutical, chemical, health care, medical diagnostics, "smart cards," radio frequency–based sensors and RFID tags, interactive packaging, merchandising displays, consumer products, and novelty items.

http://www.bluesparktechnologies.com/

Bosch Solar CISTech

The Bosch Group entered the photovoltaics industry in 2008, when it acquired the Erfurt-based ErSol group, now known as Bosch Solar Energy AG. It further expanded its photovoltaics operations a year later, after securing majority stakes in Johanna Solar Technology GmbH and aleo solar AG, based in Oldenburg and Prenzlau.

Bosch Solar Energy supplies solar cells and modules with high annual yields, even under sub-optimal levels of sunlight. The fundamental basis for this consists of state-of-the-art production equipment and highly effective processes. Since 2009, it has been constructing turn-key solar power plants to order, which feature fully developed technologies with corresponding operating efficiency. As a system provider, Bosch can offer all components required to construct a photovoltaic power plant need from a single source. As a panel provider, Bosch manufactures silicon crystalline panels and thin-film solar modules.

http://www.bosch-solarenergy.com/

Cabot Corporation

Cabot Corporation is a global specialty chemicals and performance materials company that ranks among the world's top producers of carbon black, a reinforcing and pigmenting agent used in tires, inks, cables, and coatings. Cabot also holds its own as a maker of fumed metal oxides such as fumed silica and fumed alumina, used as anti-caking, thickening, and reinforcing agents in adhesives and coatings. Other products include inkjet colorants, aerogels (a synthetic material derived from a gel), and a specialty fluid (cesium formate) for oil and gas drilling. It also makes thermoplastic concentrates and compounds (masterbatch products) used by the plastics industry.

Cabot is among a small group of carbon black producers with a global presence. (Aditya Nuvo Birla and Evonik Degussa also operate worldwide.) As a whole, the carbon black business accounts for 60% of the company's total revenues. Much of its carbon black business is done with the top three automobile tire makers, although no customer represented more than 10% of the company's total sales in 2011. The Goodyear Tire and Rubber Company accounted for about 12% of sales in 2010.

Inkjet colorants, micropowders, and elastomer composites make up the main businesses of the New Business segment. The elastomer composites products are natural latex rubber and carbon black compounds made by a liquid phase process and used for a variety of applications for the aerospace, automotive (including tires), defense, and mining industries.

As part of Cabot's strategy to focus on its core business of specialty chemicals and rubber and carbon black, the company sold its supermetals business, including its tantalum business, to Australian company Global Advanced Metals for about $400 million in 2012. The sale allows the company to invest in new growth initiatives.

http://www.cabot-corp.com/

Calyxo GmbH

Established in 2005, Calyxo GmbH produces thin-film modules based on a Cadmiumtelluride-(CdTe-) technology. Originally Calyxo had attained a worldwide exclusive licence for a highly innovative glass coating technology from the US company Solar Fields. Calyxo initially set up a pilot line with a production capacity of 8 MW in Bitterfeld-Wolfen/Thalheim (Germany) to show that the technology could be transferred to mass manufacturing and rapidly commercialised. The pilot line was set into operation in summer 2007.

Calyxo is owned by Solar Fields who holds 94,9% of the company's shares. The remaining shares of 5.1% are held by the Advisory Board Chairman Norman W. Johnston. Calyxo USA Inc. focuses on R&D activities and rapid further improvements of the Calyxo CdTe-technology while, Calyxo Germany is currently completing its pilot facility to reach a production capacity of 25 MW.

Calyxo is building a second plant to host the 60 MW expansion line in Bitterfeld-Wolfen/Thalheim (Germany). This is the decisive step to move rapidly out of the piloting phase into the mass manufacturing phase. This 60 MW line is the first block in an entire roll-out concept, which is now to be executed as rapidly and successfully as possible.

http://www.calyxo.com/

Cambridge Display Technology

Cambridge Display Technology (CDT) is the leading developer of polymer organic light-emitting diodes (known as P-OLEDs or PLEDs), which can be used in place of cathode ray tubes, standard LEDs, and display components in cell phones, digital audio players, and other applications. The company researches and then licenses P-OLED technology to makers of flat panel displays and electronic materials, such as Philips, Dow, and Dai Nippon. CDT uses technology services and development agreements to boost licensing and royalty fees. In 2007 Sumitomo Chemical acquired CDT for about $285 million in cash.

In 2005 CDT formed a joint venture called Sumation with Sumitomo Chemical to develop new types of advanced P-OLED materials. The JV helped form a closer relationship between the companies, leading to the acquisition two years later.

CDT affiliate Litrex makes ink-jet printing systems used to make P-OLEDs and other devices. (In 2005 CDT sold its 50 percent stake in Litrex to joint-venture partner ULVAC.) CDT has also formed a partnership with lithography giant Toppan Printing, through which the companies develop new ways of making polymer-based displays using roll-printing methods.

CDT hopes to apply its electronic display products to information management, communications, and entertainment applications. P-OLEDs are part of the family of OLEDs, which are thin, lightweight, and power-efficient devices that emit light when an electric current flows. P-OLEDs offer an enhanced visual experience and superior performance characteristics compared with other flat-panel display technologies such as liquid crystal displays, and have the key advantage that they can be applied in solutions using printing processes.

http://www.cdtltd.co.uk/

Cambrios Technologies

Cambrios is the leader in nanotechnology-based solutions to enable the development of electronic devices with transparent conductors. The company's proprietary nanostructured materials can be deposited using existing production equipment to achieve enhanced performance of display devices and components at lower manufacturing cost. ClearOhm, the company's first product, a directly patternable, wet-processable transparent conductive film, is poised to replace the industry standard sputtered indium tin oxide (ITO). Subsequent products will leverage this technology to produce other functional films for display and thin-film applications for multiple consumer electronic device markets.

Cambrios was founded in 2002 by Drs. Angela Belcher of MIT and Evelyn Hu of the University of California, Santa Barbara. Their vision relied upon the use of nanostructured inorganic material, fabricated and shaped by biological molecules to create novel materials and processes for a variety of industries.

Through extensive, in-house research and development, the Cambrios team discovered two main attributes of its technology: its unique ability to synthesize inorganic materials from soluble precursors and to assemble inorganic materials into functional nanostructures.

Cambrios' scientists seized the idea of making electronic materials using these proprietary nanostructures and sought out market segments with unmet materials needs or products uniquely enabled by the use of Cambrios' materials. This led to the development of Cambrios' first commercial product, a solution-process, transparent conductor.

http://www.cambrios.com/

Canon, Inc.

Canon makes printers and other computer peripherals for home and office use. Its other well-known lines include copiers, fax machines, and scanners. Canon's optical segment features products used in such diverse applications as semiconductor manufacturing equipment, television broadcast lenses, and devices used for eye examinations. Canon still operates its original camera business, which makes digital cameras, camcorders, liquid crystal display projectors, lenses, and binoculars. The company, which generates about three-quarters of its revenues outside Japan, continues to emphasize its product development and marketing efforts in Europe and North America.

Canon's imaging products segment, its largest, includes printers, copiers, scanners, and multifunction devices for the consumer and enterprise markets. Canon sells branded products and supplies partners such as Hewlett-Packard that resell under their own brands. The company is targeting color office products for growth in this segment.

Customers in Europe account for nearly a third of its revenues. Accounting for almost 30% of sales, its next largest geographic segment, the Americas, is served by subsidiaries including Canon U.S.A. and Canon Canada. The company circulates its products in Europe and North America primarily through large distributors.

In 2010 Canon acquired Océ, Europe's largest manufacturer of printers, to solidify its position in that key geographic market. The company maintained the Océ brand following completion of the transaction, operating the Dutch supplier of office machines as a division.

Canon has teamed with Toshiba to develop surface-conduction electron-emitter display (SED) products, an alternative to liquid crystal display (LCD) and plasma technologies.

Perhaps still best known for its cameras, Canon has seen its photographic business steadily decline. However, the company remains a leader in the digital camera market, where it is concentrating on high-end single-lens-reflex (SLR) devices. Canon's third primary product group, encompasses a diverse portfolio including semiconductor production equipment, LCD components, medical imaging equipment, lenses, and large-format printers.

http://www.canon.com/

Carestream Advanced Materials

Carestream is part of Eastman Kodak Company and serves customers in more than 150 countries worldwide. The company has developed a brand of FLEXX films by applying more than 100 years of expertise in nanomaterial science, thin-film technology and roll-to-roll coating know-how. Carestream films feature an innovative silver nanomaterial technology that allows for exceptional conductance and superior optical performance. The FLEXX Transparent Conductive Films offer superior flexibility, durability and affordability. FLEXX Transparent Conductive Films help printed electronics manufacturers solve brittleness, high costs and low durability problems associated with traditional ITO films.

Carestream owns a tollcoating division that specializes in high-speed, multilayer precision coating used in the application of aqueous and solvent coatings on flexible substrates for medical imaging, display, battery components, electronic components, inkjet and imaging products.

http://www.carestream.com/

Checkpoint Systems

Checkpoint Systems makes electronic article surveillance (EAS) systems, radio frequency identification (RFID) tags, electronic security devices such as intrusion alarms and digital video recorders, and electronic access control systems used by retailers that have included Barnes & Noble, Sears, Target, and Walgreens. Checkpoint's EAS units employ paper-thin disposable circuit tags attached to merchandise that are disarmed at checkout; if not disarmed, the tags trigger electronic sensors when the customer tries to leave. The company operates in some 30 countries worldwide; nearly half of its sales come from Europe.

The company operates through three business units. Its Shrink Management Solutions includes EAS and CheckView video recording, fire, and intrusion systems. The Intelligent Labels division includes RFID tags and labels and its Check-Net tags and labels service bureau. (Check-Net accounts for 15 percent of sales.) Checkpoint sells retail display systems and handheld labeling systems to retailers through its Retail Merchandising unit.

In 2009 the company added to its labeling business with the acquisition of Brilliant Label Manufacturing, Ltd. The deal expands Checkpoint's global reach, as Brilliant Label is a China-based manufacturer of paper, fabric, and woven tags and labels.

http://www.checkpointsystems.com/

CERADROP

CERADROP is the only Inkjet printer manufacturer specializing in printed electronics (PE). Its CeraPrinter Series models present new opportunities for feasibility study and the launch of new products onto the PE market.

Based on its bottom-up approach, CERADROP offers InkJet Printing Equipment, which adapts to applied electronic materials as well as to complex components designed to be printed in industries such as organic photovoltaic (OPV), OLED lighting, smart cards, antennas, and intelligent systems. This enables its customers to conceive new applications without historical constraints such as traditional software, fixed printing resolution, limited accuracy, non-adapted control tools for PE.

http://www.ceradrop.fr/

Cima Nanotech

Cima NanoTech is an advanced materials company that has developed proprietary nanomaterial technology for electronics fabrication. These materials enable increased performance in concert with faster, cleaner, and cheaper manufacturing processes, resulting in more environmentally friendly, next-generation technology.

Cima NanoTech has business development centers in Japan, Korea, Taiwan, the U.S., and Singapore that enable close, local partnerships with electronics manufacturers worldwide. Its wholly owned subsidiary, Cima NanoTech, Israel, Ltd., located in Caesarea, Israel, is the Company's R&D center and production facility. Production is also done at a contract manufacturing facility in Hiroshima, Japan.

http://www.cimananotech.com/

Conductive Inkjet Technology

Conductive Inkjet Technology (CIT) offers innovative UV-curable inks and technology for the direct writing of conductive metals onto nonporous substrates. The company promises to provide the lowest-cost enabling technology solution for many such products, including RFID tags, smart packaging, and a variety of display applications.

CIT operates under its parent company Carclo through two operating divisions, one making injection-molded plastic components for automotive, telecommunications, medical, and optical applications, as well as specialty wires for the textile industry, the other being CIT, which has a variety of potential applications, including RFID tags and display signs. Carclo has operations in China, the Czech Republic, France, India, Italy, Turkey, the United Kingdom, and the United States.

CIT has created an in-line process and materials set that enables ink-jet deposition to be separated from metallization. This separation has allowed the company to optimize its process for speed and exceptional jetting reliability, as well as optimal metal deposition, all at room temperature. It has also allowed CIT to utilize UV-curable ink technology, which offers almost instant in-line curing and excellent adhesion onto a wide range of substrates.

The CIT technology is protected by a broad umbrella of pending patents relating to chemistries, processes, and applications. Further patent applications are in process. Commercial supply of CIT systems and inks will carry a license under the relevant CIT intellectual property. In addition, technology packages for Liquid Wiring Print2Chip and microfine laser-curing technologies will be available for licensing.

CIT has recently restructured to focus on three new areas of business: printed electronics, OLED lighting, and organic photovoltaics. A flexographic printing solution has been developed enabling double-sided circuits and side-to-side interconnection.

http://www.carclo-plc.com/

Corning

Corning, which manufactures glass substrates primarily for LCD displays, is known for its kitchenware and lab products. It also makes optical fiber and cable, and other telecommunications equipment, substrates and filters for automotive emissions control products, glass and optical materials for a wide range of industries, and labware and equipment. More than half of Corning's sales (and all of its display segment customers, including AU Optronics and Sharp Electronics, each around 10% of total sales) come from the Asia/Pacific region, including nearly a quarter from Taiwan. Corning has about 80 manufacturing and processing facilities across more than a dozen countries.

Facilities in Kentucky, Japan, and Taiwan manufacture the company's superstar display product, Gorilla Glass, which swung its way up from being in 70 product models in 2009 to being in 300 in 2010. Used in products such as notebook computers, mobile phones, and TVs, that product led the troop in Corning's sales growth in 2011, as mobile computing devices continued to proliferate. Corning expects demand to keep growing, which has led the company to pursue its first major consumer marketing campaign in 10 years, touting the "tough, but sophisticated" glass through magazines, online, and in TV ads. Home to Gorilla Glass, the specialty materials segment saw revenues climb 75% in 2010, and more than 85% in 2011, bumping it past the environmental technologies segment to become Corning's third largest (nearly 15% of sales).

Its largest segment, display technologies (40%), was hampered by LCD's sluggish supply chain inventory levels, and grew only 5%. LCD demand in the end-user market has been unabated, and Corning has been investing in capacity to keep pace. In 2010 it announced a multi-year investment plan to ramp up manufacturing. Late that year, it began putting $800 million towards a new LCD glass substrate facility in China, where it expected to begin production in 2012. Now, however, the company, as well as its 50%-owned joint venture Samsung Corning Precision, are forced to take action to reduce capacity, which includes delaying certain production start-ups.

Although Corning continues to look for acquisitions, organic growth will be continue to be important. That organic focus is fed by a strong R&D culture. Besides Gorilla Glass, that culture has produced products such as its heavy metal-free EAGLE XG Slim Glass (launched in 2006) used in handheld devices and IT settings, the telecom-focused Pretium EDGE used in optical networks in data centers, and its Lotus Glass (launched in 2011) for OLED (organic light-emitting diode) and next-generation LCD applications. In 2012 it partnered up with Samsung for another equity venture, through Samsung Mobile Display, which will incorporate Lotus Glass and focus on OLED applications.

http://www.corning.com/

Creative Materials

Creative Materials develops and markets highly conductive adhesives and inks that can be applied to a variety of substrates with exceptional print definition. The company also produces a wide range of thermally conductive adhesives, encapsulants, de-potting compounds, and dielectric coatings. Its formulation expertise encompasses acrylic, polyimide, silicone, epoxy, urethane, and proprietary polymer chemistries.

Creative Materials built its reputation on providing custom formulations to meet exacting production requirements and customers' specifications at every stage of development. These products have facilitated innovative new product designs in leading global markets for electronics, medical, automotive, microelectronics, assembly, and aerospace/defense components.

Typical users of Creative Materials products are manufacturers of electronics for automobiles, computers, keyboards, cell phones, and aerospace; medical suppliers of electrodes, medical instruments, and devices; creators of decorative jewelry; and producers of heating equipment.

Creative Materials' custom-formulated lines of encapsulants, electrically conductive adhesives, inks, and coatings are used in a variety of electronic and medical applications, including:

- Printed circuitry and semiconductor packages
- EMI and RFI shielding of plastic parts and polyimide flexible circuits and ribbon cables
- Polymer thick-film circuitry, membrane switches, and electrical terminations
- Bonding capacitors
- Electrodes
- Medical devices

http://www.creativematerials.com/

Cymbet Corp.

Cymbet Corporation claims to be the first to market a true solid-state energy system using a proprietary, patent-pending low-temperature manufacturing process. The company's thin-film battery system can be integrated directly within ICs or built into the electronics they power and can be used in ICs and handheld computers, communications and medical devices, sensors, and portable electronic devices. Cymbet's technology uniquely combines existing deposition techniques with high-energy solid-state battery technology.

Cymbet has developed a unique manufacturing process that uses a patented "cold" method by which films can be deposited at 100°C, rather than the 700°C employed by competitors. Depositing at this lower temperature allows for a greater variety of substrates, specifically flexible substrates.

Cymbet combines the high-energy density of lithium cobalt oxide and the excellent properties of lithium phosphorus oxynitride (LIPON) to replace existing batteries with application-specific batteries that enable a new generation of thin, lightweight products. The company's manufacturing process permits cells to survive the rigors of solder reflow or device molding prior to cell charging. These rugged cells can be handled without the need for the "safety circuits" required by other lithium-based rechargeable batteries. Cells can be rapidly charged from any DC voltage source not exceeding 4.15 volts.

The company has introduced a solid-state, thin film microbattery for direct integration onto semiconductors or as an SMT component. The EnerChip™ can provide a few days to a few weeks of battery backup power where nonvolatility is important or primary power for sensors, active tags, and medical applications. With innovations not previously available, Cymbet EnerChips provide a thin form factor, high energy density, permanent recharge ability, high-speed surface-mount assembly, and solder reflow tolerance in an electronics manufacturing process.

http://www.cymbet.com/

Dai Nippon Printing

Dai Nippon Printing is a leading commercial printer who has diversified beyond the business of spreading ink on paper. The global firm still produces books and magazines, dictionaries, catalogs, and business forms, and it has added items such as CD-ROMs, holograms, and smart cards to the mix, while subsidiary CHI Group sells e-books. It's Lifestyle and Industrial Supplies segment makes decorative materials for use in fixtures and furniture, along with packaging for consumer products. Its Electronics segment's products include photomasks used in the manufacture of integrated circuits and color filters for LCD panels. DNP also has a Beverage unit through which it owns a majority of Hokkaido Coca-Cola Bottling.

DNP has about 60 production plants and 45 sales offices throughout Japan; it also operates about 10 plants and 20 sales offices in more than a dozen other countries. Like other leading printing companies, DNP has branched out from publishing and commercial printing into such fields as environmentally friendly packaging, decorative materials, display-related products, and electronics. In 2010 DNP's operating income improved in the Electronics and Lifestyle and Industrial Supplies segments because of a rebound in demand for flat-panel displays. As a result, DNP's total earnings swung to a net income of some ¥23 billion (about $275 million) in 2010, up from a loss of more than ¥20 billion (about $239 million) in 2009.

In addition to a recovering economy that helped with increased sales, the company has also benefitted from cost cutting efforts. On the manufacturing front, DNP has been consolidating production systems in order to increase operating efficiencies. In fiscal year 2010 it integrated the domestic printing ink business of its Intec subsidiary with leading Japanese ink company DIC Corporation to form the joint venture DIC Graphics Corp.

Elsewhere in manufacturing, DNP has expanded; in 2010 it opened a new plant in Taiwan to meet the overseas demand for photomasks. The company is responding to the recovery in the LCD market, and Electronics has been DNP's fastest-growing business. Because it makes products for both the interior (photomasks) and exterior (displays) of high-tech equipment, the company believes it is well-positioned for additional growth.

Adapting to the shrinking publishing market in Japan and beyond, DNP has streamlined its books and magazine operations by merging several of its subsidiaries under a newly established holding company, CHI Group Co. The group was formed in 2010 by the combination of DNP's bookstore chain Maruzen with library service provider TRC Inc. (TRC services include operational support and database management.) Bookseller Junkudo -- which operates about 30 shops in major Japanese cities and which

DNP acquired in 2009 -- was also integrated into CHI Group. The group is the focus of DNP's strategy to introduce more e-books to the market. CHI is capitalizing on the fact that digital publishing is one of the few bright spots in an otherwise dismal publishing arena.

Another way in which DNP is working on digital publishing is by expanding its information security business. As part of these efforts, in 2010 DNP acquired security system developer Intelligent Wave, a Japanese firm engaged in network connection, authorization, and other processing systems for credit card payments. DNP and Intelligent Wave were already cooperating to provide security services to financial institutions, and the acquisition strengthened DNP's resources for providing secure digital transactions.

http://www.dnp.co.jp/eng/

Dainippon Screen Manufacturing

Dainippon Screen Manufacturing is one of the world's largest producers of semiconductor manufacturing equipment. Dainippon Screen, known as DNS or just plain Screen, also makes equipment for turning out flat-panel displays and printed circuit boards, and supplies printing hardware and software for newspapers and other publishers. Screen specializes in equipment that cleans semiconductor wafers, coats them in chemicals during various processing steps, and then etches circuit details onto the wafer. Other operations include logistics, leasing, and printing services.

Faced with a challenging global economic market, and chip makers postponing planned capital investments, DNS saw its sales drop by 20% in 2009 and its first loss in almost a decade. The company reduced expenses by making cuts in its workforce and streamlining operations worldwide.

Before the financial crisis, DNS was looking to increase its marketing efforts in North America and China in order to make up for lackluster sales at home. Its 2008 acquisition of Silicon Light Machines (SLM) has allowed DNS to expand its imaging business in the US. The company continues to target China, where the economy has remained fairly stable, emphasizing value-added printing products such as Chinese character fonts.

Looking to expand its presence in flat-panel display production equipment, DNS is working with chemical giant DuPont to develop equipment that reduces the costs of making organic light-emitting diode (OLED) displays. Combining DuPont's OLED materials and process technology with DNS' nozzle printing technique, the companies plan to produce OLED printing and coating equipment that will make producing large size OLED displays cost effective enough to compete with LCD and plasma screens.

In 2009 DNS increased its equity share in its Sokudo joint venture with Applied Materials to 81% and made it a subsidiary. Sokudo supplies what is known as track equipment -- used to deposit and spin chemicals on silicon wafers during the photolithography processing steps, then scrub off the excess -- to semiconductor manufacturers.

DNS was established in 1943 as a printing equipment vendor and began selling semiconductor equipment in 1966.

http://www.screen.co.jp

DayStar Technologies, Inc.

DayStar Technologies makes energy-generating and -storing devices out of copper, indium, gallium, and selenium, dubbed CIGS solar cells. The company is developing manufacturing processes for its thin-film photovoltaic foil CIGS solar cells that will be cheaper to produce than conventional polycrystalline silicon solar cells, which currently dominate the market. DayStar got out of the business of installing and maintaining solar panels for residences in 2009 and in September announced plans to acquire Canada-based EPOD Solar in an all-stock transaction initially valued at about $300 million.

The development-stage company has never made money. Among other risk factors facing DayStar are that the company has never generated revenues and has no commercial products. DayStar has no experience in volume manufacturing. The company has a contract with one customer, Blitzstrom GmbH, a European system integrator and solar power system wholesaler.

DayStar Technologies is targeting customers in Asia, Europe, and North America. Its potential customers include ventures developing power systems for satellites, lighter-than-air vehicles, and other aircraft. DayStar is also targeting lightweight power systems for battery charging.

http://www.daystartech.com/

DEK Printing Machines

DEK Printing Machines (DEK) is the world's leading provider of screen printing equipment and processes for diverse industries, from surface mount technology (SMT) and semiconductor, to fuel cell and solar cell manufacture. The company manufactures precision material deposition and mass imaging for advanced electronics assembly and high-reliability screen- and stencil-printing platforms for SMT printing speed, accuracy and quality. DEK's platform products include Galaxy, Europa and Horizon iX as well as automated productivity tools and process improvement solutions. It has further perfected high-speed processes capable of depositing a wide variety of polymer materials, dielectrics and metallisation layers, with thickness accurate to within just a few microns.

DEK Solar is a leading provider of screen printing equipment and processes for fuel cell and solar cell manufacturing, and has recently announced the result of metallisation tests that show the possibility for significant cost savings and process improvements in the print process for PV. DEK has developed, in collaboration with DuPont Microcircuit Materials, an ultra-fine wire mesh screen and metal stencil to improve cost per watt through increasing cell efficiency and reducing paste consumption. These meshes can enable reductions in paste consumption of up to 30% without effecting cell efficiency by reducing busbar thickness and solder adhesion forces.

Screen printing within the semiconductor manufacturing sector falls into two application areas – wafer level packaging and substrate level packaging. Both benefit from the mass imaging capabilities of the precision screen print process delivered on robust DEK printer platforms in stencil and screen production process.

http://www.dek.com/

Delta Optoelectronics

Delta Optoelectronics, Inc. (Delta Opto), was founded in 1999 and is part of the Delta Electronics group based in Taiwan. The company develops and manufactures high-luminance, energy-saving display devices with polymer light-emitting diode (PLED) technology. Milestones in Delta Opto's history are discussed below.

In 1998, Delta Electronics, Inc. acquired PLED technology from Cambridge Display Technology (CDT). Afterward, Delta Opto was formed as a subsidiary of Delta Electronics, Inc., focusing on the development and manufacture of flat fluorescent lamps (FFLs) and polymer light-emitting diodes (PLEDs). In 2000, the company formed a strategic alliance with Dow Chemical Company to codevelop light-emitting polymers and began assembling a pilot PLED production line. In 2002, annual production of FFLs reached 200,000 units and in 2003, Delta Opto demonstrated the world's first PLED device for an MP3 player. In 2004, the company signed a cooperative memorandum with CDT for the development of full-color displays. In 2005, the company began work on 32-inch FFL panels, completed an ink-jet printing (IJP) test line, and successfully demonstrated a full-color 5.6-inch active-matrix TFT-PLED, fabricated using IJP. In 2006, Delta Opto transferred its technology to Nulight Technology Corp. as part of a joint venture between Chi Mei Optoelectronics and Delta Electronics, Inc. for the volume production of 32-inch FFL backlight panels.

http://www.delta.com.tw/

Dialog Semiconductor, GmbH

Dialog Semiconductor develops mixed-signal (analog plus digital) chips used in wireless communications, automotive, industrial, and other applications. The company, which outsources its manufacturing, specializes in audio codecs (coder/decoders) and power management chips for mobile telephones. Customers include wireless powers Ericsson and Siemens. Dialog Semiconductor gets 45 percent of its sales from Europe, chiefly Central Europe, and around 40 percent from the Asia/Pacific region, primarily Japan and China.

In early 2006 Dialog spun off its imaging division as an independent entity, Dialog Imaging Systems (DIS), which has attracted around 22 million in private equity funding from 3i Group, Doughty Hanson Technology Ventures, division managers, and Dialog itself, among other investors. DIS makes camera modules for mobile phones, using CMOS image sensors and micromotors. The business had 2005 sales of 1.45 million (about $1.7 million), while posting an operating loss of 12.5 million (nearly $15 million).

In early 2007 DIS changed its name to Digital Imaging Systems.

Chartered Semiconductor Manufacturing is Dialog Semi's principal manufacturing contractor, with some business farmed out to China Resources Microelectronics, Taiwan Semiconductor Manufacturing, and X-FAB Silicon Foundries.

Investment firm Apax Partners owns about 18 percent of the company, which began as the semiconductor operation of Daimler-Benz (later DaimlerChrysler and now Daimler). ADTRAN has an equity stake of more than 5 percent.

http://www.diasemi.com/

Dow Corning

Dow Corning began as a joint venture of chemical supplier Dow Chemical and glass producer Corning in 1943, and ranks among the longest-lasting partnerships of its kind in the US. Dow Corning produces more than 7,000 silicone-based products such as adhesives, insulating materials, and lubricants for aerospace, automotive, and electrical uses. Because silicone does not conduct electricity, it is also used in its hard polycrystalline form (silicon) as the material on which semiconductors are built. Its products are also used in the production of photovoltaic cells used to produce solar energy. Through its Xiameter brand and website, Dow Corning sells products online to more than 80 countries.

Dow Corning's 2010 revenues were up 18% over the previous year, due mainly to growth in its silicones business, particularly electronics, life sciences, solar, and industrial applications. The company also experienced growth in its polycrystalline silicon business through its joint venture ownership of the Hemlock Semiconductor Group. It also saw record sales in Asia and Latin America. Net income increased 45% in 2010.

Key to that initiative is Dow Corning's majority ownership in Hemlock Semiconductor, a company that is investing $4.5 billion into solar energy R&D. (It owns 63% of Hemlock Semiconductor, with Shin Etsu and Mitsubishi Materials taking up the rest.) Dow Corning has also opened two solar energy applications centers, in the US and South Korea, since 2008.

In a move designed to further secure its supply of raw materials for manufacturing silicon, Dow Corning formed a joint venture in 2010 with Timminco Limited at its production facility in Becanour, Quebec. Dow Corning paid Timminco about $50 million for a 49% share of the facility's annual production of silicon metal. The operation has an estimated capacity of 47,000 million tons per year.

http://www.dowcorning.com/

DuPont Microcircuits Materials

DuPont Microcircuit Materials (MCM) is a leading supplier of specialized ceramic, polymer thick-film compositions (PTF) and GreenTape low temperature co-fired ceramic (LTCC) materials worldwide. MCM technologies are advancing a wide range of applications, including photovoltaic solar energy, LED lighting solutions, automotive and consumer electronics, displays, and military defense systems.

MCM is a subsidiary of E. I. du Pont de Nemours, a top US chemical maker (along with Dow and ExxonMobil Chemicals), and it operates through eight main segments. They produce crop protection chemicals and genetically modified seeds, coatings (automotive finishes), electronic materials (photovoltaics and materials for solar energy), films and resins for packaging and other uses, performance chemicals (fluorine products and white pigments), enzymes and food ingredients, performance materials (a wide range of polymers) and safety and security materials (under brand names like Tyvek, Kevlar, and Corian). DuPont operates worldwide, about 65% of its sales being outside the US.

In 2011, DuPont acquired Innovalight, which specializes in advanced silicon inks and process technologies that increase the efficiency of crystalline silicon solar cells. The deal is designed to strengthen DuPont's position in the solar energy market, where it made $1 billion in 2010 and aims to double that by 2014. Nevertheless, the company has slimmed down, exiting the pharmaceutical business and the fibers industry (INVISTA—including Lycra and Stainmaster), and is focusing more on biotechnology and safety and protection.

Some of MCM's leading products include:

- Biomedical sensor materials
- Display materials
- Embedded passive materials
- Hybrid circuit materials
- LED lighting materials
- Low-temperature cofired ceramic (LTCC) materials
- Passive component materials
- Photovoltaic metallization
- Printable materials for printed wiring boards (PWBs)
- Printed electronic materials

DuPont offers a broad and growing portfolio of eight essential materials, including films, resins for encapsulants, encapsulant interlayers, and conductive pastes, all needed for photovoltaic module production. These innovative materials from DuPont enable solar modules to run more efficiently, last longer, and provide environmentally sustainable solutions, making the use of alternative energy easier for everyone.

DuPont Microcircuit Materials currently offers hundreds of commercial PE products to a global customer base that is more than 40 years old.

http://www2.dupont.com/MCM/en_US/

Durel

The Durel Division of Rogers Corporation began as a joint venture of 3M and Rogers in 1988. The combined strengths of these two firms in coatings and phosphor technology enabled Durel to develop products to meet the evolving needs of its customers. In September 2003, the two parent companies agreed that Durel's future was best served through its integration into Rogers Corporation.

Today, Rogers Corporation is a high-volume manufacturer of DUREL 3 electroluminescent (EL) backlighting systems used in wireless telecommunications, portable electronics, and automotive and timepiece applications. The Durel Division's vertically integrated products offer the user matched-system performance and the ability to purchase a complete solution from a single vendor.

The Durel Division led the way in the introduction of integrated circuit (IC)-based EL drivers to the market, and today offers products designed for use in a wide range of applications. DUREL EL drivers are available as RoHS and WEEE "Green" compliant.

http://www.rogerscorp.com/durel/

Eastman Kodak

Kodak has restructured itself to focus less on film sales and more on sales of digital cameras and imaging systems. Production of digital cameras, pocket video cameras, and digital picture frames has stopped. It has discontinued its Kodachrome color film too. Kodak's future is in its brand licensing business, along with providing such products as home photo printers, commercial inkjet presses, and workflow software and packaging. The company's move shakes up its three segments: Consumer Digital Imaging Group (CDG); Film, Photofinishing, and Entertainment Group (FPE); and Graphic Communications Group (GCG), and follows a decision to file for Chapter 11 bankruptcy relief in early 2012.

In its January bankruptcy filing, Kodak listed more than 100,000 creditors and debts totaling $6.75 billion. The Bank of New York Mellon, which serves as a trustee for other bondholders, is its top creditor with claims of more than $650 million. There are some well-known companies on the list, such as Sony, Nokia, Wal-Mart, Target, Best Buy, OfficeMax, Disney Studios, and CVS Caremark. On the plus side, Kodak's more than $5 billion in assets include properties in New York, Colorado, and Oklahoma.

Prior to filing for bankruptcy, Kodak had been shopping a treasure trove of more than 1,000 patents, or 10% of the company's patent portfolio, that had the potential of generating $3 billion. Its effort, which began in mid-2011, attracted no serious suitors.

Its CDG segment, which generated 29% of the company's 2011 revenue, is one of the top providers to consumers of digital still cameras, retail printing, and digital picture frames. The Kodak All-in-One Inkjet Printing System is part of this business. The FPE segment serves up traditional photographic products and services for consumers and professionals and brings in some 26% of sales. The company's GCG segment, accounting for 45% of revenue, offers software, media, and hardware products for prepress customers and those who do digital and traditional printing. Kodak in 2011 acquired the assets of the relief plate business of Tokyo Ohka Kogyo in a bid to enhance its capacity to serve customers in the packaging industry, which the company has identified as a key growth market. The newly acquired business became part of Kodak's Prepress Solutions unit and conducts business under the name of Yamanashi RPB Supply Company.

http://www.kodak.com/

E Ink Corporation

Established in 1997, E Ink develops and markets display products based on its proprietary electronic ink technology. The ink is printed onto a plastic film and contains microcapsules full of positively or negatively charged pigment chips, which can be manipulated into forming images through the application of an electrical current. The advanced technology is now being employed in retail displays, but it has potential applications in other information displays, such as an "electronic newspaper" that refreshes its own content. Lexar Media and Sony have introduced products based on E Ink's technology.

Among E Ink's investors are Air Products and Chemicals, Gannett, Hearst, Intel Capital, Motorola, Philips Electronics, Toppan Printing, and Vossloh Information Technologies. Prior to acquiring E Ink, Prime View International had worked closely with E Ink in making electronic components that go into displays utilizing E Ink's technology. E Ink has raised more than $120 million in private equity funding.

Though E Ink's displays have been used in products as diverse as flash drives and mobile phone handsets, the company's technology has garnered the most attention for its use in e-books. Amazon.com's popular Kindle reading device, in particular, has raised the company's profile.

http://www.eink.com/

Electric Vinyl, Inc.

Electric Vinyl is an award-winning leader in EL (electroluminescent) technology, offering one of the brightest, largest, and longest lasting commercially acceptable thin EL panels available. The company has manufacturing facilities in Canada and Europe.

One of the company's flagship products is a super bright electroluminescent material known as Per'f-Alite Electric Vinyl. It is as thin as a credit card, flexible, and available in large sheet production sizes. It provides a new way to backlight images, whether they are digital camera images, digital copies of traditional artwork, or original computer graphics and advertising displays.

Electric Vinyl's thin, flexible displays can be convoluted to conform to many shapes, especially gently curved spaces, round supporting columns, and other areas where a nonbulky light source would be effective. The product can even be used to uniquely illuminate a floor with just about any image that is graphically possible.

https://electricvinyl.com/

Electronic Paper and Technology Solutions

Electronic Paper and Technology Solutions (EPTSolutions) is an international group of experts from different areas whose common goal is to set new standards in displaying information anytime (always available, always updated), anyplace (on any surface and device), anywhere (in any environment, including in water, etc.), in the clearest, most readable way.

EPTSolutions originated in 2007 at the European Competence Center in the course of implementing E Ink's electronic paper technology in systems and devices for OEM customers in Europe, Russia, and Israel.

EPTSolutions' flexible displays are ideal for many consumer and industrial applications, including handheld devices, watches, clocks, public information, and promotional signs. The company offers a complete solution for displays that includes design as well as suitable driver electronics.

http://www.eptsolutions.com/

elumin8

elumin8 is part of LMG International, Ltd. (Hong Kong), a privately owned group of companies with headquarters in Hong Kong, manufacturing facilities in China, and satellite offices and representatives in 23 countries around the world. Although based in Asia, the business is owned and run by a Western management team with decades of experience in manufacturing, distribution, and project management, as well as considerable R&D expertise.

The business began in 2004 (as Luminous Media, Ltd.) with a key focus on using electroluminescence (EL) in the area of media communications and at the same time exploring the low-energy qualities of the technology. With its dedication to quality, innovation, and creativity, plus its tenacity, the company has become widely regarded as one of the world's leading EL producers.

Today the business is split into several divisions under one manufacturing group, with each division evolving to exploit a different area. elumin8 is the umbrella for energy-efficient and forward-looking highway, urban, industrial, and commercial lighting.

http://www.elumin8.com/

eMagin Corporation

eMagin develops virtual imaging and organic light-emitting diodes (OLEDs) that can be used in applications ranging from wearable PCs and virtual imaging devices to more mundane products such as DVD headset systems, video games, and high-definition televisions. The technology also extends to military uses. eMagin's products use microcircuits and displays to magnify images of text or video. Subsidiary Virtual Vision develops near-eye and virtual image display products, including headset viewer systems. eMagin markets to OEMs and directly to customers in the government, industrial, and medical sectors.

eMagin's OLED displays have broad market reach and are incorporated into a variety of near-to-eye imaging products by military, industrial, medical, and consumer OEMs that choose eMagin's award-winning technology as a core component for their solutions. In 2009, eMagin introduced its first direct-to-consumer system, the Z800 3DVisor, which provides superb 3-D stereovision and headtracking for PC gaming, training and simulation, and business applications.

eMagin's microdisplay manufacturing and R&D operations are colocated with IBM on its campus in East Fishkill, New York. System design facilities and sales and marketing are located in Bellevue, Washington. A sales office is located in Tokyo, Japan.

http://www.emagin.com/

Energy Conversion Devices

Energy Conversion Devices (ECD) makes products that generate and store power or information electronically. It owns a subsidiary called United Solar Ovonic, which accounts for more than 95 percent of its sales. The Ovonic Materials Division licenses its optical memory storage technology to Sony and Toshiba and produces materials for use in NiMH and other batteries (licensed by Sanyo). ECD's largest customers are EDF En Developpement, Solardis-Soprasolar, Centrosolar AG, and Advanced Green Tech.

In 2009 ECD acquired its largest customer, Solar Integrated Technologies, a supplier of building-integrated photovoltaic roofing products, for about $16 million in cash and assumed debt. The company sees the acquisition as a way to transition from a manufacturing and sales organization to one that offers complete systems and services. The acquisition also improves its field engineering and technical capabilities in rooftop solar for customers in Europe and the United States. Customers in France, Italy, Germany, and Switzerland account for more than two-thirds of sales.

ECD has established manufacturing facilities in low-cost regions, including Mexico and China. The company has slowed its aggressive production and expansion plans to better align with current market conditions, and is consolidating some facilities and cutting jobs.

ECD works to develop cutting-edge technologies, often with funding from government contracts and strategic alliances, and then seeks to commercialize them. Some of its projects include portable hydrogen canisters (currently being manufactured in preproduction quantities), metal hydride fuel cell stacks, and a technology to produce high-purity hydrogen at lower temperatures from multiple renewable sources (currently moving from laboratory to pilot production).

In 2009 ECD sold its Cobasys joint venture with Chevron, which makes NiMH and other rechargeable batteries to power items ranging from consumer electronics to electric vehicles, to SB LiMotive Co., Ltd., a joint venture between Robert Bosch and Samsung SDI. General Motors is tied to Cobasys for its hybrid battery supply until the end of 2010. Chevron Technology Ventures and ECD were in a legal dispute over the joint funding of Cobasys, and settled their pending arbitration with the sale of Cobasys.

The company's Ovonyx joint venture is developing ECD's Ovonic Unified Memory technology for use in nonvolatile-memory semiconductors. The technology, also known as phase-change random-access memory, could provide a successor to the NAND flash memory devices commonly used in digital still cameras, MP3 music players, and other popular consumer electronics.

http://www.energyconversiondevices.com/

Enfucell Oy

Enfucell was founded in June 2002 after a decade of research on power sources for low power applications at the Automation Laboratory of The Helsinki University of Technology by Dr. Xia-Chang Zhang, the creator of SoftBattery along with his four PhD colleagues. The company is dedicated to small power sources, and its main product is the SoftBattery, a flexible and thin 1.5 volt power source targeted for RFID (radio frequency identification), micro sensors, functional packaging, and cosmetic and pharmaceutical delivery systems based on iontophoresis. The SoftBattery is made of low cost industrial environmentally friendly materials that are disposable with other household waste.

Enfucell Ltd. has received several international recognitions for its technology, including The Technology Pioneer 2007 by The World Economic Forum, one of the most prestigeous technology awards. Additional recognitions include Red Herring 100 in EMEA region in 2007 and The Guardian/LibraryHouse CleanTech100 in 2008. In March 2007, the developer of the SoftBattery, Dr. Xia-Chang Zhang, was selected in Beijing as one of the ten most influential Chinese by China's largest media companies.

Today Enfucell has its main office and technical facilities in the Petikko industrial park, where Enfucell has built modern facilities for SoftBattery production and R&D, as well as management, administration and sales & marketing. Since January 2008 Enfucell, Inc. has been established in the US and has also a representative office in Paris, France.

Enfucell employs approximately ten people, and is owned by its founders, private investors, Veraventure Oy, a Finnish governmental venture fund, and Varma Mutual Pension Insurance Co., the largest private sector pension insurance company in Finland. In addition to its shareholders, Enfucell has been financially supported by Tekes, The Finnish Funding Agency for Technology and Innovation (www.tekes.fi).

In February 2010 Enfucell raised approximately 6 million euros, including technology development funding from Tekes.

http://www.enfucell.com/

Ercon

Ercon was founded in 1967, and has focused on evolving conductive particles technologies and developing coating materials which provide improved product performance and process ability. Many of Ercon's products have been designed to specifically address custom requirements of printers and device manufacturers in the electronics and medical diagnostics industries, optimizing coating properties to provide its customers with advantages in economy and performance. Ercon is dedicated to advancing the functionality of conductive materials to enable its customers additional capabilities in the areas of diagnostic sensor technologies, such as electrochemical and force-sensitive applications.

Ercon manufactures an extensive line of polymer thick-film inks and conductive compositions, providing innovative products for a wide array of applications. These coatings are employed by companies using a variety of application techniques, such as screen-printing (flat-bed and rotary), flexographic/rotogravure, slot-die extrusion, spray and dip coating.

Ercon’s products are used worldwide for their performance, reliability, print quality, cost-effectiveness, and versatility. Ercon is committed to providing its customers with high-quality products and services. This commitment has led Ercon to become a leading manufacturer and preferred source for electrochemical sensor coating materials worldwide.

http://www.erconinc.com/

EV Group

EV Group (EVG, formerly known as Electronic Visions) was founded as an engineering partner for the semiconductor industry and has grown into an internationally acclaimed manufacturer of highly innovative precision systems. Today the company is a world leader in wafer-processing solutions for semiconductor, MEMS, and nanotechnology applications. Key products include wafer bonding, lithography/nanoimprint lithography (NIL), and metrology equipment, as well as photoresist coaters, cleaners, and inspection systems.

In addition to its dominant share of the market for wafer bonders, EVG holds a leading position in NIL and lithography for advanced packaging and MEMS. Along these lines, the company cofounded the EMC-3D consortium in 2006 to create and help drive implementation of a cost-effective through-silicon via (TSV) process for major ICs and MEMS/sensors. Other target semiconductor-related markets include silicon-on-insulator (SOI), compound semiconductor, and silicon-based power-device solutions.

Founded in 1980 in St. Florian, Austria, EV Group operates via a global customer support network, with subsidiaries in Tempe, Arizona; Albany, New York; Yokohama and Fukuoka, Japan; Seoul, Korea; and Chung-Li, Taiwan. The company's unique "triple i" approach (invent—innovate—implement) is supported by its vertical integration, allowing EVG to respond quickly to new technology developments, apply the technology to manufacturing challenges, and expedite device manufacturing in high volume.

http://www.EVGroup.com/en/

Evonik

Evonik Industries is a multinational company made up of subsidiaries Degussa (chemicals and plastics), STEAG (power generation), and Wohnen (real estate). Degussa operates globally and across multiple chemical platforms; it accounts for about three-quarters of Evonik's business. STEAG operates power generation plants, both in Germany and abroad in Colombia, the Philippines, and Turkey. Evonik's real estate operations include 60,000 housing units in Germany. Investment firm CVC Capital Partners owns a 25 percent stake in the company.

STEAG operates power generation plants with 9,000 MW of output in Germany, making it the country's second largest power generator behind E.ON. Its foreign operations yield another 2,700 MW of output. The company also designs and builds its own plants.

In addition to the 60,000 residential housing units owned by the company, Evonik also has a 50 percent stake in THS Treuhandstelle, which has more than 75,000 residential units of its own. Evonik Wohnen had been called Immobilien under its previous ownership by the company RAG.

Following the spin-off of Evonik from RAG, Evonik indicated a desire eventually to go public. Prior to that, CVC paid $3.7 billion for its stake. The separation of Evonik from RAG came as a result of a deal with the German government to take over the heavy liabilities of the country's coal industry. CVC paid its stake to the government-controlled RAG Foundation, which will also benefit from the eventual public offering of Evonik.

http://www.evonik.com/

Excellatron

Excellatron Solid State, LLC manufactures rechargeable lithium ion and thin-film batteries. Initial markets for this technology will be military applications, implantable medical devices, and other applications that require high performance. This technology will also enable a series of new products where existing battery technology cannot compete, e.g., Smart Cards, active Radio Frequency Identification (RFID) tags, and Micro Electro-Mechanical Systems (MEMS). The company was founded in 1998 and is based in Atlanta, Georgia.

Excellatron has been engaged in the development of production technology for TFB (thin-film batteries) for the past six years. Rechargeable lithium and lithium-ion thin-film solid-state battery technology was originally developed at the Oak Ridge National Laboratory (ORNL). Excellatron has bridged the gap between the laboratory samples and commercial products. The thin-film batteries developed by Excellatron have a long shelf life and cycle life. They are available on both ceramic and flexible polymer substrates. Samples have endured thousands of cycles with minimal degradation. Excellatron is on track to be the first manufacturer of thin-film batteries and to become a dominant player in this disruptive technology arena.

Excellatron has moved thin film battery technology far beyond laboratory development and has created the state of the art production technology that makes thin film batteries commercially viable. With its progress in Plasma Enhanced Chemical Vapor Deposition (PECVD) production technology, the cost of TFB (thin-film batteries) manufacturing will be significantly reduced. We believe that Excellatron's thin film batteries will play a significant role in the emerging active smart card and RFID tag markets for both civilian and military applications, including Homeland Security related applications.

http://www.excellatron.com/

Ferro Corporation

Ferro is a leading global producer of technology-based performance materials for manufacturers, ranking as the world's largest supplier of:

- Electronic materials for passive components used in the manufacture of multilayer ceramic capacitors
- Specialty glass and colorants
- Ceramic glaze frit and stain technology
- Porcelain enamel frit

In the United States, Ferro holds strong market positions in polymer additives and specialty plastic compounds and colorants.

Ferro makes all kinds of colorants, including ceramic glazes, pigments, and porcelain enamels. The company's products are used in construction and by manufacturers of appliances, cars, electronics, and household furnishings. Ferro also produces industrial chemicals (including stabilizers, plasticizers, and lubricants) used by makers of fuels, foods, cosmetics, pharmaceuticals, and plastics.

Headquartered in Cleveland, Ohio, Ferro has global operations selling products in more than 100 countries and has approximately 6,800 employees.

http://www.ferro.com/

First Solar

First Solar, Inc. manufactures solar modules with an advanced thin-film semiconductor technology and provides comprehensive photovoltaic solutions that significantly reduce solar electricity costs. The company provides an economical and environmentally responsible alternative to existing peaking fossil fuel electric generation. First Solar set the benchmark for environmentally responsible product life-cycle management by introducing the industry's first comprehensive collection and recycling program for solar modules. From raw material sourcing through end-of-life collection and recycling, the company is focused on creating cost-effective renewable energy solutions that protect and enhance the environment.

A worldwide shortage of polycrystalline silicon is holding back some producers of silicon-based solar cells; they can't get enough raw materials to meet demand. First Solar uses a sheet of glass as a substrate, coated with a film of cadmium telluride, for its products. The company produces its solar modules at a plant in Marlboro, Ohio, and it has a second factory in Germany. First Solar is constructing a third manufacturing facility in Malaysia. About 90 percent of the company's sales of solar modules are to six customers in Germany—Blitzstrom, Colexon Energy, Conergy, Gehrlicher Umweltschonende Energiesysteme, Juwi Solar, and Phoenix Solar.

In late 2007 the company signed a long-term module supply agreement with a subsidiary of Babcock & Brown and Ecostream Switzerland GmbH, a subsidiary of Econcern BV. The agreement is estimated to be worth about $1 billion over four years, from 2008 to 2012. To handle the increased volume of production as a result, First Solar's board authorized the construction of a second manufacturing plant in Malaysia. The new plant's four production lines will bring to 16 the number of production lines the company has in Malaysia, increasing capacity there to 704 MW as of 2009.

First Solar's principal manufacturing objective is to provide for large-scale manufacturing of solar power products at low costs so as to enable penetration of price-sensitive solar power markets. The company currently has two adjacent facilities, totaling approximately 100,000 square feet and 330 employees, dedicated to manufacturing and research and development. Its Marlboro facilities include a complete line of equipment to manufacture String Ribbon wafers, fabricate and test solar cells, and laminate and test modules, with a total capacity of approximately 15 megawatts per year if operated at full capacity. Going forward, however, First Solar expects its Marlboro site to continue to manufacture and to test, pilot, validate, and benchmark new manufacturing and product platforms; therefore, the actual production expected from Marlboro is in the range of 12–14 megawatts.

http://www.firstsolar.com/

Flexcell

The Swiss company VHF-Technologies SA, better known under the brand name Flexcell, was founded in 2000 at the Ecole d'Ingénieurs du Canton de Neuchâtel in Le Locle, France. The aim was to create an industrial process for a technique for applying amorphous silicon by very high frequency (VHF) plasma deposition, developed at the Institute of Microtechnology (IMT) of the University of Neuchâtel.

Flexcell's unique technology makes it possible to use a thin, flexible plastic substrate instead of glass. In comparison with the production of traditional crystalline modules, the technology requires 300 times less semiconductor raw materials, resulting in high production volumes and low energy consumption.

Within the space of a few years, VHF-Technologies SA has developed into a high-tech photovoltaics company. In 2007, Flexcell became part of the German Q-Cells AG group, a manufacturer of highly efficient solar cells made of mono- and multicrystalline silicon.

Owing to its highly flexible PV foil, Flexcell is able to deliver innovative mobile solar chargers and to provide integration solutions for the building industry (Building Integrated Photovoltaics).

http://www.flexcell.com/

Front Edge Technology, Inc.

Front Edge Technology (FET) was established in 1994. FET develops, manufactures, and markets next-generation, ultra-thin rechargeable batteries for card-type applications.

FET's product, NanoEnergy, is thinner than a piece of paper. When embedded in micro devices, NanoEnergy acts as an autonomous power source, enabling new functions for these micro devices and greatly enhancing their value. FET is working with its customers to develop next-generation self-powered microsystems.

FET is building a NanoEnergy production line with designed annual capacity of 200,000 1-mAh NanoEnergy units. This production line includes six industrial-scaled, in-line vacuum deposition systems, as well as other supporting equipment. Samples of NanoEnergy made by this production line have been delivered to FET's customers for their product development.

http://www.frontedgetechnology.com/

Frontier Industrial Technology

Since 1987, Frontier Industrial Technology has designed and manufactured custom-configured coating machinery for many Fortune 1000 customers. Frontier machines are at work worldwide today in the paper, film, foil, textile, adhesives, and microelectronics branches of the converting industry.

Frontier designs and engineers state of the art production slot die coating systems up to 100" wide. Pilot/lab scale coaters can be furnished in a range from small board coaters through roll-to-roll pilot coaters with dryer zones. Single or multiple layers can be applied in one pass.

Frontier Industrial Technology can design and build a custom slot die coating station to replace or as an addition to an existing coating method on a customer's in-house line. All of Frontier's coating stations come equipped with its WebFlight vacuum assist technology. Their slot dies can be positioned in increments of 6 micron or less.

Frontier Coating Systems are custom built to customer's specifications and needs. The following is a sample of the equipment and applications that can be integrated into a Frontier machine: Turnkey Coating Systems, Laboratory Development Coaters, Pilot Lines, Coating Modules, Multi-Layer coating, Patch Coaters, Flotation Dryers, Winders, Edge Guiding, Explosion Proofing, LEL Monitoring, Laminators, Fluid Delivery Systems, Thickness Gauging, Clean Room Features, and Defect Identification.

http://www.frontierindustrial.com/

FUJIFILM Dimatix

FUJIFILM Dimatix is a leading provider of ink-jet print heads for commercial and industrial printing. The company is transforming ink-jetting into a microproduction process that will revolutionize the manufacture of electronic and bioscience applications. The company's technology innovations and world-class fabrication processes enable high-performance, microprecision printing and deposition of traditional inks and nanoparticle fluids on all types of surfaces, including flexible substrates.

Founded as Spectra in 1984 with an exclusive license relationship with Xerox, FUJIFILM Dimatix has developed significant intellectual property and multiple generations of proprietary drop-on-demand ink-jet print heads capable of producing high-quality digital images in a wide variety of printing and fluid-jetting applications. The company invests heavily in research and development, maintaining one of the most capable ink-jet R&D groups in the world, with over one-third of its staff actively engaged in product engineering.

The Spectra Printing Division, located in Lebanon, New Hampshire, designs and manufactures piezoelectric ink-jet print heads and related components. Its products are used worldwide by leading manufacturers of industrial printing and imaging systems. OEMs and system integrators use the devices in a wide variety of systems for display printing, industrial marking and coding, textiles, graphic arts, postal and addressing tasks, and decorative applications.

The company is also developing new markets and applications, such as direct imaging at full production speeds onto baked goods and other edible products using food-grade colorants. This has allowed FUJIFILM Dimatix to open the world of food decoration to the large industrial food companies.

The Materials Deposition Division, headquartered in Santa Clara, California, designs and manufactures piezoelectric micropumps and related components. The company's products are used for the precise, digital material transfer of functional fluids for additive materials deposition processes.

Additive materials deposition is used in large and diverse industrial markets such as the flat panel display and electronics fabrication, 3-D mechanical, life science, optical, and chemical markets. In these applications the company's micropumps are used to deposit aggressive, conductive, reactive, and other fluids and coatings with high precision and in precisely controlled amounts. The precision of these pumps makes it unnecessary to subtract, etch, and recover superfluous material.

http://www.fujifilmusa.com/products/industrial_inkjet_printheads/index.html/

FUJIFILM Holdings Corporation

FUJIFILM Holdings makes color photographic films and papers, digital cameras, and photofinishing equipment and chemicals. It leads the film market in Japan and has hammered away at rival Eastman Kodak's lead in the United States. FUJIFILM Holdings' other businesses include document solutions (copy machines, printers, paper, and more) and information solutions (medical imaging products, flat panel display materials, optical devices). FUJIFILM Holdings operates in Europe, Australia, Asia, and North and South America, although 60 percent of its sales come from Japan. It adopted a holding company structure and changed its name from Fuji Photo Film to FUJIFILM Holdings in 2006.

FUJIFILM Holdings has diversified far beyond the film industry (it boasts more than 230 subsidiaries) to invest more in digital technologies and less in traditional film. To that end, the company acquired Santa Clara, California-based Dimatix, a maker of ink-jet printer parts, in 2006 and renamed it FUJIFILM Dimatix. (On the whole, FUJIFILM generates more than 40 percent of its revenues through a joint venture with Xerox—called Fuji Xerox Co.—that makes and markets printers and office copiers.)

FUJIFILM Corporation and Universal Display Corporation announced in July, 2012, that Fujifilm has sold and Universal Display has purchased the entire worldwide patent portfolio of more than 1,200 OLED patents and patent applications of Fujifilm for US$105 million.

http://www.fujifilmholdings.com/

Fuji Electric

Fuji Electric has organized its businesses into three main segments: Energy & Electric Systems, Electronic Devices, and Retail Systems. Its Energy & Electric Systems segment makes components and instruments used in automation, electric power, industrial plant, and facility construction applications. The unit also makes power semiconductors, sensors, and photoconductive drums. Its Electronic Devices group makes magnetic disks. The Retail Systems group makes vending machines, currency handling devices, and refrigerated display cases.

Faced with ongoing losses and a troubled Japanese economy, the company has worked to restructure its business units trying to become profitable. The global economic downturn has brought more challenges, as demand for semiconductors, magnetic disks, and other component product lines continues to drop. In order to reduce expenses, the company has instituted workforce reductions and staff reallocations, temporary work stoppages, cut wages, cut research and development expenditures, halted capital investment, and streamlined its product groups to refocus on energy and environmental applications.

In April 2010 it reorganized its three segments into six -- Energy Solutions, Environmental Solutions, Semiconductors, ED&C Components, Vending Machines, and Magnetic Disks.

In order to boost its energy and environment business, in 2009 Fuji Electric moved its semiconductor and photoconductor business units from Fuji Electronic Device Technology (FDT) to Fuji Electric Systems (FES). This change is intended to enhance the company's business development in infrastructure (such as railways) and green products (including solar and wind power products and smart grid electric power networks). FDT will specialize in making magnetic disks, which accounted for 6% of sales in 2010. In February 2011 it established a joint venture with GE to develop, manufacture, and market smart meters for Japanese electric utilities.

Also in 2009 Fuji Electric merged its electric and construction units, Fuji Electric Engineering & Construction and Fuji Denki Sosetsu, with Furukawa Electric Co.'s Furukawa Engineering and Construction. The new company -- Fuji Furukawa Engineering & Construction -- provides engineering and construction services for a wide range of projects, including construction of larger facilities, with a focus on green building and environmentally sound construction techniques.

Other restructuring efforts include shifting some production operations overseas while realigning facilities in Japan to improve productivity. The company merged its R&D company -- Fuji Electric Advanced Technology (FAT) -- into the holding company, in order to encourage technology development for the group as a whole. The integrated R&D organization will target development of power semiconductors, specifically for auto electronics for hybrid vehicles, power supplies, and industrial plant engineering, along with development of solar cells. FAT was dissolved as a separate organization.

http://www.fujielectric.co.jp

Fuji Xerox Co., Ltd.

Fuji Xerox provides digital imaging and printing equipment to the Asian market. Its products include digital printers, digital copiers, multifunction machines, projectors, engineering plotters, image processing systems, fax machines, and related software. The company counts convenience store chain Seven-Eleven Japan among its customers. A 50/50 joint venture when it was founded in 1962, Fuji Xerox is now owned 75 percent by FUJIFILM and 25 percent by Xerox.

Fuji Xerox generates the majority of its revenue in Japan, but markets its products throughout the Asia/Pacific region. It has targeted China as a market for future growth.

http://www.fujixerox.co.jp/eng/

Fujikura

Fujikura was established in 1885 by founder Zenhachi Fujikura. The company produced silk and cotton binding used for electric equipment.

Fujikura is a major manufacturer of wire and cable for the information and telecommunication industries. Fujikura operates through three main divisions: Telecommunications, Electronics & Auto, and Metal Cable & Systems. Its product lines include optical fibers and cables, sensors, electronic components, insulated cables, coated and magnetic wires, and connectors and harnesses. Fujikura's product development is concentrated in the areas of fiber optics, consumer electronics, electric power, and industrial applications such as conductive inks for printed electronics.

Fujikura struggled in 2009 as the global recession decreased demand for the company's products. Sales began to rebound the following year and fiscal 2010 (ended March 2011) delivered mixed results. Its real estate segment's operating income improved more than 40% when Gatharia opened after years of development. Telecom also showed improvement but Metal & Cable Systems stumbled on price competition and Electronics & Auto stalled on plummeting demand.

Fujikura plans to continue building fiber optics plants in China, where demand remains steady. In electronics, the company is looking at ways to launch products faster while the auto segment is getting new production plants. Metal Cable & Systems is humming on Japan's post-earthquake reconstruction efforts as well as expanding into China, Southeast Asia, and South America.

http://www.fujikura.co.jp/eng/

G24i

G24 Innovations (G24i), a UK-based company, is the world's first to commercially manufacture next-generation dye-sensitized thin-film solar cells, an alternative to traditional silicon solar cells.

Dye-sensitized thin-film solar cells are unique in that they are extremely lightweight and durable, and produce electricity in low-light and indoor conditions. As a result, G24i's advanced solar cells are perfect for powering mobile electronic devices such as mobile telephones, cameras, and portable LED lighting systems.

On a larger scale, G24i's flexible thin film integrates effectively into clothing, tents, and electronic advertising displays, and works well for indoor building-integrated photovoltaic systems where local regulation requires on-site generation or significant energy-efficiency measures.

G24i's proprietary high-speed roll-to-roll manufacturing process allows for large-volume production at its 23-acre, 187,000-square-foot facility.

http://www.g24i.com/

Goss International Americas

Goss International Americas supplies presses and finishing systems for graphical printing, packaging and other printing applications. The company is differentiated by its printing process knowledge, technical expertise, and comprehensive industrial manufacturing capabilities.

Recently, Goss has taken another step forward in the evolution of printing by applying its process knowledge to the field of printed electronics. The advanced process knowledge and technical expertise that make Goss a premier supplier of printing equipment also allows the company to provide printing services for electronics and to develop processes aimed at high-quality functional printed electronics applications. Goss can print demonstrators and prototypes as well as provide full-scale production for a variety of users. The flexibility of the Goss equipment portfolio enables process customization to meet the requirements of many new printing applications.

Goss International is headquartered in Durham, New Hampshire.

www.gossinternational.com/

GSI Technologies

GSI Technologies, formerly Graphic Solutions International, LLC, and Graphic Solutions, Inc., changed its name in early 2007 and reorganized into two divisions: Industrial Graphics and Functional Printing. The Industrial Graphics division employs a variety of printing processes, such as flexography, hot stamping, web- and sheet-fed screen printing, and photofinishing (photoetching) to deliver high-quality pressure-sensitive labels, aluminum nameplates, and polycarbonate panels. The company's second division, Functional Printing, is a leading producer of medical electrodes, passive and powered RFID products, smart card inlays, and electroluminescent lamps.

GSI now gets 85 percent of its $30 million in annual revenues from printed electronics. It uses largely conventional graphic printing equipment, with drying ovens, to make things like diabetes glucose test strips, electrochromic and electroluminescent displays and smart cards with display insets, microfluidic devices, battery testers, and soon drug delivery patches and heating elements.

GSI Technologies also manufactures RFID antennas, printed circuitry, and thin flexible batteries for microelectronics, as well as a turnkey RFID system. GSI's label and polycarbonate overlay constructions are recognized by both the UL and CSA standards and its aluminum nameplates meet military requirements. The company also supplies a variety of security label options, including a security thread.

Through the years, GSI has expanded into printing pressure-sensitive labels, aluminum nameplates, polycarbonate panels, and conductive printed products for the medical market. In 2000, it became the first licensed manufacturer of thin, flexible batteries in sheet form. Later, it began producing RFID antennas, medical electrodes, smart cards, RFID systems, and electroluminescent lamps. Since 2004, it has been a part of Thrall Enterprises, a family-owned holding company with offices in Chicago.

http://www.gsiinternational.com/

Gwent Electronic Materials, Ltd.

Gwent Electronic Materials, Ltd. (GEM Ltd.) was founded in 1988 for the purpose of manufacturing materials for the electronics and associated industries. Recently, the company has grown to become a major supplier of pastes and inks. The current capacity of its production facility is in the range of 100,000 to 200,000 kilograms of paste per year. GEM Ltd. uses an extensive range of testing and analysis equipment to ensure that its products meet the highest standards.

GEM Ltd.'s product range includes conductor pastes that may contain precious metal or nonprecious metal, for all forms of substrates, passive, or active components; dielectric pastes for all forms of substrates, passive, or active components; polymer-based pastes for all forms of substrates, both precious metal containing and nonprecious metal containing; pastes for sensors, such as industrial, automotive, and biosensors; and pastes for all forms of passive components. GEM Ltd. also has a complete range of a new type of synthetic metallo-organic material for the electronics industry and for decorative applications on a wide range of substrates or materials.

http://www.gwent.org/home.html

H. C. Starck

H. C. Starck is an international group of companies headquartered in Goslar, Germany, with more than 3,400 employees at 14 production sites in Europe, North America, and Asia.

The company manufactures metal powders, thermal spray powders, metal products, and specialty chemicals. Its powders go into everything from concrete to sporting goods, from pigments and plastics to medical and dental supplies. Starck also makes electroconductive polymers and colloidal silica for the electronics industry. It has been owned by private investors Advent International and The Carlyle Group since 2007.

The two investment groups paid about $1.6 billion for H. C. Starck. They intend to build up H. C. Starck and put forward a future public offering. The company was originally acquired by Bayer in 1986 and was part of Bayer MaterialScience until Bayer sold H. C. Starck to fund, in part, its acquisition of Schering.

http://www.hcstarck.com/

Haiku Tech

Haiku Tech is a global provider of screen printing and coating equipment. The company uses advanced high-accuracy screen printing technology for laboratory-scale development and industrial-scale mass production for such applications as photovoltaics-using or roll-to-roll equipment. Haiku Tech's coating technology uses slotted die and doctor blade technology. Extreme care is taken to control and reach the highest accuracies in coating weight by using a stable equipment platform with innovative features.

Together with its partner companies, Keko Equipment and Polymer Innovations, Haiku Tech has over 40 years of experience designing custom printing (including roll-to-roll) and coating equipment, as well as screen printable pastes and coating materials.

http://haikutech-printedelectronics.com/

Heliatek GmbH

Heliatek was spun-off in 2006 from the Technical University of Dresden (IAPP) and the University of Ulm. The company develops organic solar cells consisting of so-called "small molecules"—organic dyes that are synthesized from hydrocarbons. Heliatek's goal is to mass-produce organic photovoltaic panels using a rapidly deployable and efficient roll-to-roll process.

Heliatek received $27 million in a second round of financing under the lead of the venture capital firm Wellington Partners in 2009. The company will be utilizing the new funding primarily to build an initial production facility in Dresden. From this initial step through mass production, the company will be using its proprietary tandem technology to efficiently produce flexible and very lightweight PV modules on a film substrate. Modules will weigh a mere 500 grams per square meter, instead of today's customary 20 kilograms per square meter. This will open up a forward-looking market for mobile applications, for architectural solutions, and for independently supplying regions with weak infrastructures.

Recently, Fraunhofer ISE certified a power conversion efficiency of 6.07 percent for a tandem solar cell using Heliatek's proprietary tandem cell technology. The cell, with an active area of 2 cm^2, already possesses many of the essential characteristics of a large solar module. Heliatek developed it in cooperation with the Institute of Applied Photo Physics (IAPP) of the Technical University of Dresden based on results of the projects "Innoprofile" and "OPEG." The cell represents an important milestone on Heliatek's way to production of organic solar cells. In the medium term, Heliatek plans to increase the conversion efficiency to 10 percent.

http://www.heliatek.com/

Henkel

Henkel's business is divided among three units: laundry and homecare, which generates more than one quarter of sales; cosmetics and toiletries, approximately 20% of sales, and adhesive technologies, 50% of sales. Each unit claims a large share of its market through established brands. All told, the company's top-10 brands account for more than 40% of sales. In cosmetics and toiletries 90% of sales are driven by the business unit's top-10 brands; in laundry and homecare, more than 80%, and in adhesive technologies, about 55%.

Henkel manufactures products at 180 facilities dotting 56 countries. Its largest plant, located in Düsseldorf, Germany, makes detergents and household cleaning products, as well as adhesives for consumers, craftsmen, and industrial customers. The company's cosmetics and toiletries are produced at eight plants, with the largest located in Wassertrüdingen, Germany.

The company is concentrating on its higher-performing brands simultaneous with strengthening customer service. Henkel's strategy includes acquisitions and divestments to engineer a balanced growth portfolio. To supplement its adhesives business, Henkel acquired Cytec Industries' pressure-sensitive adhesives (PSA) product business. The deal followed Henkel's investment in constructing its largest adhesives plant in Shanghai.

The Adhesive Technologies business sector comprises five market- and customer-focused strategic business units: Adhesives for Consumers, Craftsmen and Building; Transport and Metal business; General Industry business; Packaging, Consumer Goods and Construction Adhesives business; and the Electronics business. The company’s printed electronics brand is maintained under its Loctite brand.

http://www.henkel.com

Heraeus Holding

Heraeus Holding's largest subsidiary is precious metals trader W.C. Heraeus, which also processes precious and specialty metals into products used in the aerospace, automobile, chemical, electronics, and pharmaceutical industries. Among Heraeus Holding's 100 other subsidiaries and affiliates are Heraeus Kulzer (dental and medical products), Heraeus Quarzglas (equipment and optics made from quartz glass), Heraeus Electro-Nite (temperature sensors used in the steel and auto industries and appliances), and Heraeus Noblelight (infrared, ultraviolet, and other specialty light sources). The Heraeus family owns the 150-year-old holding company.

The company operates globally, with Europe and Asia together accounting for more than three-quarters of its business.

In 2010 Heraeus sold its ceramic color business to Ferro, while acquiring Ferro's precious metal preparation and lustres operations. The two-way deal will enable both companies to focus on their core businesses. Also that year, Heraeus made two more strategic acquisitions, buying Clevios, the conductive polymers business of HC Starck GmbH, and a majority stake in South Korean dental products distributor Huden Dental.

Since 2008 it has added to its business with acquisitions in three areas: medical components, quartz, and ceramic colors. Heraeus bought business units from the likes of Synovis Life Technologies, BASF Catalysts, Saint-Gobain, and Kulicke & Soffa.

http://www.heraeus.com

Hewlett-Packard

Hewlett-Packard provides one of the tech world's most comprehensive portfolios of hardware, software, and services. Products include PCs, servers, storage devices, printers, and networking equipment. Its services unit provides IT and business process outsourcing, application development and management, consulting, systems integration, and other technology services. HP's software products include enterprise IT management, data management, business intelligence, and carrier communications applications. The company markets to consumers, businesses, governments, and schools worldwide. About two-thirds of sales come from outside the US.

In 2012 HP announced a sweeping reorganization intended to thwart faltering profits and a declining share price (shares have lost half of their value in the past two years) by streamlining operations and by focusing more on sales to businesses than consumers. The company is looking for a simplified organizational structure to boost innovation and save money. The company expects headcount reductions as part of the initiative will number around 27,000 (about 8% of its workforce) by the end of fiscal 2014, though that number will vary based on how many employees participate in the early retirement plan. HP plans to reinvest its savings in each segment around three areas of strategic focus: cloud computing, big data and security, and other areas that show growth potential.

HP has announced some of its plans for each segment. For its services segment, the company wants to add to its cloud computing, security, and information analytics capabilities, as well as shift its portfolio to include more profitable and higher growth services. In its software unit, HP plans to increase development of onsite and cloud-based security, big data, and lifecycle and infrastructure applications. In its enterprise servers, storage, and networking business, the company plans to increase its development of each product line to create a converged infrastructure that will be the foundation for other initiatives including cloud, virtualization, big data analytics, social media, and modernization of legacy products.

As part of the restructuring, HP plans to combine its PC and printer business groups into its new HP Printing and Personal Systems Group. Both units have struggled with changes in the marketplace. PCs are facing stiff competition from smartphones and tablets, as those devices are increasingly able to handle more of the functions of a traditional PC. Sales of printers and inks, once a primary source of revenue for HP, are falling as more businesses and consumers share documents and photos online. The company plans to fund research and development that will differentiate its products across the core printing and PC product lines, as well as invest in marketing and tools that will make it easier for customers to do business with HP.

The Imaging and Printing Group (IPG), which accounts for about 20% of company sales, provides inkjet, laser, and large-format printers. Its comprehensive line also includes copiers, digital presses, scanners, multifunction devices, software, and supplies. In addition to printing and imaging giants ranging from Canon to Xerox, HP clashes with its PC nemesis Dell in the printer market; Dell sells branded printers made by Lexmark and others. IPG also oversees HP's digital photo printers and online photo services. HP is also moving its printing business into the cloud. That is the strategy behind the 2011 acquisition of Germany-based Hiflex Software, which provides Web-based services and management systems for printing. The IPG segment, while not steadily declining, has not experienced any significant growth in years, reporting sales that were essentially flat in 2011.

The growth areas for an enterprise-focused company like HP come from its breadth and depth of new technologies, such as cloud computing, unstructured data, data center consolidation and automation, digitization, analytics, and IT security, helping the company to expand beyond traditional consumer PC sales. Geographically, the company is looking to grow by developing more business in such emerging markets as Brazil, Russia, India, and China.

http://www.hp.com/

Hisense

Hisense Group is a well-known brand in China for consumer electronics and household appliances. Its main product lines include TV sets, LCD computer screens, mobile phones, air conditioners, refrigerators, and washing machines. The company operates more than 20 domestic marketing centers, 200 after-sale service stations, and roughly 10,000 repair outlets. Its international operations include about 10 subsidiaries and several offices in North and South America, Europe, Australia, South Africa, Southeast Asia, and the Middle East. Hisense Group operates factories in Africa and China. The firm exports its goods to some 100 countries worldwide.

http://www.hisense.com

Hitachi Chemical

Hitachi Chemical is a subsidiary of industrial giant Hitachi, Ltd., and produces chemicals and related products through two units: Electronics-Related Products (semiconductors and displays) and Advanced Performance Products (carbon sliding materials, films, and motor brushes for the automotive industry). Hitachi Chemical's electronics products include materials for making semiconductors and displays, as well as printed circuit boards. Its chemicals include basics such as carbon and graphite materials and other organics, including varnishes, resins, and polyethylene. Japan constitutes about 70% of company sales.

http://www.hitachi-chem.co.jp

Imprint Energy

Imprint Energy was founded in 2010 to reshape the battery landscape through the commercialization of its breakthrough, zinc-based rechargeable battery technology (Zinc Poly) developed by the company's founders at the University of California, Berkeley. The company aims to improve portable power by significantly lowering its cost and by removing form factor limitations and safety concerns. Imprint Energy's novel electrochemistry system utilizes non-toxic, non-volatile materials that enable scalable, print-based manufacturing of ultrathin, flexible, rechargeable batteries that offer market-leading volumetric energy density.

After winning several business plan competitions, Kincaid and Dr. Ho incorporated the company in 2010 and successfully raised seed capital from Dow Chemical's venture group. Shortly afterwards, Imprint Energy's original strategic advisor, Dr. Devin MacKenzie, formerly of Add-Vision, Inc., joined the company full-time as CEO to help Kincaid and Dr. Ho to navigate the university to find a scale-up process and build a product.

http://www.imprintenergy.com/

Indium Corporation

Indium Corporation is a materials supplier to the global electronics, semiconductor, solar, thin-film and thermal management markets. Products include solders, preforms, and fluxes; brazes; sputter targets; indium, gallium, and germanium metals and compounds; and Reactive NanoFoil. Founded in 1934, Indium Corp. has global technical support and factories located in China, Singapore, South Korea, the United Kingdom, and the USA.

Indium's products include pastes, wires, fluxes, preforms and sphere alloys.

http://www.indium.com/

Infineon Technologies AG

Infineon Technologies spun off its Memory Products unit as a stand-alone business, Qimonda, because the vagaries of the dynamic random access memory (DRAM) chip market convinced Infineon to focus on more stable product fields. Infineon, which vies with STMicroelectronics to be Europe's number-one chip producer, makes semiconductors for myriad automotive, computing, communications, and industrial applications. Former parent Siemens remains one of Infineon's top customers; Siemens sold its remaining equity stake of about 18 percent in 2006.

Infineon is a member of several joint ventures and strategic alliances; partner companies include chip makers IBM and Intel, chip contract manufacturer Chartered Semiconductor, and telecom equipment maker Ericsson (which sold its chip business to Infineon).

Infineon is supplying radio frequency identification (RFID) devices to the US government that will go into American passports. The secure devices will be embedded into passports and contain the same information that is printed inside the passport. Infineon is making secure RFID chips for passports issued by a number of governments around the world, including those of Germany, Hong Kong, Norway, and Sweden. Its identification devices are also embedded in electronic identity cards issued by Australia, Belgium, Finland, Hong Kong, Italy, and the United Arab Emirates, as well as in secure ID cards issued by the US Department of Defense.

http://www.infineon.com/

Infinite Power Solutions, Inc.

Infinite Power Solutions, Inc. (IPS)—a US-based, clean-technology company—is the global leader in developing, marketing, and manufacturing solid-state, rechargeable thin-film microenergy storage devices for a variety of microelectronic applications. Founded in 2001, IPS is privately held, with corporate headquarters and manufacturing facilities in Littleton, Colorado. The company has completed buildout of the world's first volume manufacturing facility dedicated to the production of its revolutionary thin-film Micro-Energy Cell (MEC) products (often referred to as thin-film batteries). IPS has recently commenced production activities at this state-of-the-art facility to address growing demand among customers in the wireless sensor, active RFID, powered smart card, medical device, consumer electronics, automotive, and civil/military/aerospace markets.

THINERGY MEC products provide unrivaled performance in terms of power density, capacity, and cycle life. THINERGY MECs are deeply embeddable and, when combined with ambient energy harvesting, enable autonomous, perpetually powered solutions for decades of use. Essentially, they are batteries that never need to be replaced.

http://www.infinitepowersolutions.com/

InkTec

InkTec Corporation was founded in 1992 and has been developing ink-jet inks for desktop printers and related LFP products. The company completed development of a silver conductive ink, TEC (transparent electronic conductive), in 2005. Through the use of nanotechnology, InkTec is seeking to apply its products to RFID tags, printed circuit boards, reflective films, and displays.

InkTec is comprised of five divisions: the desktop division, the LFP division, the printed electronics division, the printing systems division, and the antimicrobial division.

http://www.inktec.com/english/

Innovalight

Innovalight is focused on bringing high-efficiency, low-cost solar modules to the marketplace. To enable a manufacturing paradigm shift, the company has been developing a silicon ink since 2002. Historically, silicon has been processed either as a solid or as a gas. Using liquid-based processing, Innovalight will dramatically improve the cost and efficiency of today's solar modules.

The company was recognized as a Technology Pioneer at the Annual Meeting of the World Economic Forum held in Davos, Switzerland, and was selected by the United States Department of Energy for its 2008 PV Incubator program. The company has been extensively profiled by *Time*, CNN, and other major news and industry organizations as a technology leader crusading for new, cleaner energy solutions.

In June, 2011, DuPont announced the acquisition of Innovalight in an effort to increase its sales to the PV industry. Most of its customers are based in Asia, and include major Chinese solar companies JinkoSolar Holding Co Ltd, Yingli Green Energy Holding Co Ltd and JA Solar Holdings Co Ltd.

In June, 2012, DuPont filed a lawsuit against Heraeus Materials Technology and its customer SolarWorld Industries America, Inc. for allegededly infringing on a patent related to front-side metallization paste compositions used in solar cell technology.

http://www.innovalight.com/

International Solar Electric Technology, Inc.

International Solar Electric Technology, Inc. (ISET) is a private California corporation with a wide range of expertise in next-generation thin-film solar electric products and systems. ISET has carried out extensive R&D work in the area of photovoltaics—the technology for direct conversion of sunlight into electricity. Major research breakthroughs include development of novel, low-cost manufacturing alternatives for fabrication of “printable” high-efficiency solar cells that are unique to the solar energy industry.

In 2006, ISET began development of a pilot production facility for manufacturing printed CIGS photovoltaic modules. ISET’s laboratories and pilot facilities are located in a 24,000 ft^2 facility in Chatsworth, California.

ISET has developed an ink-based process for manufacturing thin-film CIGS solar cells and modules on both rigid and flexible lightweight substrates. This patented technology offers fundamental improvements over existing solutions for both terrestrial and space power applications.

ISET offers technology transfer, customized PV products, PV system design services for both stand-alone and grid-connected systems, and general consulting services relating to PV technologies.

http://www.isetinc.com/

Intrinsiq Materials

Intrinsiq Materials manufactures highly functional nanotechnology copper and nickel electronic inks for use at room temperature for the printed electronics industry. Its products include conductive and silicon inks for solar cells, plastics and paper, touch screens and backplanes.

The company's technology is a screen-printable, low-temperature, curable blend of nano- and micro-copper, offering superior performance. C-SP ink is a highly functional, appropriately metal-loaded concentration of copper ink that can be deposited via conventional screen-printing methods. C-IJ is an inkjetable, low-temperature, curable copper ink comprised of Intrinsiq's proprietary nano-materials and exhibits significant shelf life. It is compatible with commercially available inkjet systems, ensuring that Intrinsiq's copper inks are a robust solution.

Intrinsiq Materials' inkjetable, low-temperature, curable nickel ink is available for key metal applications and under development is an inkjetable, low-temperature, curable silicon ink that exhibits a long shelf life and is compatible with low-temperature substrates.

http://www.intrinsiqmaterials.com/

ISORG

ISORG is the pioneering company in organic and printed electronics devices for large-area photonics and image sensors, developing a disruptive technology converting plastic, paper and glass surfaces into smart surfaces.

ISORG is a start-up company of CEA-LITEN, based in Grenoble (France).

ISORG offers a new generation of high performance, thin and flexible electronic sensors with 3D product integration capability for a large range of markets (industry, consumer electronics, environment, medical and security).

www.isorg.fr/

Johnson Laminating and Coating

Founded in 1960 in Carson, California, Johnson Laminating & Coating started out as a specialized supplier of food and custom designed packaging. Over the years, to better meet the needs of its customers, it expanded its offerings to include the manufacture of window films, silicone coating and custom laminations for the electronics industry. Today, Johnson's custom roll-to-roll laminating and coating knowledge of plastic films, foils and coated paper is used in the industrial, transportation, aerospace, electronics and graphic arts markets.

http://www.johnsonlaminating.com/

Kammann Machines

Kammann is one of the world's largest suppliers of graphic screen equipment providing precision-based print and coverting solutions for over half a century. The company is is a wholly owned subsidiary of Kamman Maschinenbau GmbH of Germany.

Kammann provides inline, roll-to-roll, printing and fabricating systems for a wide variety of organic, inorganic, metallic and nano-compounds and incorporates screen or inkjet print modules.

http://www.kammann.com

Kaneka

Kaneka Corporation is a diversified company whose products include anti-hypertensive intermediates, but also margarine and shortening. Its largest individual segment makes makes food products. But its chemicals units include both basic chemicals and plastic resins (caustic soda and sealants). Other units manufacture magnet wire, optical films, synthetic fibers, and pharmaceutical intermediates. Kaneka was among the first Japanese chemical companies to expand overseas when it launched a Belgian subsidiary in 1970, and still draws a relatively significant portion of sales from outside the country (about 19% in 2008).

The company is focusing on the development of electronics, functional plastics, and life sciences (intermediates). In 2008 it began commercial production of hybrid technology thin-film solar cells, and in 2009 decided to boost investment in this area, in response to the growing adoption of solar panels as an energy technology in the US and Europe. It also acquired Sekisui Plastics' expanded polystyrene foam business in order to meet the growing demand for the insulating material in Japanese homes as they become more energy-efficient.

In 2010 Kaneka acquired a majority stake in Eurogentec SA, a Belgian company that manufactures and markets proteins, oligonucleotides, and other biologics for biopharmaceuticals and other applications. Kaneka paid $44 million for Eurogenetec, which will operate as a consolidated subsidiary.

http://www.kaneka.com

Kimoto

Kimoto Tech, Inc. is a wholly owned subsidiary of Kimoto Co. Ltd, headquartered in Tokyo, Japan. The company's Cedartown location consists of a 110,000 square foot manufacturing facility and a second facility of 13,000 square foot for advanced measuring and analytical instrumentation — all devoted to the development and testing of new film coating products. The facilities consist of two autonomous production lines comprised of automated film and coating delivery systems that are computer-controlled coating systems and have precision drying capabilities.

The combination allows the company to undertake any film coating project, from customized formulations and products to an extensive product line for graphic arts applications. Kimoto also offers complete solution packages for today's demanding customers.

Kimoto's well-trained customer service representatives are a ready source for all order-status information and can offer invaluable aid in expediting orders when circumstances require revised delivery schedules. Additionally, technical specifications and application information is available to aid customers with unique or demanding application requirements.

http://www.kimototech.com/

KIWO

Kissel + Wolf GmbH (KIWO) is a leading manufacturer of stencil making consumables used in close-tolerance screen printing applications such as printed electronics, including photovoltaic, RFID, EL and membrane switch, and label, nameplate and graphic overlay. KIWO manufactures premium quality photopolymer direct liquid emulsions and capillary films, screen printable adhesives and chemical sundries for screen cleaning. KIWO's global scope is impressive with over 110 distributors worldwide.

www.kiwo.com/

Konarka Technologies, Inc.

Konarka Technologies, Inc., a leading developer of thin-film solar panels, has filed for bankruptcy protection under Chapter 7 of the federal bankruptcy laws. Under chapter 7 proceedings, the company's operations cease and a trustee is tasked with liquidating the company's assets for the benefit of creditors. Howard Berke, chairman, president, and CEO of Konarka, said, "Konarka has been unable to obtain additional financing, and given its current financial condition, it is unable to continue operations."

Further information about the company, including a copy of its petition in bankruptcy, is contained on Konarka's website.

http://www.konarka.com/

Konica Minolta Holdings

Konica Minolta Holdings manufactures business and industrial imaging products. Its business line includes copiers, laser printers, fax machines, and multifunction devices. Konica Minolta primarily targets production printing companies, copy service providers, and print shops. The company also makes optical devices, including lenses and LCD film; medical and graphic imaging products, such as X-ray image processing systems, color proofing systems, and X-ray film; photometers, 3-D digitizers, and other sensing products; and textile printers.

Konica Minolta was hit hard by the global economic recession that began in late 2008, with sales of its printers and office equipment impacted when businesses scaled back their spending, just as consumers also cut back their spending on consumer electronic devices that use the company's films, lenses, and other components. In response, the company announced in mid-2009 that it was reducing its fixed costs, including plans to cut back its workforce by more than 15 percent (about 6,000 positions) and reduce research and development spending.

In recent years the company has focused its product strategy on dominating certain areas in which it has a large share of the market, such as color multifunction printers, films for large LCD televisions, optical lenses for Blu-ray players, and glass hard-disk substrates. Recently, Konica Minolta has been developing OLED lighting as one of its promising new businesses.

The company announced the construction of a new roll-to-roll pilot coating line to manufacture OLED lighting within its Hino facility in Tokyo. The pilot facility, which was completed in the autumn of 2010, will work toward establishing the technology for mass production and sale of OLED lighting. In March 2007, Konica Minolta signed a strategic alliance agreement with General Electric Company of the United States to accelerate the development, with the aim of commercializing the OLED lighting.

http://konicaminolta.com/

Kovio, Inc.

Kovio Inc., a privately held Silicon Valley company, is developing a new category of semiconductor products using printed silicon electronics and thin-film technology. This new manufacturing technology combines the low cost of graphics printing with the power and functionality of silicon-based semiconductors. The company was founded in the MIT Media Laboratory by a team of scientists that recognized the significant impact that combining silicon and print technologies could have on the world.

Printed silicon electronics enables the manufacture of high-performance semiconductor devices over large areas and flexible substrates, at a fraction of the cost of conventional silicon technology. Kovio's printed electronic products and solutions have a unique and compelling value proposition in multiple industries, including retail, pharmaceuticals, consumer electronics, transportation, manufacturing, and energy.

As an alternative to today's expensive RFID solutions, Kovio leverages its printed electronics technology to make item-level RFID solutions affordable and to enhance the value of standard RFID products through added intelligence, such as displays, sensors, and other features. Furthermore, Kovio will transform conventional passive displays in the advertising, entertainment, and education markets into dynamic and interactive signage with wireless interfaces. The company also will make advances into the pharmaceutical and health care industries with printed biosensors, intelligent labeling, and other innovations.

At the core of Kovio's technology is the integration of printed silicon electronics and thin-film technology. Based on breakthroughs in nanomaterials and printing technology, Kovio has developed printable silicon-based inks and process innovations. Kovio's technology enables the fabrication of stable, high-performance, low-power integrated circuits that can operate at frequencies of MHz and above.

http://www.kovio.com/

KSW Microtec AG

KSW Microtec is a worldwide leading supplier of RFID (radio frequency identification) components for standard and special applications such as logistics and public transport, as well as for security-sensitive applications like contactless credit cards and access systems. The company's business divisions cover passive RFID, active RFID, and services.

KSW Microtec launched the thinnest flexible-temperature data logger in the market in 2009. The KSW-VarioSens temperature data logger is a semi-active RFID transponder in a label format; it measures temperature with an integrated sensor and records the data by means of a paper-thin battery. The product is able to evaluate the measured data for relevance and save only the important data. The water-repellent surface and the self-adhesive back side allow the product to be attached to individuals. The KSW-VarioSens Basic is a credit card–sized RFID label that works via wireless communication in the ISM band at 13.56 MHz, allowing for transparent access to the label, which is made tamperproof by a three-level password hierarchy.

The KSW-VarioSens Basic label enables the user to measure temperatures in a configurable measurement interval, compare them with standard values, and store related information regarding the temperature characteristics. This temperature information can be collected by an RFID reader and processed afterwards according to user need.

http://www.ksw-microtec.de/

Landa Corporation

On April 2, 2012, Landa Corporation announced the unveiling of Nanography, a new digital printing category for sheetfed and web presses. The Landa Nanographic Printing process is a technology for mainstream commercial, packaging and publishing markets (Landa Digital Printing unit operates under the umbrella of Landa Corporation). The unit focuses on developing next-generation digital technology for the printing industry.

Led by Benny Landa, who started the digital printing revolution in 1993 with the launch of the iconic Indigo digital press, the company is now set to start a new revolution in print. Landa Nanographic Printing Presses offer the versatility of digital with the qualities and speed of offset printing—at unmatched cost-per-page.

Nanographic Printing technology combines the performance of offset with the versatility of digital printing and is disruptive for mainstream commercial, packaging and publishing markets. It is expected to ignite a second revolution in print.

Nanographic Printing Presses print in up to eight colors, operate at high speeds of up to 13,000 pages per hour for sheetfed and up to 200 meters per hour for web, at 600 dpi or 1200 dpi resolution. Sheet formats span B3, B2 and B1 and web formats range from 560 to 1020 mm.

NanoInk colorants are the eco-friendly 'fuel' of Landa's innovative Nanographic Printing process.

http://landanano.com/

LG Philips LCD Co., Ltd.

In 2009, Philips sold its nearly 15 percent stake in LG Display for about €630 million (about $900 million) in order to focus on its core business. The joint venture was formed when Philips and LG Display merged their LCD businesses in 1999 to own 38 percent and 33 percent of LG Philips LCD, respectively.

LG Philips LCD had five LCD production plants in Gumi, South Korea, and an R&D center in Anyang, near Seoul. In recent years, the company has added production facilities in Paju, Korea, and Nanjing, China. LG Philips also plans to build an LCD module assembly plant in Guangzhou, China.

Today, LG is one of the world's top producers of thin-film transistor liquid-crystal displays (TFT-LCDs) for laptop and notebook computers, desktop PC monitors, television sets, and a variety of applications in automotive navigation, avionics, consumer electronics, instrumentation, and medical equipment.

http://www.lgphilips-lcd.com/

Liquavista BV

Liquavista was founded in 2006 as a spin-off of Philips Research Labs in Eindhoven, The Netherlands. The company is backed by Amadeus Capital, GIMV and Prime Technology Ventures and is headquartered in Eindhoven.

Based on the principles of electrowetting, Liquavista has developed a new type of electronic screen technology that will change the way people interact with electronic products. Liquavista's displays create bright and colorful images that ensure excellent indoor and outdoor viewability and use dramatically less battery power. Users can engage with their favorite applications for longer before a recharge is necessary and battery sizes can be reduced, allowing devices to be thinner and lighter.

The first products to use Liquavista screens will be the next generation of electronic readers. Liquavista's technology enables new types of paperlike display that will provide vastly improved usability, content compatibility, and cost compared with first-generation electronic paper technologies. Liquavista's platforms for making electronic reader displays were made available for transfer to manufacturing partners in 2009. The manufacturing process is compatible with conventional display fabrication methods and is offered as an upgrade to existing manufacturing facilities.

The company's ultimate vision is to build on the extraordinary optical performance and unique power efficiency of its technology to lead a green revolution in low power displays for notebook PCs, desktop monitors, and televisions.

http://www.liquavista.com/

Liquid X Printed Metals

Liquid X is a technology company headquartered in Pittsburgh, Pennsylvania that manufactures functional metallic inks. Its well-known technology transforms various metals into ink form which is then deposited onto a wide variety of substrates. When heated at low temperatures, the ink converts to the base metal and exhibits comparable features. Liquid X's technology allows customers to print metal traces and films that deliver results comparable to the bulk metal with better functionality.

Liquid X inks are unique because, unlike other metallic conductive inks, they contain actual metal atoms, not nanoparticles or metal flakes. The processing parameters of Liquid X metallic inks are attractive due to the low conversion temperatures and short processing times. The resulting films or traces exhibit desirable characteristics such as high conductivity, thin and precise features, and excellent adhesion. An advantage of the low temperature processing is the ability to use a wide range of substrates from fibrous materials such as paper and gauze to flexible, organic material such as plastics. In addition, low viscosity provides the opportunity for the use of a variety of deposition methods such as inkjet, slot die, flexography, offset, and gravure.

http://www.liquid-x.com/

Litrex

Litrex was founded in 2001 and is the world leader in precision ink-jet systems for electronics and color displays. The company was acquired by Cambridge Display Technology for an undisclosed amount. Litrex pioneered the Piezo Micro Deposition inkjet printing technology for precision manufacturing of the next generation of LEP colour displays and electronic devices.

CDT, which owns the fundamental Intellectual Property and know-how portfolio for LEP technology, has been leading LEP research and commercial development for applications in electronic displays and lighting. To date, inkjetting of high resolution, full-colour polymer displays has been demonstrated at the R&D level. The next step is to scale to volume manufacturing to offer a complete solution to display manufacturers. The acquisition of Litrex will allow CDT to speed inkjet technology development and promote the commercial sale of production-grade tools for inkjet printing LEP displays, which are part of the growing Organic Light Emitting Device (OLED) market.

In the flat panel display industry, Litrex's precision ink-jet systems have the advantage of dramatically reducing both manufacturing costs and processing steps. These systems are a technology enabler for polymer light-emitting diode displays in which colored light-emitting structures can be printed directly onto a variety of substrate materials.

Litrex is also currently developing a variety of additive processes to simplify the fabrication of liquid-crystal displays (LCDs), which have become very popular in laptop and computer monitor applications as well as direct-view television.

Process development is also ongoing in industries as varied as photovoltaics (solar cells), biosensors, microarrays, precision coating (including architectural glass), and RFID antenna printing. Litrex's systems have proven extremely effective as a precision coating system, creating controlled layer thicknesses from 400Å to 4µ thick. Uniform coating (±5 percent) may be achieved over very large areas. Because precision ink-jet uses a digital file, it can print selective areas so there is far less waste and no "edge bead" cleaning needed after coating. Another advantage of it being digital is that it needs no masks or plates, and "retooling" is as simple as loading a new file.

Litrex has many systems worldwide capable of printing substrates ranging from less than 200 mm and up. Litrex is located in Pleasanton, California, where it maintains its headquarters, research and development, and manufacturing facilities.

http://www.ulvac.com/

Luminous Media, Ltd.

Luminous Media (Hong Kong), Ltd. is part of LMG International, a privately owned group of companies with headquarters in Hong Kong. The company was established in 2005 and is a leading manufacturer of dynamic advertising and marketing products that use electroluminescence (EL) technology.

Luminous Media's products are manufactured in Asia under a management team of Western specialists, allowing it to produce high-quality products at a competitive price. The company distributes its products around the world and currently has representation in over 23 countries.

The company now supplies some of the biggest brands in the world with a variety of products ranging from advertising communications to lighting components for the automotive industry.

http://www.eluminousmedia.com/

MacDermid Printing

MacDermid Printing Solutions provides the printing industry with sleeves and rolls, photopolymer plates, ColorSpan inkjet printers, and other related products. The company's equipment is used to print a wide range of items, including aluminum cans, books, boxes, labels, magazines, newspapers, paper cups, and pet food bags. MacDermid Printing Solutions also serves the textile and steel industries with its sleeve and roll lineup. Its package printing line is sold directly and through partnerships like Kodak. The company operates as a subsidiary of global specialty chemical manufacturer, MacDermid.

MacDermid Printing Solutions took shape when its parent company acquired the Electronics and Printing Products Division of Hercules in 1995, and subsequently Polyfibron (formerly the Printing Products Division of W. R. Grace) in 1999. The two printing services businesses were merged and took on the MacDermid name plate.

Since then, MacDermid Printing Solutions has looked to distinguish itself in the market through a series of product roll outs. In 2009, the company introduced its fifth and sixth in a just over a year -- two photopolymer printing plates, MVP (a medium durometer plate) and Digital MVP. The MVP and Digital both tout improved press productivity, with finer resolution and imaging provided by the Digital.

http://www.macdermid.com/

MAN Roland

MAN Roland Druckmaschinen AG is the world's second largest printing systems manufacturer and the world's market leader in web offset printing.

MAN Roland operates out of Offenbach, Augsburg, and Plauen in Germany. It employs a staff of almost 9,000 and has annual sales of €1.7 billion, with an export share of 83 percent. Web and sheet-fed offset presses as well as digital printing systems are the major product lines for publishing, commercial, and packaging printing. The company's field of business ranges from small-format sheet-fed presses to production systems for newspaper printing in runs of millions.

MAN Roland is closely involved with the OE-A(Organic Electronics Association), a working group within the VDMA (German Machinery and Plant Manufacturers Association), in the field of printed electronics that focuses on printed strip conductors and structuring processes. As a technological trendsetter, the press manufacturer is active in this emerging technology at an early stage to foster development of marketable solutions.

http://www.manroland.com/

Mark Andy, Inc.

Mark Andy is a well-known brand in the traditional tag and label industry, with strong experience in narrow web flexography. Mark Andy supplies the industry with reliable, productive equipment and enjoys good profit margins. Customers rely on Mark Andy for solutions to conversion objectives, from simple/productive flexo to high-end customization.

Mark Andy makes packaging products whose shape can be readily changed. Products include roll stock, bags, pouches (flat, standup, and retort), shrink sleeves, lids, and wraps, that use paper, plastic, film, foil, metallized or coated papers and film, or any combination of these materials.

http://www.markandy.com/

MEMC Electronic Materials

MEMC Electronic Materials supplies silicon wafers to some of the world's leading semiconductor makers. The company makes wafers in sizes ranging from 100mm to 300mm in diameter. In addition to its standard prime polished wafers, MEMC makes epitaxial wafers (which have an added layer of single-crystal silicon) for advanced chips, as well as lower-grade wafers used to test chip-making equipment and production lines. The company also makes solar-grade polysilicon, which goes into making photovoltaic solar cells. Solar wafers are becoming a fast-growing product for MEMC.

In the midst of a polysilicon shortage in the solar cell industry, MEMC signed a letter of intent in 2006 to provide solar-grade silicon wafers to Motech Industries over an eight-year period. The companies expected the agreement to be worth $1.6 billion over eight years to MEMC, with Motech operating on a take-or-pay basis for the wafer supply. Motech is a Taiwanese manufacturer of solar cells, test and measurement instruments, and solar power systems. In mid-2006, however, MEMC and Motech called off their negotiations without completing a definitive agreement.

Soon thereafter, MEMC signed a definitive agreement with Suntech Power Holdings to supply solar-grade silicon wafers to Suntech for 10 years. MEMC sees the supply agreement being worth $5 billion to $6 billion over a decade. Suntech will advance funds to MEMC as an interest-free loan or a security deposit as part of the proposed deal. The wafer supplier will also get a warrant to purchase an equity stake of up to 5 percent in Suntech.

www.memc.com

Memtron Input Components

Memtron Input Components (part of Esterline Technologies) produces custom-designed input components including membrane switches, passive and active PC board–backed switches, elastomeric keypads, and touchscreen integrated panels. All of these can be developed to withstand harsh weather, altitude, chemicals, and rough handling. A Memtron device can potentially be found in any end-use application imaginable—from hospital surgical rooms to restaurants to manufacturing plant floors to oil rigs.

Operating as a business unit of parent company Esterline Corporation (NYSE: ESL), Memtron leverages 30 years of interface expertise and technology development to implement fast-turn prototypes and designs for low-cost manufacturing. Worldwide procurement abilities—strengthened through Esterline—contribute to its value proposition. Dock-to-stock supplier status, certified with ISO 9001:2000 international manufacturing standards, and a state-of-the-art 45,000-square-foot manufacturing facility all help customers balance real market needs with a measurable cost/time advantage.

Memtron is a licensed supplier of patented and proprietary technologies, including PushGate switch solutions and the low-profile, sealable ThinCoder rotary switch by DuraSwitch Industries. A flexible, dedicated-team structure and companywide commitment to customer requirements enable the company to deliver quality products that meet aggressive deadlines with minimal costs. Extensive in-house capabilities permit custom component manufacture in prototype and production quantities.

http://www.esterline.com/

Merck Millipore

In 2010 Merck acquired Millipore (now EMD Millipore), a maker of specialty separation filters and laboratory equipment used by the life science, chemical, and biotechnology industries, for €5.2 billion ($7 billion). The purchase boosted Merck's position in these high-growth segments and also helped the firm gain a greater foothold in the highly competitive US market. Following the purchase, Merck's chemical operations consist of two units, Millipore and the Performance Materials unit, which handles liquid crystal, pigment, and cosmetic ingredient manufacturing.

The German firm is ancestor to US drug giant Merck & Co., but the American firm broke away during WWI. Subsequently, the company's current North American operations can't use the Merck name; they instead operate under the name EMD, including EMD Millipore, which operates as Merck Millipore in the rest of the world. Likewise, the Merck Serono division operates as EMD Serono in the US market.

www.merckmillipore.com/

Microvision, Inc.

Microvision's patented retinal scanning display (RSD) technology uses a small, wearable projector to cast moving images directly onto the wearer's retina. These products will enable doctors to view X-rays as they perform surgery, and consumers to immerse themselves in the 3-D terrain of computer games. Microvision has demonstrated the PicoP, a full-color projection display that is small enough to be embedded into mobile phones and other handheld electronic devices. The product is based on the company's Integrated Photonics Module and incorporates green lasers developed by Corning and Novalux (now Arasor).

Microvision is expanding into commercial markets such as automotive instruments, entertainment, industrial manufacturing, medical devices, and surgical instruments. The company has development partnerships with Canon, BMW, and Volkswagen of America. Microvision is also seeking to provide product engineering services and to license its technology to manufacturers. It announced a development contract with Motorola in mid-2007 to integrate its PicoP projector into a handheld device.

Microvision began shipping its first product—the Nomad wearable display—in 2002, but continues to generate more than half of revenues through development contracts with the US government. The Nomad is used at a number of automobile dealerships, and also at military repair depots. Microvision's former subsidiary, Lumera, is developing new types of optical materials for networking applications.

Dorset Management owns nearly 6 percent of Microvision. Satellite Strategic Finance Associates holds around 5 percent of the company.

http://www.microvision.com/

Midori Mark Co., Ltd.

Since 1935, Midori Mark has been developing various products in the field of special printing through innovative products such as electroluminescent lamps, ITO touch screen panels, membrane switches, and flexible circuits, as well as transcription marks, stickers, and printing on aluminum plates.

Midori Mark's membrane switches and flexible printed circuits reduce weight and thickness and minimize the shape and volume of various electronic products. They have also been widely used for office automation machines and home appliances.

In 2004, Midori Mark began production of an electronic ink POP product with E Ink Corporation.

http://www.midorimark.co.jp/index_e.htm/

MuTracx

MuTrac^x was spun out of Océ in January 2009, the first such spin out from Océ's Inkjet Application Centre (IAC) in Eindhoven, The Netherlands. The company operates as a totally independent business with a strong relationship with Océ, which remains a shareholder.

MuTrac^x primary focus is to revolutionize and dominate the PCB inner layer production market. The company is intent on producing the first fully digital inner layer printer based on inkjet technology and has named this machine Lunaris.

Lunaris offers exceptionally high yield and productivity, providing 100% correct panels via an in-line validation process. As such, the company will provide the world's first true industrial inkjet application by digitizing the inner layer manufacturing process, replacing the current lithographic process with a simple one-step solution. This technology offers several cost advantages including improvements in yield, labor, running costs, environmental impact, and reduced complexity and lead times.

The MuTrac^x technology is the only solution in which print heads and resist are manufactured by the same vendor – Océ – because they are the most reliable and tuned for optimal performance. The result is the stable jetting of resist in the form of known drop sizes, known angles, known frequency and known timing. Subsequently, the company needs to control the flow and how the droplets interact with each other on the substrate in order to get a perfect facsimile of CAM data.

http://www.mutracx.com/index.html

Nanogap

Nanogap was formed in 2006 to commercialize proprietary technology on the production and use of novel nanoparticle materials. During this process the company has worked with customers and advisors to understand the needs of industry and the challenges involved in commercializing nanotechnology. As a result, the company is able to offer optimally dispersed materials that are custom tailored to specific requirements, ensuring maximum product performance and value. In line with this development process, Nanogap has invested in an extremely versatile production facility in fully equipped new premises. This allows the company to control and optimize product parameters such as particle size, shape and surface functionalisation and to offer products in a variety of carrier fluids, while providing production capacity to service growth and success.

Nanogap is a spin-out company from the University of Santiago de Compostela, Spain, born from the NanoMag research group, with more than twenty years experience in production and properties of nanoparticles, and more than 250 publications in scientific journals. This scientific pedigree is a key advantage for Nanogap in the marketplace as the Directors of the NanoMag research group are supported by leading scientists in the fields of materials science, energy and medicine.

http://www.nanogap.es/

NanoInk, Inc.

NanoInk, Inc. is an emerging technology company specializing in nanometer-scale manufacturing and applications development for the life science and semiconductor industries. Using Dip Pen Nanolithography (DPN), a patented and proprietary nanofabrication technology, scientists are enabled to rapidly and easily create nanoscale structures from a wide variety of materials. This low-cost and scalable technique brings sophisticated nanofabrication to the laboratory desktop.

Using its high-resolution NanoEncryption technology, the NanoGuardian division of NanoInk is able to offer pharmaceutical customers innovative solutions to fight counterfeiting and illegal diversion of blockbuster pharmaceutical products. Other key applications include nanoscale additive repair and nanoscale rapid prototyping.

Located in the new Illinois Science + Technology Park north of Chicago, NanoInk currently has over 140 patents and applications filed worldwide and has licensing agreements with Northwestern University, Stanford University, University of Strathclyde, University of Liverpool, California Institute of Technology, and the University of Illinois at Urbana-Champaign.

http://www.nanoink.net/

NanoMas Technologies, Inc.

NanoMas Technologies engages in research, development, engineering, and commercialization of nanotechnology and nanomaterials. The company offers various inks such as silver and gold nanoparticle inks, conjugated polymer inks, and polymer dielectric inks, as well as conductor and semiconductor nanocrystal inks for printable electronics. These inks are designed for applications in various technologies including flexible and flat-panel displays, RFID antennae and integrated circuits, printed circuit boards, reflective mirrors and metallic coatings, and printable solar cells. It also develops functional nanoparticulates, including silver and gold nanoparticles and decorated carbon nanotubes. In addition to inks and nanoparticulates, NanoMas provides carbon nanotubes and carbon nanofibers incorporating various physical, mechanical, electrical, and optical properties for applications in multifunctional polymer nanocomposites, biosensors and medical diagnostics, and novel drug delivery.

NanoMas Technologies products allow production of printable conductor, semiconductor, and dielectric inks for printable electronics. Printed electronics are area scalable, mechanically flexible, and manufactured in a fashion similar to that employed in the printing industry.

NanoMas Technologies, Inc., based in Endicott (Binghamton) New York, was founded in 2006 by three seasoned inventors, widely recognized as experts in the field of nanotechnology, ink development, and material science. NanoMas closed Series A financing of $2.7 million in September 2008 led by BASF Venture, Earthrise Capital (NY), and Nano Material Investors (NY). Leveraging its core nanoparticle manufacturing process, the company intends to deliver formulated products that exceed expectation in the high-growth markets of solar cell manufacturing, printed electronics, and electronics assembly.

http://www.nanomastech.com/

Nanosolar

Nanosolar makes solar panels using high-throughput thin film process technology. The technology start-up company's design and product innovations produce solar cells that can be as efficient and last as long as conventional silicon solar cells. The key part of the company's technology is that it can "print" (coat with a chemical solution) the most expensive layers of a solar cell. Founded in 2002, Nanosolar received financial backing from leading technology investors, including Benchmark Capital, Stanford University, and Mitsui & Co.

Nanosolar, which is led by technology entrepreneur Martin Roscheisen, also attracted funding from AES, The Carlyle Group, EDF Energies Nouvelles, OnPoint Technologies, and Swiss Re. The company has raised about $500 million in private equity funding.

Nanosolar is equipping factories in Silicon Valley and in Germany as it scales up for volume manufacturing of solar panels. (It shipped its first panel to a paying customer in late 2007.) In San Jose, California, Nanosolar took over a former Cisco Systems plant for its US manufacturing facility, becoming the rare Silicon Valley start-up that actually does manufacturing in Silicon Valley. (Most companies contract out their manufacturing, or place plants in lower-cost countries.) The company's European plant is located near Berlin.

According to Nanosolar, the Berlin factory is automated to sustain a production rate of one panel every 10 seconds, or an annual capacity of 640 MW when fully operational. The company also reported that NREL independently verified several of the company's CIGS cell foils to be as efficient as 16.4 percent.

http://www.nanosolar.com/

Nissan Chemical Industries

Nissan Chemical Industries, Ltd. has 120 years of history providing many unique products in a wide range of fields, from basic chemical products supporting our daily lives to electronic industrial materials that contribute to technological innovation in the IT and display industries. By communicating with its users, it intends to continue developing products that meet their high-level needs. Nissan Chemical Industries, Ltd. has annual sales of $1.5 billion and employs 1700 people worldwide.

Since its founding in 1887 as Japan's first chemical fertilizer manufacturer, Nissan Chemical Industries has grown to include a wide range of industrial and specialty chemicals, electronic materials, agrochemicals, and pharmaceuticals. Nissan Chemical's chemical products include melamine, ammonia derivatives, silica products and electronic coatings, and acids. Its smallest segment, pharmaceuticals, includes anti-hypertensive, anti-inflammatory, and lipid-lowering drugs. The company's agricultural unit makes herbicides, insecticides, and fungicides and owns the rights to sell Monsanto's Roundup brand of herbicides in Japan. Sales within its home country account for three-quarters of Nissan Chemical's business.

http://www.nissanchem.co.jp/english/index.html

NovaCentrix

NovaCentrix was founded in 1999 as Nanotechnologies, Inc. with technologies for producing nanoparticle powders and dispersions. In 2006 the name was changed to NovaCentrix to reflect its new focus on markets such as solar power and printed electronics. Today NovaCentrix ships processing tools and conductive inks, and works with clients to perfect technologies and processes for printed electronics manufacturing, all while retaining the capabilities for advanced nanoparticle production.

NovaCentrix has focused considerable effort on the development of commercial-scale production of high-performance nanopowders from essentially any conductive material. The company has leveraged its proprietary pulsed-plasma synthesis process to offer the industry a unique combination of high performance and yet economical control of metal nanoparticles ranging from as small as 10nm to 100nm. The company also produces a select range of high-performance nanoscale oxides, such as iron oxide and niobium pentoxide.

The PulseForge family of tools sinter or anneal thin-film materials in only milliseconds, and are able to do so on a wide variety of substrates, including low-temperature, flexible materials. These tools are intended for product innovators and manufacturers in printed electronics who need alternatives to traditional materials and processing techniques. The use of PulseForge tools can save time and money, and enable new types of products in applications like solar, RFID, displays, smart packaging, and even flexible circuits.

http://www.novacentrix.com/

Novaled AG

Novaled AG is a world-class technology provider in organic light-emitting diode (OLED) technologies based in Dresden, Germany. It has been in operation since March 2003. The company has developed into a leading technology provider of intellectual property for the OLED industry and has attained the world record in power efficiency.

Novaled's PIN OLEDs are especially suited for the next generation of portable displays. In particular, the company's market applications are well suited for automotive controls and instruments, consumer electronics, digital entertainment, digital photography and imaging, and architectural lighting.

Novaled is a key player in European OLED projects and a member of a worldwide network of display and lighting organizations. Together with the Dresden University of Technology and the Fraunhofer Society, Dresden, Novaled has developed a unique OLED Competency Center and formed an industrial cooperation arrangement with Ciba Specialty Chemicals. The latter produces the unique organic dopant and transport materials developed by Novaled. In contrast to conventional OLED, Novaled's hole and electron transport as well as charge carrier injection are dramatically enhanced, eliminating additional process steps such as ITO treatment.

Novaled's IP portfolio covers several key areas such as:

- Novel use of organic materials for doping
- New materials for doping
- Novaled PIN structure
- Outcoupling
- Transparent OLEDs

http://www.novaled.com/

Novalia

Founded in 2004, Novalia is an early-stage company with considerable experience in the growing printed electronics industry. The company uses its knowledge of conventional printing to integrate conductive inks with other existing print processes. The conductive inks enable touch-sensitive input and light/sound output.

Novalia claims to have developed a “printed electronics control module” consisting of a power source, an integrated circuit (I/O control and interaction flow), and a sound transducer. Its IPM enables communication between the printed item and the user; the direction the dialogue takes depends on each experience—essentially “what you get out depends on what you put in.”

To date, Novalia has teamed up with Blue Spark to develop interactive PE projects. The company is located in the Cambridge Science Park, United Kingdom.

http://www.novalia.co.uk/

NRG Solar

NRG Solar is one of the nation's largest developers of solar power. The company claims to be a Fortune 500 company that is headquartered in Princeton, New Jersey and owns and operates one of the country's largest and most diverse power generation portfolios. From large-scale solar generating facilities to installations on commerce rooftops. NRG Solar states it has more than 2,000 megawatts (MW) of projects under development or construction.

www.nrgsolar.com/

NXT PLC

NXT is a provider of unique sound and touch screen solutions and is best known for its flat panel loudspeaker technology. The company has its origins in the world-renowned British audio industry and is responsible for the development of the distributed mode loudspeaker (DML), an award-winning audio technology that can be applied across numerous industries to create highly differentiated products and solutions.

NXT is a public company traded on the London Stock Exchange. The company is headquartered in Huntingdon, United Kingdom, and has sales offices in Hong Kong, Japan, and the United States, with additional sales staff based in Korea and central Europe. NXT has licensed its technology for over 100 products or solutions to more than 250 companies, including Philips, NEC, LG, Kensington, Logitech, Oregon Scientific, Toshiba, and Kenwood.

NXT's technologies are unique and based on harnessing the natural modes of vibration in a panel to reproduce sound. These technologies are derived from a profound understanding of bending wave physics and its applications to sound generation. NXT's fundamental technologies are the distributed mode loudspeaker and the audio full range (AFR) loudspeaker. Common to both technologies is the ability to control and manipulate the natural modes of a panel speaker system. DML provides techniques to turn a panel of almost any shape or size into a loudspeaker, while AFR confers specific solutions for circular panels.

Quite separately, and as a result of the company's core knowledge, NXT invented a unique touch screen technology using bending waves. This technology has been exclusively licensed to 3M and is known commercially as dispersive signal technology (DST).

http://www.nxtsound.com/

Ohio Gravure Technologies

Ohio Gravure Technologies Inc, formerly Daetwyler R&D Corp, is an Engineering R&D and Software Development company that makes precision equipment and software for the gravure printing industry. Ohio Gravure Technologies Inc is a member of the Heliograph Holding GmbH (formed January 2009).

Ohio Gravure Technologies is leveraging its industry leadership for the printed electronics market with its MicroStar MicroEngraving System and AccuPress MicroGravure Printer which can hold accuracies as tight as 5µm. The MicroStar system, unlike laser engraving and etching, provides low roughness inside the cell, variable cell shapes and depths, and screenless cell placement, all with a single cut. The award-winning AccuPress system, with layer to layer registration accuracy below 5 microns, will soon be available with a light-curing and roll-to-roll addition.

http://www.daetwyler-rd.com/

Optomec

Optomec is a leader in delivering additive manufacturing solutions for high-performance applications in the electronics, biomedical, aerospace, and defense markets.

Additive manufacturing is a breakthrough technology that enables functional end products or product features to be grown from powdered materials in a layer-wise manner. The approach is inherently more efficient and flexible than traditional subtractive manufacturing methods, and the benefits are compelling in terms of reduced manufacturing and material costs, reduced process time, and improved product performance. Further, additive manufacturing enables the realization of next-generation product designs at virtually any scale.

Optomec's commercial LENS and Aerosol Jet systems use its proprietary additive manufacturing technologies to deliver cost-effective development, production, and repair of a wide range of end products. Today, LENS systems are fabricating and repairing high-value metal components from aircraft engine parts to medical implants. At the nano- and microscales, Aerosol Jet systems are being used to produce high-density circuitry, embedded components, and an array of biomedical devices.

Optomec is a privately held company founded in 1982, with corporate headquarters located in Albuquerque, New Mexico, and a recently expanded applications facility in Saint Paul, Minnesota. Its customers include many internationally recognized entities in industry, academia, and government.

http://www.optomec.com/

ORFID

Orfid is a online resource for organic electronics professionals, investors and entrepreneurs. The site offers organic electronics news and other organic electronics manufacturing resources. Organic electronics is defined as electronics that deals with conductive polymers, plastics, or small molecules. In polymer based organic electronics the polymers and small molecules are carbon-based much like the molecules of living things. Organic electronics examples include: plastic solor cells, organic semiconductors, dielectrics, conductors and organic light emitters including light-emitting diodes used in high-definition televisions.

ORFID was founded in 2003 as a combined corporate and academic spin-off by Convergent Ventures (a Los Angeles-based venture investment and development company), Precision Dynamics Corporation (a Los Angeles-based, privately held manufacturer of RFID devices for personal identification), and Dr. Yang Yang, a leading expert in organic electronics and Professor of Engineering and Materials Science at the University of California, Los Angeles.

http://www.orfid.com/

Ormecon GmbH

Ormecon GmbH was originally founded as Ormecon Chemie GmbH & Co. KG in 1996, as a subsidiary of Zipperling Kessler, with the goal of commercializing products based on the organic metal nanotechnology known as ORMECON.

The first products to be introduced were ORMECON CSN for final solderable surface finishes on printed circuit boards and other organic metal nanotechnology-based products and processes, like CORRPASSIV. Later, dispersion processes for inorganic electroluminescence, OLED hole injection layer deposition, and ITO replacement were developed. Since then, Nanofinish (a trademark owned by Ormecon/Enthone), a nanotechnology PCB surface finish, has been launched.

Ormecon started in 1996 with seven employees; by late 2008 the company, at that point known as Ormecon International, had around 60 employees, working in marketing, sales, product management, production (of the organic metal itself and various dispersions), research, development, and quality assurance.

In 2006, a wholly owned subsidiary (Ormecon China) was established with 4 employees, growing to 12 employees by 2008. A PCB surface finish subcontracting business was established in Shenzhen (Shajing), China.

The most recent step in the company's history was the acquisition in 2009 of Ormecon International by Enthone, a CooksonElectronics division. Product development is mainly focused on additional new PCB surface finish processes, electroluminescence, EMI shielding, energy recovery and storage, OLEDs, and polymer electronics.

http://www.zipperling.de/

Ormet Circuits, Inc.

Ormet Circuits, Inc. was incorporated in 2003 to manufacture and market conductive pastes and inks for the printed circuit board fabrication and microelectronics industries. The company occupies an 18,000-square-foot facility in San Diego that had previously been Honeywell Incorporated's Advanced Polymer Operation.

Ormet materials provide high electrical and thermal conductivity, good solderability, adhesion to most substrates, and low curing temperatures. During cure, Ormet ink becomes a fused metal network that alloys itself to conventional circuit materials. The metal network is permeated by a polymer that adheres to the substrate, providing mechanical reinforcement. These properties represent the patented composition of Ormet's ink products.

Applications for use are in the connection of copper layer pads in the *z* plane and in filling plated vias for thermal transfer of heat away from silicon.

http://www.ormetcircuits.com/

OSRAM GmbH

OSRAM is one of the two leading lighting manufacturers in the world. This global company, with headquarters in Munich, employs more than 35,000 people throughout the world. Through a joint venture with Valeo, OSRAM makes headlight and taillight assemblies that are distributed in North America. The company also makes lamp-related products (ballasts, fixtures), as well as light-emitting diodes (LEDs). Another OSRAM unit produces lighting components, such as glass, metals, and wiring. OSRAM supplies customers in about 150 countries and manufactures at 49 sites in 18 countries. In late 2012 Siemens announced it was spinning off OSRAM.

OSRAM continues to see growth opportunities in the global trend toward solid-state lighting (LEDs) and opto-semiconductor light sources. The company purchased Germany-based Siteco Lighting from Barclays Private Equity in mid-2011. The addition not only gives OSRAM expose to new markets, such as sports stadiums, but expands the company's LED capabilities. In 2009 OSRAM was first to launch an LED lamp equivalent to the 40-watt light bulb. It also benefits from a strong position in the high-growth Asia/Pacific region. Through a joint venture with Hong Kong's Traxon Technologies, OSRAM has expanded its geographic footprint to offer its LED lineup used by the architectural, hospitality, and shop lighting market sectors.

Some of OSRAM's R&D activities take place in the Special Products Division, which trades under the name of Precision Materials & Components (PM&C) at its US subsidiary. The company develops components needed to produce lamps, such as glass, wire, metals, and phosphors—most of which are destined for OSRAM factories throughout the world—and also creates semi-finished products that are not intended for lamp manufacture but for other sectors of industry, notably materials and components for the chemical, machine tool, automotive, and electrical industries.

http://www.osram.com/osram_com/

PARC

Palo Alto Research Center (PARC) has been a global center for commercial innovation for 40 years and a pioneer in the development and commercialization of thin film transistors, circuits, and sensors. With deep knowledge of printing technology applied in domains such as displays, image sensors, and medical sensors, PARC's technical expertise and facility support printed dielectrics, nanoparticle metals, and organic, oxide, and silicon (amorphous, polycrystalline, and printed nanowire) semiconductors. PARC's clients include display manufacturers, consumer electronics firms, IT companies, government agencies, and materials suppliers to the printed electronics market.

PARC offers three unique capabilities to industry partners:

- *Material Characterization:* Characterizing and optimizing material performance in devices and circuits for printed electronics market materials suppliers
- *Application Development:* Designing circuits and fabricating proof of concept, including sensors and display elements for clients exploring specific applications
- *Full System Prototyping:* Integrating complete systems containing printed electronics and conventional thin-film components and/or standard silicon circuitry

http://www.parc.com/

Parelec

G & W RFID, LLC acquired the assets of Parelec, Inc. on August 1, 2008, including the registered names "Parelec" and "Parmod." The new company, G & W RFID, is developing and marketing conductive polymer (inks) technologies utilizing the combined intellectual property of the two companies, which consists of 33 international patents and applications. The conductive inks and pastes are ideally suited for RFID inlets used in smart cards and labels, tickets, flexible circuits, and membrane switches, and in high-density applications such as chip-scale packaging. The two key products defined in the patents are Parmod and PrintTrack.

Parmod is defined as an 80 percent silver-based fast-curing conductive ink that yields a virtually continuous pure metal circuit trace or wire. PrintTrack is defined as electrical devices on paper and corrugated packaging that employ printing with Parmod conductive inks. The inks are cured to form a circuit with highly conductive metal traces and the electrical device (microchip) is attached with adhesive.

G & W RFID is positioned to provide the best and most affordable RFID solutions in the business. It can make RFID tags that are considerably less expensive, easier to produce, easier to install, more environmentally friendly, and with better performance than other tags on the market today.

http://www.parelec.com/

PChem

PChem is an innovative materials provider of silver nanoparticle based inks and printed product to the rapidly growing printed electronics market. Its technology, when compared to incumbent and competing printed electronics technology, provides higher conductivity; can be applied at lower temperatures on flexible substrates, including plastic and paper; and enables significantly lower production costs through faster, energy-efficient processing and significantly less precious metal ink consumption.

PChem's novel silver nanoparticle conductive inks can be used as the top electrode of a photovoltaic system (represents approxiimately 2/3 manufacturing cost of the system) in organic photovoltaics, thin-film, and Si-wafer solar power systems. Compared to incumbent material, PChem technology is more cost effective (up to 67% less expensive), environmentally friendly, water based and lower-input processing at commercial volumes, and superior in its conductivity and flexibility, enabling more robust and efficient solar cells.

Due to the inherent advantages listed above, PChem's technology enables novel new applications in smart packaging, including sensors and interactive pharmaceutical packaging. In the area of lighting, PChem's technology can greatly enhance the commercial viability of organic light emitting diode (OLED) and other lighting solutions and accelerate the growth of vast new commercial and consumer markets. Compared to incumbent material used in OLED lighting, PChem technology is more cost effective and able to be processed in large format, superior in its conductivity and flexibility, enabling more efficient and brighter lights.

In the market for consumer electronic devices, simple consumer electronic devices like small promotional toys for children and interactive games can be enabled by PChem's technology. "Extreme" volumes in the billions can be made economically feasible because of PChem's technology, which enables printing on inexpensive packaging substrates, cost effective products that are durable and can stand up to extreme handling, and electromagnetic Interference/Radio Frequency (EMI/RF) Shielding:

The highly conductive films possible using PChem's inks can greatly enhance the EMI/RF shielding effectiveness (SE) of even very thin films. In cases where very high SE is required, PChem's technology can enable significant cost savings because as much as 75-90% less raw material (i.e., silver) can be applied in order to achieve the same SE as a polymer thick-film (PTF) ink. Where less SE is required, or where transparent conductive films (TCF) can be used for shielding, PChem's printed TCF again enables significant cost savings as it uses less raw material. In addition, PChem's TCF are more flexible and generally have higher optical transparency. Compared to incumbent material, PChem's technology enables a significant cost advantage on flexible, highly transparent, and highly conductive films for a number of shielding applications.

http://nanopchem.com/

PixDro BV

PixDro is a product development company specializing in the research and development of industrial ink-jet applications and the manufacture of advanced ink-jet systems for research and industry. Its experience in the ink-jet market has resulted in various innovative technologies and products.

The company's products consist of printing modules embedded in a system architecture, allowing PixDro to customize systems to the various requirements of process and application.

As part of the OTB-Group, PixDro offers complete printing solutions, including pre- and postprocessing. If necessary, it will cooperate with other system/print head providers to supply customers with the optimal system.

http://www.pixdro.com/

Plastic Logic

Plastic Logic develops semiconductor production technology based on processes similar to those found in commercial ink-jet printing. The technology is meant to enable chip makers to produce semiconductors and flat-panel displays by layering flexible films of polymers one on top of the other. Plastic Logic touts its technology as cheaper than standard lithography-based chip production. The company's investors include Amadeus Capital Partners, Bank of America, BASF, Dow Chemical, Intel, Oak Investment Partners, and Siemens. Plastic Logic was spun off from Cambridge University's Cavendish Laboratory in 2000.

The company has raised more than $200 million in private equity funding. It preserves its research and development in Cambridge, England, its executive management, product engineering, sales, and marketing headquarters in Mountain View, California, and a $100 million manufacturing facility in Dresden, Germany. Funding for the start-up plant came in 2007 from new and existing investors. The facility is gearing up to fabricate display modules for portable electronic reader devices. The devices will enable consumers to read books and publications without using a cell phone, PC, or PDA.

In September 2012, Plastic Logic unveiled a new 10.7 inch reflective flexible colour display that enhances the content viewing experience while maintaining the same durable, thin, and light properties of the monochrome version. To this end, Plastic Logic has restructured its business and is focusing on licensing its technology to other companies. This is a diversion from its ill-fated attempts at reaching the consumer market with the QUE e-Reader and its most recent offering geared towards the Russian educational system.

http://www.plasticlogic.com/

Plextronics

Plextronics, Inc. is an international technology company that specializes in printed solar, lighting, and other electronics. Headquartered in Pittsburgh, Pennsylvania, the company's focus is on organic solar cell and OLED (organic light-emitting diode) lighting, specifically the conductive inks and process technologies that enable those and other similar applications.

Particularly relevant as the worldwide search for renewable energy becomes more urgent, the company's technology will enable the mass production of printed devices, such as low-cost organic solar cells and high-efficiency lighting.

With a company vision of enabling 15 billion printed electronic devices by 2015, Plextronics is creating technology capable of commercial-scale manufacturability and performance. The company's device design, process technology, and Plexcore branded inks enable the formation of active electrical layers—the key drivers of printed electronics.

The company's three main product categories are Plexcore OC (organic conductive inks), Plexcore OS (organic semiconductive polymers), and Plexcore PV (organic photovoltaic ink systems).

Plextronics is a privately held company with select partners and strategic corporate and venture investors. Some of the country's most prominent venture capital firms in the light, power, and circuitry markets have invested in the company. Plextronics has also teamed up with multinational companies in joint development agreements, strategic alliances, and research partnerships.

The company was founded in 2002 as a spin-off from Carnegie Mellon University, based upon conductive polymer technology developed by Dr. Richard McCullough. Over the past six years, Plextronics' scientists have refined and further developed this technology to deliver exceptional performance for printed electronics.

http://www.plextronics.com/

PolyIC GmbH & Co. KG

PolyIC develops technology for making integrated circuits (ICs) that are printed on flexible polymer films rather than etched into traditional rigid wafers of silicon. Flexible microchips stand to have many applications, for example in radio frequency identification (RFID) chips used to track goods in transit. If PolyIC meets its stated goal, it will develop equipment that makes it as easy to print semiconductors as it is to print newspapers today. The company was formed late in 2003 as a joint venture between industrial titan Siemens and printing and stamping specialty company Leonhard Kurz GmbH & Co. KG and is located in Fuerth, Bavaria (Germany).

PolyIC develops and markets products based on the platform technology printed electronics for several applications.

Touch Sensors & Passive Devices: Touch sensors based on the PolyTC technology offer transparent, conductive and flexible possibilities for touch screens and capacitive keys in any variants. Furthermore, this technology enables the setup of flexible circuit structures as passive devices for a huge variety of further applications. The highlight is the possibility to combine decoration and function to achieve a maximum of design flexibility.

Printed Electronics & Displays: Printed smart objects concerning the PolyLogo product line offer interesting possibilities such as radio activated displays in the field of marketing. Printed RFIDs with the brand name PolyID enable thin and flexible applications of radio detection. In the future Organic Photovoltaics (OPV) will make energy harvesting possible.

PolyIC focuses on its expertise in materials, new adapted chip design methods as well as mature and newly developed mass production processes of roll-to-roll printing in order to develop and market this new technology.

In June, 2012, PolyIC announced that its PolyTC film proximity switches were being used in home lighting manufactured by Occhio GmbH. The lights are controlled using simple, intuitive hand gestures without needing to touch the lamps. The light can be dimmed or brightened by moving your hand in the proximity of the lamp head. A quicker hand gesture near the lamp head switches the lamp on or off. PolyTC film is integrated in the lamp head lenses and acts as a sensor for gesture-based controls. Using the proximity effect, approaching hands are detected and the movement translated into the appropriate command.

The ìo 3d lamps can be obtained from specialist shops. Occhio is one of the most successful lighting products of recent years. This multifunctional and modular system is unique in the lighting market.

http://www.polyic.com/

Poly-Ink

Poly-Ink is a start-up that was born as a result of the meeting between a young research engineer graduated from the National Polytechnic Institute of Grenoble (INPG - France) and an entrepreneur who in 1987 created a company specializing in inkjet and laser cartridge recycling.

The company has developed and patented a family of products, inks and primer, using the inkjet printing technology as process and carbon nanotubes as conductive fillers. The properties of the primer proposed by Poly-Ink enables the printing of conductive inks on all kinds of substrates (paper, polymer film, etc).

http://www.poly-ink.fr/en/

Power Paper, Ltd.

Founded in 1997, Power Paper, Ltd. is the creator and licensor of printable microelectronic clean technology and patches. Power Paper's printable batteries provide a fully printable, integrable, and disposable power source. They also have a long shelf life and deliver superior electrical performance due to their overall structure and efficient active inks. In addition, Power Paper printable batteries are comparatively less expensive.

Power Paper pioneered the industry's first printable thin and flexible batteries over 10 years ago, and today its competitive IP and know-how has powered products of the world's leading brands in cosmetic patches, RFID tags, consumer electronics, pharmaceutical applications, and industrial applications.

Investors, led by Infinity Group, include Apax Partners, Amadeus Capital Partners, and Bank of America Capital Partners.

http://www.powerpaper.com/

PragmatIC Printing

In 2010, PragmatIC Printing acquired the printed electronics business of Nano ePrint, including its patented technology for planar nano-electronic devices that can be fabricated uniquely in a single layer of semiconductor via single-step imprint patterning. PragmatIC has extended this proven imprinting process to conventional thin-film transistor designs and a variety of self-aligned structures. This approach allows a full range of device and circuit architectures to be printed in transparent, flexible semiconductors at micron and sub-micron scale.

PragmatIC's technology is able to print electronic logic at very high speeds while dramatically reducing circuit size and simplifying manufacture, thereby opening up prospects for low-cost, high-performance printed electronics across a range of applications.

PragmatIC's imprint process combines the benefits of a simple roll-to-roll compatible printing method with a proven ability to achieve both micron & sub-micron scale features with high yield. PragmatIC has therefore developed and patented a range of planar and self-aligned device architectures that dramatically simplify manufacturing by reducing the number of process steps and eliminating or minimizing registration requirements.

In July, 2012, PragmatIC Printing Ltd and ITW Foils and Thermal Films Group, a group of businesses which are a part of Illinois Tool Works Inc., announced a licensing agreement enabling ITW to develop and sell novel printed electronics solutions incorporating PragmatIC's unique technology. ITW will also join the collaborative PragmatIC Pilot Production Program (P4) as an integrator, working with PragmatIC's other partners to ensure a complete and scalable supply chain for these solutions.

http://www.pragmaticprinting.com/

Preco, Inc.

Preco, Inc. began as Gramling Tool and Die Company, founded in 1956 by tool and die maker G.T. (Bill) Gramling. The company originally supplied dies and fixtures primarily to the gasket industry. The company grew over the next 20 years to be one of the most successful tool and die companies in the Midwest. Projects included providing dies and fixtures for the largest vending machine manufacturer at the time, special machines such as a spiral handrail tubing bender for government projects, and the first "fibrillator," a machine that turned extruded plastic film into fiber that could be spun. This spun fiber resulted in outdoor carpet, first developed by the Gulf Oil Research Center in 1968.

Over time, Gramling Tool and Die applied the same processes they used to develop machines in their core markets to other industries. This resulted in the development of the first "Preco-style" press/die, specifically designed to run on presses as an integral part of processing for the printing industry.

Gramling was purchased in 1976, changing the name to Preco Industries, Inc. The company was known at that time as a hydraulic die cutting press manufacturer. Then, fiber optic photocell capabilities enabled registration of imaged materials to a die, and CCD machine vision systems soon allowed registration in three axes simultaneously.

Preco Laser Systems, LLC (then Laser Machining, Inc.) was founded in 1978 and later acquired by Preco Industries, Inc. A key player driving advancement of industrial laser technology to solve problems not achievable with conventional processing, the company built expertise in laser systems design, manufacturing, and laser contract manufacturing services benefiting customers worldwide.

Today, Preco, Inc. is the result of the strategic merger between Preco Industries, Inc., a premier provider of advanced die cutting and screen printing equipment, and Preco Laser Systems, LLC, a proven technology leader in industrial laser systems and contract manufacturing services (CMS). For its customers, it means even more material handling options and knowledge to help select the best processing options.

Preco is a leading manufacturer of die cutting, screen printing and laser systems for materials processing. With years of technical capability in precision processing systems, the merger resulted in an enhanced and broadened range of material processing services offered, from engineering expertise in freestanding and inline systems, to thoughtful collaboration with customers for optimal solutions as well as Contract Manufacturing Services.

http://www.precoinc.com/

Printcolor Screen Ltd.

Printcolor Screen Ltd. has established itself as a market leader in technologically advanced solutions for screen, pad and digital inks. The company covers a wide range of applications in the screen printing industry including UV-curable inks, water based inks, and solvent based inks and high solid inks. Beyond the traditional silk-screen printing industry, Printcolor Screen can provide customers with specialized and technically advanced products for specific industrial printing and coating needs.

Printcolor Screen Ltd. also offers high-quality pad transfer printing inks that are solvent based, 2 Component and now even UV curable. Its 700 series of pad printing inks are loaded with maximum pigment levels to provide high-opaque printing results and the majority of these products have been developed according to the demands and needs of this specialized industrial sector. The “universal use” nature of these pad printing inks allows the end-user a great deal of flexibility covering many substrates with just a few inks.

Printcolor Screen Ltd. produces UV-curable inks for the flexographic printing sector, which are well suited for the UV printing of many plastic substrates. In addition to UV flexo inks, we also produce UV-curable clear and over-coating varnishes and specialized primers.

Printcolor Screen has special digital ink systems for many types of printers and print heads (inkjet applications) for high-quality printing applications. These digital inks are produced in both solvent based and UV curing technology. The company also specializes in primers and protection varnishes which enable its clients to significantly increase the range of application and use possibilities, by providing a full spectrum of consumable inkjet goods.

http://en.printcolor.ch/

Printechnologics

Printechnologics is a leading technology developer in printed functionalities, creating electronic systems produced entirely by a common printer. Printechnologics introduced its first commercially viable product – Touchcode, an electronic data tag – in 2010. Touchcode technology can be integrated into any printable material, and is completely recyclable, invisible and flexible. Furthering the evolution of printed paper, Printechnologics ensures that every kind of printed product, from advertising leaflets to labels and forgery-proof packaging, is ready for the digital age. These first production products have the potential to inspire a series of inventions that will change everyday life.

Printlogic creates products with the ability to print on paper and foils. It uses an inexpensive and environmentally friendly technology that is flexible, cheap, nontoxic and recyclable. The printing process is amazingly easy and uses inexpensive machinery. Its leading product, Touchcode, is an invisible electronic data tag that can be printed on nearly any surface – including paper, carton or foil – to establish a link between online and offline communications. In order to activate the data, a user simply needs a touchscreen smartphone or tablet and the app that correlates with the printed material. Placing the document – in this case, a card – on the device's screen will automatically trigger the device to access and play the coordinating content.

In 2011, more than 25 million of Printechnologics' Touchcode cards were produced, and company founder and CEO Sascha Voigt estimated that Printechnologics would produce more than 100 million that year for major brands ranging from ICON magazine, iSupergol and Nukotoys.

On October 15, 2012, Touchcode was recognized in the Wall Street Journal's Technology Innovation Awards, which honors outstanding technological breakthroughs and innovations. The Germany-based company was a "Gold Winner" for being considered the most innovative solution. In addition, Touchcode won the "Wireless" category for enabling a seamless connection between off- and online content.

Printechnologics has been a 3M New Venture Company since 2010.
http://www.printechnologics.com/

QUALCOMM MEMS Technologies

QUALCOMM MEMS Technologies, Inc. (QMT) has developed the industry's first MEMS display for mobile devices—a true technological innovation that offers low power consumption and superb viewing quality in a wide range of environmental conditions, including bright sunlight. The display works by reflecting light so that specific wavelengths interfere with each other to create color. The phenomenon that makes a butterfly's wings shimmer is the same process used in QUALCOMM's mirasol displays. QUALCOMM MEMS Technologies, Inc. supports QUALCOMM's overall strategy of increasing the capabilities of mobile devices while minimizing power consumption.

QUALCOMM MEMS Technologies, Inc. is a wholly owned subsidiary of QUALCOMM, Inc. and is headquartered in San Diego, California, with offices in San Jose, California, Taoyuan, Taiwan, and Hsin-chu, Taiwan.

http://www.qualcomm.com/qmt/

ReneSola, Ltd.

Through its main operating subsidiary in China, Zhejiang Yuhui Solar Energy Source Co., Ltd., ReneSola makes silicon-based ingots and wafers that go into producing photovoltaic solar cells and modules. ReneSola's customers include JA Solar, Motech Industries, Solarfun Power, Suntech Power, and Topco Technologies. The company grows silicon ingots in its own furnaces, using raw feedstock or scrap polysilicon, then saws those ingots into wafers for manufacturing solar cells. ReneSola gets most of its revenues from Asian customers, with China alone accounting for more than 60 percent of sales.

ReneSola used proceeds from its stock offering in the United States to expand its solar wafer manufacturing facilities and to purchase additional wafer-making equipment. It also used proceeds to invest in its polysilicon manufacturing capabilities, to pay for raw materials, and for general corporate purposes.

Solar-grade silicon wafers provide about 90 percent of ReneSola's sales. The company ceased producing solar cells and modules in early 2006 to focus on the solar wafer market.

In 2007 ReneSola bought a 49 percent interest in Linzhou Zhongsheng Semiconductor Silicon Material Co., Ltd., a polysilicon manufacturer in Henan Province, China. Linzhou Zhongsheng Steel Co., Ltd. holds the majority ownership in Linzhou Zhongsheng Semiconductor. Also in 2007 ReneSola established a wholly owned subsidiary in Sichuan Province, Sichuan ReneSola Silicon Material Co., Ltd., to produce raw materials for wafer manufacturing.

In late 2008 ReneSola sold its interest in Linzhou Zhongsheng Semiconductor Silicon Material to Linzhou Zhongsheng Steel for about $6 million in cash and nearly $23 million in cash or credit for polysilicon.

www.renesola.com/

Roth & Rau AG

Roth & Rau provides production lines and equipment for the manufacturing of solar cells and films. The company primarily focuses on making plasma process equipment (for coating, modifying, and structuring surfaces). Roth & Rau serves customers such as businesses in the semiconductor and automotive sectors, research institutes and universities, and research and development departments in a variety of industries, including health care and textiles. Roth & Rau distributes its products around the globe.

www.roth-rau.de/

Samsung Electronics Co., Ltd.

Samsung Electronics is one of the world's largest semiconductor manufacturers and South Korea's top electronics company. It makes many kinds of consumer devices, including DVD players, big-screen TV sets, and digital still cameras; computers, color monitors, LCD panels, and printers; semiconductors such as DRAMs, static RAMs, flash memory, display drivers, MP3 player chips; and communications devices ranging from wireless phones to networking switches. The company, which is the flagship member of Samsung Group, also makes microwave ovens, refrigerators, air conditioners, and washing machines.

Samsung is coping with the economic downturn by plowing $1 billion into the Chinese market and cutting non-R&D spending. More than a quarter of all Samsung employees are involved in R&D activities, and the company spends an average of about 9 percent of sales on R&D. Over the long term, the company is looking to grow in key product areas: color laser and multifunction printers, notebook PCs, and commercial air conditioners. Samsung is also expanding its B2B (business to business) distribution channels and global sales networks, as it aims to be the top global brand in every sector of consumer electronics.

In July 2009 the company and LG Electronics entered into a joint venture to develop core digital television chips, which have been imported in the past. LG Electronics will design the chips and Samsung will manufacture and test the end product. Once the chips are commercialized, both companies forecast a savings in import costs as well as an export profit.

Samsung is one of the few Asian chip makers to have built a wafer fabrication plant, or fab, in the United States. The company picked Austin, Texas, as the site of its first wafer fab outside of South Korea in 1996, and Samsung Austin Semiconductor began production for customers at its fab in 1998. The parent company later implemented a $500 million upgrade for the facility. In 2005 Samsung chose Austin as the site of a new semiconductor plant, one that produces chips on silicon wafers measuring 300mm (approximately 12 inches) across. That decision was officially confirmed in 2006. Construction of the new facility cost around $220 million, and equipping the fab cost $3 billion.

http://www.samsung.com/

Schreiner PrinTronics

Schreiner PrinTronics is a printed electronics company that develops and produces innovative film, sheet and foil systems with integrated electronic functionalities such as lighting, switching, conducting, measuring, and displaying.

Schreiner PrinTronics has developed special antenna technology in a newly developed RFID label that achieves a range of four meters despite its small dimensions. As a result, it is superbly suited for marking metal or carbon assembly parts and components as well as loading aids, metal containers and cage pallets.

Schreiner PrinTronics is one of several companies that are part of the Schreiner Group that is headquartered in Germany.

http://www.schreiner-printronics.com/

Seiko Epson

Seiko Epson, also referred to as just Epson, is a manufacturing arm of the Seiko Group, the internationally known watchmaker. The company is a top printer manufacturer, producing dot-matrix, inkjet, laser, and thermal printers, as well as printer components. Its product portfolio also includes projectors, scanners, and personal computers; electronic devices and components, including semiconductors and LCDs; and precision products such as lenses and factory automation equipment. Other Seiko Group companies include Seiko Holdings and Seiko Instruments.

With facilities in more than 40 countries, the company markets its products worldwide. It has regional headquarters in China, the Netherlands, Singapore, and the United States.

The company's electronic devices segment (about a quarter of sales) encompasses LCDs and semiconductors. Seiko Epson offers displays through its Epson Imaging Devices subsidiary, which produces displays for mobile phones, automobiles, and industrial applications. The company's semiconductor products include application-specific ICs, controllers, LCD drivers, and microcomputers. Its Epson Toyocom subsidiary develops quartz optical, sensing, and timing devices. In 2009 Seiko Epson agreed to transfer assets relating to small and medium-sized TFT-LCDs to Sony. Such LCDs are used in small electronics such as cell phones and cameras.

http://www.epson.com/

Semprius

Semprius, Inc. is commercializing a novel process for printing high-performance semiconductors on any substrate, including glass, plastic, and other semiconductor materials. Initial applications of the technology include solar modules, LCD and OLED displays, and advanced disk drives.

Semprius delivers a unique high concentration photovoltaic (HCPV) module design that begins with its proprietary micro-transfer printing process. This process enables Semprius to use the world's smallest solar cell - approximately the size of a pencil point - to create solar modules with unmatched costs and performance advantages. In 2012, Semprius set a new world record for photovoltaic module efficiency, reaching 33.9 percent.

Semprius is also licensing its micro-transfer printing technology for nonsolar applications to enable a wide variety of new products requiring large-area, thin, lightweight form factors, unprecedented performance, high reliability, and low cost. Applications include flat panel displays, flexible electronics, large-area sensors, RF devices, and other applications requiring heterogeneous integration of high-performance semiconductors.

http://www.semprius.com/

Sensormatic

Sensormatic is a division of Tyco Fire & Security. It has been estimated that nearly 80 percent of the world's top 200 retailers rely on the company's visible and concealed antitheft system products as well as its hard tags, labels, deactivators, and detachers.

Sensormatic is a leading supplier of retail source-tagged labels for store-level productivity and loss prevention. The company has introduced SmartEAS solutions for alarm management, people counting, and known-loss logging. These solutions deliver user-friendly exception-based reports, derived from data the EAS systems capture, to retailers who want rapid business intelligence to better manage loss-prevention and store operations.

Sensormatic RFID solutions provide the physical foundation for greater supply chain efficiency and visibility, boosting sales through greater availability of goods and cutting costs through process optimization. The company offers labels, antennas, readers, and device management software, as well as a full range of design, deployment, and support services. Sensormatic solutions are delivered through ADT Security Systems, Inc. in most areas of the world, as well as through a global network of distributors and partners.

With $11 billion in annual sales and more than 90,000 employees, Tyco Fire & Security includes more than 60 brands that are represented in more than 100 countries. Its products are used to safeguard firefighters, prevent fires, deter thieves, and protect people and property.

http://www.tyco.com/

Sharp Corporation

Sharp is best known for its consumer electronics, but is also a leading maker of electronic components and computer hardware and peripherals. Its flagship components business makes LCDs (used in everything from airplane cockpits to PCs to pinball machines), flash memory, integrated circuits, and laser diodes used in optical data drives. Sharp also makes PCs, printers, and cell phones; consumer audio and video products, such as Blu-ray disc players and LCD TVs; and a variety of appliances, such as air-cleaning systems and steam ovens. The company is one of the world's largest manufacturers of photovoltaic solar cells.

Sharp is targeting such products as LCD TVs, next-generation phone handsets, and home networking gear for growth. On the components side, the company sees demand for advanced LCDs increasing as new handheld devices come into the mainstream. Sharp shifted the focus of its television business from traditional cathode-ray-tube-based TVs to flat-panel LCDs.

In 2008 Sharp and Sony agreed to form a joint venture to operate an LCD panel plant in Sakai City. The plant will make LCD panels and modules for LCD TVs for both companies. Sharp will own 66 percent of the JV, with Sony owning 34 percent. Sony will reportedly invest ¥100 billion ($926 million) in the LCD JV.

Sharp spent about ¥6 billion (about €44 million, or more than $50 million) on building an LCD module assembly plant in Poland. The facility began production in 2007, providing LCD modules for TVs being sold into European markets. With the increase in demand for LCD screens, the market has become very competitive. To combat that increased pressure, Sharp has teamed with rival Toshiba. The deal calls for Sharp to buy 50 percent of its system LSI chips for TVs from Toshiba, which will in turn buy about 40 percent of its LCD panels from Sharp.

http://www.sharp.co.jp/

Si-Cal

Si-Cal has leveraged its 40+ plus years being an industry leader in the roll-to-roll screen printing industry based in Westborough, MA to become a leader in the field of printed electronics. The company prints conductive / functional inks on state of the art equipment with the capability to print on carbon / vinyl as well as polyester and other types of films, 1 to 10 mils thick. Si-Cal prints a wide variety of printed medical device products including electrodes for EKG and iontophoresis drug delivery, defibrillator pads, diagnostic test strips and radio opaque markers. The company also prints RFID antennas and other printed electronics components. Its wide format equipment has exceptional registration capability for very tight tolerances and can print many functional ink layers extremely accurately.

www.si-cal.com/

SiPix Imaging, Inc.

SiPix Imaging, Inc. is a leader in display innovation. The company offers custom display module manufacturing to enable system designers to get to market rapidly and achieve a strong return on investment.

In its Fremont, California, roll-to-roll production facility, the firm manufactures low-power electrophoretic display material, cuttable to custom sizes. Based on the patented Microcup structure, the flexible material is impact- and moisture-resistant. With SiPix's e-paper, designers may now choose from multiple saturated color combinations.

In Chung-Li, Taiwan, a SiPix production facility provides display module development services and volume manufacturing. This resource gives customers rapid system development and quick market entry.

Since SiPix was established in 1999 in California, it has filed over 100 patent applications and developed a core expertise in roll-to-roll display solutions and integration.

Direct drive modules are available from SiPix. Segmented displays using SiPix e-paper are used for many applications, such as pricing labels, clocks, and smart cards. The electronic paper is laminated onto a flexible or rigid electrode-patterned backplane, individually addressing each segment. This enables the background and individual segment colors to be directly driven and separately controlled.

Active-matrix displays using SiPix e-paper are used for applications such as electronic books on flat or curved surfaces. The electronic paper is laminated onto a rigid or flexible matrix-patterned backplane, individually addressing each pixel. No film alignment with the matrix backplane is necessary.

http://www.sipix.com/

SMARTRAC

SMARTRAC is the leading developer, manufacturer, and supplier of RFID and NFC transponders and inlays. The company produces ready-made and customized transponders and inlays used in access control, animal identification, automated fare collection, border control, RFID-based car immobilizers, electronic product identification and passports, contactless credit-cards, industry, libraries and media management, laundry, logistics, mobile & smart media, public transport, retail, and many more. Its 2011 sales were $168 million, a decrease of 7% compared with $180 million in 2010.

SMARTRAC was founded in 2000, went public in July 2006, and trades as a stock corporation under Dutch law with its registered headquarters in Amsterdam. The company currently employs about 4,000 employees and maintains a global research and development, production, and sales network.

http://www.smartrac-group.com/en/

Solarmer

Solarmer Energy, Inc. is a developer of transparent, flexible plastic solar panels, the next wave in generating renewable energy from the sun. These solar panels are opening the door for a wide range of new application areas in renewable energy, which are not currently addressable with conventional silicon solar panel technology. The company's solar panels have the potential to reduce the cost of renewable energy down to 12–15 cents/kWh and less than $1/Watt, which means plastic solar panels will be the first solar panels capable of generating electricity at costs on a par with conventional fuel costs.

Solarmer was founded in 2006 to commercialize this technology, which was developed by Professor Yang Yang at the California NanoSystems Institute at UCLA. The company has licensed this technology from UCLA and additional technology developed by Professor Luping Yu at the University of Chicago. The plastic solar panels, made from very thin layers of plastics and other materials, convert solar energy into electricity in a very cost-effective way.

Solarmer's headquarters are located in El Monte, California, in a 9,000-square-foot facility. The company has 26 employees, including researchers with backgrounds in materials science, organic and inorganic chemistry, physics, electrical engineering, and chemical engineering.

http://www.solarmer.com/

Solar Frontier

Solar Frontier K.K., a 100% subsidiary of Showa Shell Sekiyu K.K., has a mission to create the most economical, ecological solar energy solutions on Earth. Building on a legacy of work in solar energy since the 1970s, Solar Frontier today develops and manufactures CIS (denoting copper, indium, selenium) thin-film solar modules for customers in all sectors around the world. Solar Frontier's gigawatt-scale production facilities in Miyazaki, Japan, integrate compelling economical and ecological advantages into every module: from lower energy requirements in manufacturing to the higher overall output (kWh) of CIS in real operating conditions. Solar Frontier is headquartered in Tokyo, with offices in Europe, the U.S.A., and the Middle East.

In January, 2012, Solar Frontier announced that it plans to ship up to 150 MW of copper-indium-gallium-selenide (CIGS) panels for a power project in California. The company completed a 900 MW factory in late 2010 and brought all of its production lines into commercial production mode by the summer of 2011. The first shipment of its CIGS solar panels to customers took place in February 2011. Solar Frontier began to focus on developing CIGS technology in 1993 and started mass-producing CIGS panels in 2007. It built a second plant two years later, and together the two factories had 80 MW of annual production capacity.

The 150 MW solar power plant in Kern County touted by Solar Frontier is the largest CIGS power plant in the world and among the biggest of any kind of solar plant. The company delivered the first 26 MW of panels last quarter to developer enXco. The project was split into two phases with the first 60 MW due to come online by the end of 2012, and the second phase to be completed by June 2013.

http://www.solar-frontier.com/eng/

Solexant

Solexant is a start-up company developing third-generation thin-film PV technologies that dramatically increase solar cell efficiency and reduce manufacturing costs, therefore enabling the commercialization of solar modules that generate electricity at competitive rates without depending on government subsidies. Using printable nanomaterial technologies exclusively licensed from leading universities, Solexant's flexible solar cells harvest energy from the entire solar spectrum.

Solexant was founded in 2006 by Dr. Damoder Reddy, along with scientific founders and scientific advisory board members Prof. Paul Alivisatos of UC Berkeley, Prof. Paras Prasad of SUNY Buffalo, and Prof. Sue Carter of UC Santa Cruz.

The Solexant patent application describes an electroluminescent device and touts the advantages of using nanomaterials called quantum dots. "The next generation emissive display technology is expected to be based on newly emerging nanomaterials called quantum dots," the patent filing states. "Emission in these displays is from inorganic materials such as CdSe, which are inherently more stable than OLED materials." Reddy's previous venture was Nuelight Corp., a semiconductor company he founded. It develops OLED display devices to improve flat-panel displays in such consumer objects as smart phones, portable DVD players, laptop monitors, and televisions.

http://www.solexant.com/

Solicore

Solicore is a leader of embedded power solutions, offering its Flexion product portfolio of advanced ultra-thin, flexible, lithium polymer batteries for powered cards, RFID, and micro medical devices. Solicore has developed an advanced battery technology that is ultra-thin, flexible, safe, and environmentally friendly, which significantly enhances the capabilities of lithium-based batteries. The company's patented and proprietary technology is based on polyimide chemistry that has created a truly solid-state electrolyte.

Solicore also offers technology integration services that enable customers to accelerate their time to market and increase product design efficiencies. Solicore's headquarters, R&D, and manufacturing facilities are located in Lakeland, Florida.

Solicore's primary target markets include:

- *Powered Cards:* Product applications include: one-time-password (OTP) cards, stored value, gift, loyalty, contactless, multitransit, biometric, smart, and health insurance/government secure ID cards, tracking of high-risk items such as blood and pharmaceuticals, and of high-value items such as cardiac catheters and stents.
- *RFID Devices:* Battery applications include: electronic shelf labels, inventory powered tags, supply chain tracking with increased read distance and information storage, time and temperature indicators, and monitoring and tracking of the elderly, children, and other individuals considered high risk
- *Medical Devices:* Applications requiring battery power include: wireless patches used for outpatient, transdermal administration of medication, wireless TENS patches, wireless patches for patient monitoring such as EKG leads, vital signs monitoring, and patient wristbands

http://www.solicore.com/

Soligie

Soligie is a leader in utilizing high-speed manufacturing to produce printed electronics with a variety of conductive, resistive, and proprietary materials on flexible substrates such as PET, paper, and foil. The company is on the cutting edge of a new industry that merges nanotechnology, electronics, and advanced printing technologies to enable production of printed electronic components using high-speed, fully additive, roll-to-roll processes.

Soligie offers a full range of services including concept design, circuit design, design for manufacturability, and final volume production, and currently serves the medical device, smart packaging, RFID, and flexible interconnect markets. Soligie's design and manufacturing have achieved ISO 9001:2000 and ISO 13485:2003 certification through the combined use of emergent materials and proprietary manufacturing processes. Electronics components such as memory, sensors, displays, and batteries will be integrated into applications on thin flexible substrates.

Soligie was founded in 2005 with the goal of filling a critical gap in the supply chain for printed electronics manufacturing services. Initial operations were conducted within an existing Taylor Corporation company. During this time it developed its expertise in printing functional materials, identified critical equipment requirements and developed processes for effective printed electronics manufacturing. In 2007, Soligie completed the build out of its current facility in Savage, MN, took delivery of its initial equipment set and commenced full scale operations.

Soligie remains a wholly owned subsidiary of Taylor Corporation, one of the largest privately held companies in the United States with more than 80 domestic and foreign subsidiaries. Soligie is made up of a team of electronics manufacturing experts with the ability to leverage Taylor Corporation's printing experience.

http://www.soligie.com/

SonoPlot, Inc.

SonoPlot designs and sells Microplotter materials dispensing systems for drawing features as small as 10 to 20 microns. Its patented ultrasonic dispensing technology enables true contiguous lines for superior conductive traces and enables the deposition of a wide range of materials, including solutions containing graphene, carbon nanotubes, nanoparticles, and polymers. This technology allows the Microplotter to print inks with viscosities up to 450 cP without the difficulty of tuning them to the printer. Integrated digital video and precise positioning allow for accurate alignment and dispensing on substrates. The Microplotter systems provide unparalleled price per capability in the market.

www.sonoplot.com/

Sontor GmbH

Sontor started out as a subsidary of Q-Cells to commercialize the micromorph silicon-based thin-film technology that had been developed in the Jülich Research Center. Sontor's test laboratories have grown into a progressive factory that, with the help of modern technology by leading machinery manufacturers, produces solar modules of the highest quality and reliablity on an industrial scale. Mass production has commenced of the micromorph silicon-based thin film and thereby helps to make photovoltaic the energy source of the future.

In micromorph silicon-based thin-film technology two layers of silicon (an amorphous and a crystalline) are applied to a glass substrate. This tandem concept increases the module efficiency by more than 10%. The amorphous layer converts the visible part of the sun's spectrum, while the crystalline layer converts the part nearer to the infrared light area.

Recently Sontor has been taken over by the Wilms Gruppe Menden which offers the company a strong partner and technical network.

http://www.sontor.de/

SouthWest NanoTechnologies

SouthWest NanoTechnologies (SWeNT) is a privately-held specialty chemical company that manufactures high quality single-wall and specialty multi-wall carbon nanotubes, printable inks and CNT-coated fabrics for a range of products and applications including energy-efficient lighting, affordable photovoltaics, improved energy storage and printed electronics. SWeNT was created in 2001 to spin off nanotube research developed at the University of Oklahoma.

SWeNT produces carbon nanotubes using the patented CoMoCAT catalytic method in fluidized bed reactors. This results in selective synthesis of single-wall carbon nanotubes and remarkable control of diameter, chirality and purity.

http://www.swentnano.com/

Speedline Technologies

Speedline Technologies makes electronics assembly equipment, including systems used to print and clean printed circuit boards. It has installed more than 5,000 stencil printing and dispensing systems around the globe. The company also makes reflow ovens, coating equipment, wafer bumping systems, and packaging and encapsulation equipment used in semiconductor manufacturing. As part of Illinois Tool Works' Specialty Systems Group, Speedline Technologies gets to leverage its parent company's network which spans 750 businesses and nearly 50 countries.

The company was established in 1988 and later became part of Cookson Group, which aggregated four separate product lines under the Speedline name in 1998. Cookson sold the business in late 2003 for about $10 million to KPS Special Situations Fund. KPS sold Speedline to Illinois Tool Works (ITW) in late 2006.

http://www.speedlinetech.com

ST Microelectronics

STMicroelectronics (ST) is one of the world's largest and most respected semiconductor companies; it competes with Texas Instruments to be the top maker of analog chips. ST makes many types of discrete devices (such as transistors and diodes) and integrated circuits (ICs), including microcontrollers, memory chips, and application-specific ICs. It sells to manufacturers in the telecommunications, computer, consumer electronics, industrial, and automotive markets. Clients include Alcatel-Lucent, Bosch, Hewlett-Packard, and Nokia (more than 17 percent of sales). STMicroelectronics makes more than two-thirds of its sales outside Europe.

ST focuses on intensive product development, especially in close concert with key long-term strategic allies such as Alcatel-Lucent, Nokia, and Seagate Technology. It joined memory chip maker Hynix in a venture to build a multibillion-dollar chip factory in China. The company also expanded its product range through a series of small, complementary acquisitions. Its product breadth lends to its expertise in SoC (system-on-a-chip) ICs, which integrate disparate functions onto a single device.

To strengthen its position in SoC design and in the $1.5 billion market for digital TV chips, in 2008 ST acquired Genesis Microchip for around $336 million in cash. Genesis was among the leading vendors of video chips for flat-panel displays and digital TVs. Genesis became part of ST's Home Entertainment & Displays Group.

ST reorganized its product groups at the beginning of 2007. Among the moves, Intel and ST combined their flash memory businesses into a new stand-alone company named Numonyx. ST sold its flash memory assets to the new company, including its NAND flash joint venture and NOR flash resources. ST received an equity stake of nearly 49 percent in Numonyx and $364 million in cash and notes. Francisco Partners invested $150 million in the new venture, taking an equity stake of about 6 percent.

http://www.st.com/

Sumation Co., Ltd.

Sumation is a joint venture operating as a leading center of P-OLED materials expertise. The company combines the high-quality chemicals manufacturing experience of Sumitomo with the leading-edge P-OLED development know-how of CDT and Sumitomo, to ensure that display and lighting producers have access to the very best-performing materials, wherever they are in the development life cycle.

The joint venture offers the strongest materials set in the polymer OLED sector, including the current best-performing full-color P-OLED materials based on polyfluorene chemistry, which CDT and Dow Chemical have separately developed over the last ten years.

The Lumation business of Dow Chemical was purchased by Sumitomo Chemical and transferred to Sumation in 2005. It will also have exclusive access to “next-generation” high-efficiency materials based on dendrimer chemistry, which CDT gained through the acquisition of Opsys in 2002.

Sumitomo and CDT have been working together since 2003 on the dendrimer class of materials and have made great progress. The former range of Sumitomo P-OLED materials will now be manufactured and supplied by the joint venture.

The synergies of combining the experience of these companies is already increasing the pace of development of P-OLED materials, and in turn this is expected to accelerate the adoption of the technology in the next generation of consumer products such as mobile phones, portable DVD players, and televisions.

http://www.sumation.co.uk/

Sumitomo Chemical Co., Ltd.

Sumitomo Chemical makes chemicals for almost everything made and grown under the sun. About one-third of the company's sales come from petrochemicals and plastics such as polypropylene, ethylene, and elastomers. Sumitomo's other major units make pharmaceuticals, agricultural chemicals (insecticides, herbicides, and fertilizers), and basic chemicals such as caustic soda and methanol. The company also makes chemicals for electronics and fine chemicals. It is part of Japan's Sumitomo Group. Its pharmaceutical business operates through Dainippon Sumitomo Pharma. Sumitomo ranks among Japan's top three chemical producers, along with Mitsubishi Chemical and Asahi Kasei.

The pharmaceuticals unit was formed through the 2005 merger of the company's pharma operations with Dainippon Pharmaceuticals. Sumitomo Chemical still owns just more than half of the company, whose products include medications for cardiovascular disease and gastrointestinal disorders, as well as anti-allergy pharmaceuticals.

http://www.sumitomo-chem.co.jp/

Sung An Machinery

Sung An Machinery, better known as SAM, manufactures Extrusion Coating and Laminating Machines, Solution Coating and Laminating Machines, Rotogravure Printing Machines, and In-Line Flexographic Printing Machines. SAM North America in Fulton, NY and SAM Sung An Ralph Pagendarm in Hamburg, Germany provide Sales, Project Management, Technical Support, Service and Spare Parts to its growing customer base. SAM opened its Printed Electronics Laboratory (SPEL) to meet increasing requests for new product development. The laboratory houses a custom coating line specializing in the development of process and equipment for printed electronics including OPV solar cell, OLED, lighting and others.

www.sungan.net/rnd/rnd1.php/

Sun Chemical

Sun Chemical is the world's largest inks maker; it also makes all manner of coatings. In addition to inks and coatings for paper, packaging, metal, and other products, Sun Chemical manufactures printing plates for corrugated packaging. Its inks and coatings products are sold under the Sun Chemical, Kohl & Madden, US Ink, and Coates brands. The company operates more than 300 manufacturing, sales, and service locations in Europe, Asia, and the Americas. Sun Chemical has been a subsidiary of Japanese inks and coatings maker DIC (formerly Dainippon Ink and Chemicals) since 1987 when the latter bought the graphic arts division of what is now Sequa.

Sun Chemical provides materials to various markets such as cosmetics, plastics, coatings, publication, packaging, and other industrial entities. The company also offers consulting services, smart color applications, and Sun Care services. The company's operations are spread across various regions, including North America, Europe, Latin America, and Asia. Sun Chemical is headquartered at Parsippany, New Jersey.

Sun Chemical Electronic Materials Group develops inks for the photovoltaic market. The group has designed materials for crystalline, thin film, and organic photovoltaic technologies. With an eye towards the future, the company is developing materials in the US, in Europe, and in Asia to improve efficiency of crystalline silicon solar cells/modules, organic PV, and thin-film modules.

In mid-2012 the company entered the metallic pigments market with its purchase of Austria's Bend-Lutz Werke. The acquisition, which Sun Chemical used to form its new Metallics Business Unit under the Performance Pigments Division, adds metallic pigment plants in Austria, Poland, Russia, and the US to the company's existing aluminum pigment site in China.

Sun Chemical’s expertise in a wide variety of materials and printing processes, ranging from conductive inks to barrier coatings, offers major advantages to the PE market. There is a lot of commonality in what needs to take place throughout the PV segments, from c-Si to thin film in order to make improvements. The company is working on advanced materials, including transparent conductors, graphite and silver inks. Its digital inkjet program for electronics in the UK is also a huge asset and brings together options for how materials are dispensed.

http://www.sunchemical.com/

T-Ink, Inc.

T-Ink — for "thinking ink" — was formed in 2001. It initially produced novelty and promotional items like toys, interactive place mats and T-shirts. Some time later, it merged with another organization (details have not been provided) and is now a leading designer, manufacturer, and marketer of unique and innovative conductive inks, coatings and breakthrough applications (collectively "inks") used to significantly enhance the interactive capabilities of a wide range of products.

T-INK's patented technologies are designed to replace switches, wires, buttons, speakers, lights, sensors, microphones, antennas and batteries with printed ink for touch- and motion-activated applications. The company has a significant IP portfolio, including a substantial number of issued and pending patents, supported by over 2000 ink configurations which the Company has formulated for its unique applications.

T-Ink manufactures electronically conductive ink in the form of buttons, switches, and wires for the toy, packaging, and consumer product industries. A new low-cost printing process allows the use of specially formulated inks to be printed on a variety of materials, including paper, fabric, and plastic. The printed ''switch'' is printable, flexible, washable, and easy to apply.

T-Ink's technology is being licensed and utilized by a wide variety of partners such as McDonalds, Creata Worldwide, Toys-R-Us, Essential Reality, Milton Bradley, Famossa, Funtastic, Presiozi, Fisher Price, Elmers, and Bandai. The company has launched a youth consumer brand, Tinkworks, to participate in the growing market for reading and learning tools for children.

T-Ink's patented technology is designed to replace switches, wires, buttons, speakers, lights, and batteries with printed ink touch-activated applications. Highlights of this technology include:

- Uses almost any printing environment, including offset, flexographic, and gravure, without altering equipment
- Flexible, washable, and nontoxic conductive ink
- Can be applied to hard-wired surfaces, including paper, fabric, and packaging
- Can be formulated in virtually any color, including clear, with multiple activation points
- Extremely cost-efficient manufacturing process for large volumes

T-Ink's conductive ink technology is used by major companies in a variety of applications that include novelty and juvenile products, promotional items, packaging, POS, and textiles. Its newest solutions extend to transportation, security, gaming, industrial, construction, medical device, and RFID applications.

http://www.t-ink.com/

Taiyo Ink Mfg. Co., Ltd.

Taiyo Ink was established as a manufacturing and marketing company for printing ink in Minato-ku, Tokyo, in 1953. In 1976, the company decided to switch from printing ink, its main product since its founding, to solder resist products and other chemical materials for the electronics industry. In 1992, Taiyo Ink began research and development of plasma display panel materials. Sales of plasma display panel material have expanded, and this area has become the company's second largest.

Since the mid-2000s, the main suppliers of printed wiring boards have shifted from Europe and the United States to Asia, and particularly to China. Taiyo Ink established Taiyo Ink (Suzhou) Co., Ltd. as a local production base for the Chinese market, which has become a global industrial center, and began full operation in July 2003. By 2005, sales of flat-panel display materials exceeded ¥3 billion in the financial year ended March 2005. Sales have continued to expand rapidly with the growth of the plasma TV market.

Taiyo Ink currently employs approximately 775 people.

http://www.taiyoink.co.jp/english/

Terepac

Terepac Corp., a privately-held emerging technology company in Waterloo, Ontario, was founded in 2004 by Mr. Ric Asselstine and Dr. Jayna Sheats, based on patented inventions by Dr. Sheats and Mr. Asselstine's experience with innovative Internet companies and the conventional printing industry. Following early development and proof of concept in university laboratories, a 250,000-square-meter facility was established near the University of Waterloo campus, where the company maintains several close contacts. The company has since filed more than a dozen patent applications, established numerous R&D relationships, and built pilot-scale manufacturing equipment and supporting infrastructure to serve customers with a very rapid scale-up of production capability. Its technical staff includes distinguished PhD scientists and engineers and experienced veterans of industrial development and operations, and it has established a technical and marketing presence on three continents, including forming a subsidiary in Dresden, Germany, which will be a vital participant in multiple European initiatives.

Terepac has developed a system for transfer printing electronic components of any lateral size and thinness down to microns or below, at high speeds and accuracy. With costs far below any competing technique and no sacrifice in performance, this platform technology introduces revolutionary advances in assembly and packaging of micro- and nanoelectronics. Ubiquitously deployed real-time location systems, wireless sensors, RFID tags, and embedded electronics products will provide input to a Microelectronic Nervous System™ (MNS), a Terepac-enabled network that reports not only an object's location but also its condition, creating a uniquely powerful tool for economic competitiveness, quality of life, and sustainability.

http://www.terepac.com/

Thieme GmbH & Co. KG

Thieme has been a family-owned enterprise for more than 50 years and is a technology leader in the areas of polyurethane and printing systems. The custom parts manufactured at Thieme include plastic enclosures, housings, covers, structural parts and system solutions for device manufacturers in the medical, automotive, analytical, laboratory, industrial, agricultural, commercial and heavy equipment industries. Its digital and screen-printing systems are state-of-the-art and distinguish themselves by the highest printing quality and efficiency.

Thieme began as a contract manufacturer of machine components. This advanced to specialized machines and in 1965 to a second business area in plastics. Beginning in 1972, the company specialized in high-quality moulded parts of polyurethane (PUR) and ten years later the integration of energy absorbers for the automobile industry. Today, Thieme is recognized globally as one of the leading specialists for high-quality moulded and functional parts made from PUR and other plastics.

In 1976, Thieme started production of screen-printing machines. Today the company manufactures large format multi-colour lines of the THIEME 5000 series, which are part of the Nonplus ultra for graphic applications. Thieme has also developed a multitude of solutions for the area of technical screen printing including those for the photovoltaic industry. With the innovative printing machine M-Press Tiger, Thieme recently entered the digital printing market.

In 2002, Frank Thieme became the principal shareholder of the company, a position which he has held for the past 50 years.

http://www.thieme-us.com/

Thin Film Electronics

Thin Film Electronics (TFE) is a Norwegian and Swedish company working mainly in the field of printed electronics. By using the physical, chemical, and electrical properties of advanced polymers, TFE can add new functionality to printed products such as boxes or magazines.

Thin Film Electronics is a research and development company. The company has pioneered a new technology in electronics based on the use of solution-processable, smart materials. Thin Film focused on using this technology for large-area, 3-D memory and data processing systems. Commercial production and marketing is pursued in collaboration with major industry partners through licensing.

TFE's unique polymer memory technology can be used in any printed electronics application in which nonvolatile random access memory is preferred, such as to store information on a package that can later be displayed to the customer.

Thin Film's memory technology combines the properties of specially developed polymers with a unique system architecture. Ultimately, the result will be an all-organic memory system with manifold advantages in speed, production, energy consumption, storage capacity, and cost.

In the Thin Film system, a substrate is coated with extremely thin layers of polymer. The layers in the stack are sandwiched between two sets of crossed electrodes. Each point of intersection represents a memory cell containing one bit of information. To activate this cell structure, a voltage is applied between the top and bottom electrodes, modifying the organic material. Different voltage polarities are used to write and read the cells.

The electrodes are printed directly onto the polymer layers. Expanding memory capability is a matter of coating a new layer on top of an existing one. Being solution-based, the polymer memory arrays can easily be applied to large surfaces with regular coating techniques, such as spin coating.

http://www.thinfilm.se/

Tokyo Electron, Ltd.

Tokyo Electron Limited (TEL) is the one of the world's largest manufacturers of semiconductor production equipment. TEL's chip-making systems include chemical vapor deposition, thermal processing, etching, cleaning, and probing equipment. The company also makes flat-panel display (FPD) and photovoltaic (PV) production equipment, and distributes other companies' chip-making equipment, computer systems, networking products, and software in Japan. Subsidiary Tokyo Electron Device distributes chips, boards, and software made by companies including AMD, Microsoft, and Texas Instruments. Chip production equipment accounts for about 80% of TEL's sales; customers outside Japan account for around 60% of total sales.

The global recession is driving down sales of digital home appliances, mobile phones, and PCs, creating a downturn in the semiconductor industry, which is severely impacting suppliers of semiconductor equipment. TEL's sales in fiscal 2010 were down about 18% from the prior year; as a result, the company posted its first net loss in around a decade.

Its customers started to make capital investments in 2009 and the trend continued through 2010. New consumer products, such as smartphones/tablet/PCs, were driving demand for new semiconductors -- and next-generation semiconductor manufacturing equipment -- in both emerging and established markets. In 2010 TEL announced it would build a plant in China to take advantage of the booming market in that country, particularly in the solar cell and module manufacturing sector. Also fueling its capacity to meet these new product demands was its acquisition in 2012 of Massachusetts-based NEXX Systems, which expanded certain advanced wafer-level packaging capabilities.

To unlock the potential of the Asian solar market, TEL turned to OC Oerlikon, or more specifically its Oerlikon Solar subsidiary, a maker of thin-film silicon PV production equipment. The companies have had an agreement since 2009 that joins the Swiss company's PV technology with TEL's sales and customer support network. In 2012 TEL agreed to buy Oerlikon Solar; the company has identified PV cell production equipment as its third core business. By integrating the solar equipment maker's technology with its own field service and production capabilities, TEL plans to accelerate growth in the solar equipment sector.

TEL is also working with Sharp to develop a plasma system for thin-film PV production. It inked another agreement late in 2010, this time with Epson. The companies will develop OLED (organic light-emitting diode) display manufacturing equipment that combines Epson's inkjet method with TEL's production equipment technology.

http://www.tel.com/

Toppan Printing Co., Ltd.

Toppan Printing prints commercial products (posters, catalogs, calendars), securities and cards (checks, bank passbooks, magnetic cards), publications (magazines, books, CD-ROMs), and packaging products (containers, labels). In addition, the company's Toppan Photomasks subsidiary manufactures electronics-related materials (photomasks for semiconductors, color filters for LCDs) and industrial materials (decorative sheeting, wallpaper). The company has operations throughout Asia, Australia, Europe, and North America. Founded in 1900, Toppan Printing has become one of the world's largest printing and publishing companies.

In late 2007 Toppan acquired additional shares in rival Tosho Printing Co., Ltd., thereby increasing its stake in Tosho to nearly 45 percent. As a result, Tosho became a subsidiary of Toppan Printing. Toppan aims to strengthen its competitiveness by taking advantage of Tosho Printing's expertise in the book printing business.

The company's printing businesses, which account for more than half of revenues, provide a stable profit source that allows Toppan to invest in higher growth industries like electronics manufacturing. Toppan plans to increase production capacity and research and development investment in its manufacturing operations, particularly for color filters (used in LCD panels) and rear-projection TV screens. In 2005 Toppan acquired DuPont Photomasks; the purchase made Toppan one of the world's top suppliers of photomasks. Since 2005 Toppan has been engaged in an ongoing joint development project with IBM for advanced photomask manufacturing.

http://www.toppan.co.jp/

Toshiba Mobile Display

Toshiba Mobile Display Co., Ltd. (TMD) changed its name from Toshiba Matsushita Display Technology Co., Ltd. in May 2009. The company offers LCDs with high added value, especially in the field of small and medium-sized displays.

TMD products play an active role in the computing, controlling, power, and communications industries. The company's portfolio includes personal and professional computers (notebook PCs, servers), telecommunications and medical equipment (mobile phones, X-ray machines), industrial machinery (power plant reactors, elevators), consumer appliances (microwaves, DVD players), electronic components (electron tubes, batteries), and semiconductors. Its portfolio also includes air traffic control and railway transportation systems.

TMD has used partnerships (often with competitors) to fuel product development. It merged its LCD operations with those of Matsushita, forming Toshiba Matsushita Display Technology. Toshiba formed an alliance with rival Fujitsu that will focus on system-on-chip (SoC) operations, opening possibilities for greater semiconductor product integration in the future. Toshiba has partnered with Canon to develop surface-conduction electron-emitter display (SED) panels, which it views as the successor to LCD televisions. It also joined with Sony and IBM to develop new microprocessors.

http://www.tmdisplay.com/tm_dsp/en/index.html

ToyoChem Co., Ltd.

ToyoChem is a Japanese conglomerate that is comprised of five manufacturing divisions: Printing and Information, Packaging Materials, Polymers & Coatings, Colorants, and Functional Materials. These companies make offset inks, inks for metal, printing machinery, printing devices, prepress systems, inkjet materials, gravure inks, flexographic inks, gravure cylinder, can coating finishes, resins, adhesives, coating & painting materials, natural products, organic pigments, processed pigments, plastic colorants, and materials for LCD color filters.

In April 2011, the Toyo Ink Group brought in a holding company structure focused on Toyo Ink SC Holdings Co., Ltd., which is developing a worldwide business network around three core operating businesses, Toyo Ink Co., Ltd., Toyochem Co., Ltd. and Toyocolor Co., Ltd., with more than 7,000 employees in approximately 70 companies in 19 countries worldwide. Starting with the manufacturing and sales of printing inks, the operating activities at the Toyo Ink Group have expanded to the development and production of organic pigments and resins, which are the raw materials for ink, and are now expanding again from value-added inks for a range of printing applications to functional materials, natural materials and electronic materials.

http://www.toyo-chem.com/en/

ULANO

Ulano specializes in the manufacture of screen printing stencil-making films and emulsions, and screen chemicals. The company also supplies masking films, inkjet media, automated coating equipment, exposure test positives, and stencil evaluation tools.

Ulano's administrative and manufacturing headquarters is in Brooklyn, New York, where it also has research and development laboratories, and a technical training center. Ulano has an international representative office and training center in Schlieren/Zurich, Switzerland, an Asian regional office in Singapore, and a branch office in Shanghai, China.

www.ulano.com/

Unidym, Inc.

Unidym, a majority-owned subsidiary of Arrowhead Research Corporation, is a leader in the manufacture and application of carbon nanotube (CNT)-based ink and conductive film products and CNTs, novel materials with extraordinary electrical, mechanical, chemical, and thermal properties. Unidym provides CNT-enabled products, specialized CNT materials, and intellectual property to a wide range of customers and business partners.

With the addition of the experience and strengths of Carbon Nanotechnologies (CNI), Unidym's current patent portfolio contains more than 200 foreign and domestic patents and patent applications, including more than 90 issued patents. The portfolio includes fundamental patents covering carbon nanotube composition, production (synthesis, purification, and dispersion), and use in many different application areas, including electronics, composite materials, energy storage/generation, medical devices, and drug delivery.

Unidym is focused on the electronics industry, in which its initial product is a transparent electrode for touch screens, flat-panel displays, solar cells, and solid-state lighting. Unidym is developing thin-film transistors for printable electronics and the emerging flexible display market. Additionally, Unidym has developed a range of proprietary CNTs for conductive polymers, structural reinforcement materials, and antistatic films.

Unidym's product line builds upon the growing trend in the electronics industry to replace today's high-cost materials and manufacturing processes with simpler, lower-cost production techniques similar to those found in the printing industry.

http://www.unidym.com/

UniJet

UniJet Co. Ltd is a total solution provider of inkjet printing systems and technology, especially for electronic material deposition. UniJet supplies printing systems ranging from R&D systems to mass production systems for LCD, PDP, OLED, PLED, solar cell, PCB, RFID, semiconductor packaging, and various coating applications. Mass production systems are customized to meet the application requirements and specifications with R2R printing systems. UniJet also offers process know-how for various application developments as well as for application specific inks.

www.unijet.co.kr/

Universal Display Corporation

Universal Display, through sponsored research agreements with Princeton University, the University of Southern California, and the University of Michigan, is developing organic light-emitting diodes (OLEDs) for flat-panel displays and other applications. Its OLED technologies use organic semiconductor materials to overcome limitations in LCDs, such as poor image and color quality. Universal Display is licensing its technology to makers of televisions, computer screens, and consumer electronics devices.

Universal Display is expanding through development and licensing agreements with partners such as AU Optronics, AIXTRON, Idemitsu Kosan, Nippon Steel Chemical, PPG Industries, Samsung SDI (about 35 percent of sales), Seiko Epson (11 percent), Sony, and the US government. The company is researching applications for the US Army that include head-mounted displays, displays on durable metal foil, and penlike communication devices with roll-up displays.

Universal Display is also expanding its research efforts into related OLED display technologies such as phosphorescent OLEDs (PHOLEDs), printable PHOLEDs, flexible OLEDs (FOLEDs), and transparent OLEDs (TOLEDs), as well as organic vapor phase deposition tools for manufacturing the displays. Universal Display is providing red PHOLED chemicals to Tohoku Pioneer, a subsidiary of Pioneer Corp., for use in passive-matrix OLED cell phone displays.

FMR (Fidelity Investments) owns around 10 percent of Universal Display. Mazama Capital Management holds about 8 percent of the company. Invesco has an equity stake of approximately 7 percent. Officers and directors of the company, along with the adult children of founder and chairman Sherwin Seligsohn, together own about 19 percent.

http://www.universaldisplay.com/

Veeco Instruments

Veeco Instruments offers precision equipment for manufacturing components, such as thin-film magnetic heads, photovoltaic solar cells, and semiconductor devices. Its deposition, etching, and lapping and dicing systems are used in the hard-disk drive, sensors, semiconductor photomask, microelectromechanical (MEMS), and coatings industries. The company targets applications in the light-emitting diode (LED), solar, and data storage markets. Elec-Tech and Sanan Optoelectronics are top customers. Veeco gets around 90% of sales from outside the US.

Customers in Asia/Pacific account for nearly 85% of revenues; those in China make up two-thirds of sales. Veeco has development, manufacturing, sales, and service facilities located in the US, China, Japan, Singapore, South Korea, Taiwan, and across Europe.

Veeco's LED and solar segment is the company's largest (at 85% of sales) and has experienced a high rate of growth over the years. In 2011 sales increased 4% on new customer acquisition, particularly in China, offset by a slowdown in orders in the latter half of the year due to overcapacity in industry. The unit makes metal organic chemical vapor deposition (MOCVD) and molecular beam epitaxy systems, which it sells to manufacturers of LEDs, power semiconductors, concentrator photovoltaic solar cells, and wireless devices. A multi-chamber MOCVD developed for use in producing high-brightness LEDs, provided significant market share gains in both revenues (Veeco held a 65% global share of total MOCVD revenues) and units shipped in 2011.

Sales for Veeco's smaller data storage segment rose 12% to record levels in 2011 on increased capital spending by data storage customers investing in capacity and next-generation technology. Products include ion beam etch and deposition systems, diamond-like carbon, physical vapor deposition, chemical vapor deposition, and slicing, dicing, and lapping systems. These instruments are necessary to create the thin-film magnetic heads that read and write data on hard-disk drives. The equipment can also be used in optical coating applications. Orders were impacted by flooding in Thailand, a region where many hard disk drives are produced, during the third quarter of 2011, though the disaster resulted in an unexpected increase in orders by the end of the year.

Veeco is allocating additional R&D spending toward end markets that it believes offer significant growth opportunities, such as LEDs, optical communications, photovoltaic solar cells, wireless networking, and other communications applications.

As part of its strategy to focus on its LED, solar, and data storage businesses, in 2010 Veeco sold its metrology instruments business to Bruker for about $229 million in cash. The business includes atomic force and scanning probe microscopes for surface inspection and measurement and optical industrial metrology instruments. Veeco reasoned that the division, which is profitable and growing, will be a better fit as part of a company that plans to continue to focus on developing scientific instruments, such as Bruker. The sale also gives Veeco the financial flexibility to make acquisitions and expand customer support for its business in Asia.

Further freeing up cash, Veeco discontinued its CIGS business late in 2011. Used in the manufacture of thin-film CIGS (copper, indium, gallium, selenide) solar products, Veeco cited factors that included lower-than-expected market acceptance of the CIGS technology, which was supposed to create more cost-effective solar technology, and improved performance of mainstream silicon solar technologies.

www.veeco.com/

Victrex Polymer Solutions

Victrex Polymer Solutions, a division of Victrex plc, is one of the world's leading manufacturers of high performance polymers, including VICTREX PEEK Polymer and APTIV films. With over 30 years focus and expertise and a product portfolio with one of the broadest ranges of polyaryletherketones on the market, Victrex is more than a material supplier. Offering unmatched product and technical service capability to deliver security of supply, and capitalizing on its unique integrated supply chain, four state-of-the-art technology centers and global technical, sales and marketing teams, Victrex helps customers and end users achieve the greatest possible benefit from the use of its high performance materials to achieve cost-effective, reliable solutions for long-life applications of today and in the future.

www.victrex.com/

Vorbeck Materials

Vorbeck Materials Corp. is a technology company established in 2006 to manufacture and develop applications using Vor-x, Vorbeck's patented graphene material developed at Princeton University. Vorbeck launched the world's first commercial graphene product with the introduction of Vor-ink, a graphene-based conductive ink for electronics applications. Products using Vor-ink circuits are available in major retail chains today. Vorbeck Materials is the first and only company to receive EPA approval for the commercial production and sale of graphene-based products.

Vor-ink enables new applications in the printed electronics industry through its ease of processing and exceptional conductivity. Vorbeck's unique graphene-based conductive ink, Vor-ink, creates robust films with outstanding flexibility and crease resistance. Even in thin coatings (1 micron), Vor-ink maintains its rated conductivity.

Vor-ink is specifically formulated for screen-printing applications. Viscosity and solids content ensure optimal coverage and exceptional conductivity on paper, paperboard, and PET films. Vor-ink screen provides sufficient flexibility for even the most demanding applications.

http://www.vorbeck.com/

Xaar

In 1990, Xaar was formed in Cambridge, UK to acquire, develop and commercially exploit a new digital inkjet printing technology arising out of work done by Cambridge Consultants Ltd . Xaar's business concentrated on licensing four granted patents and know-how to printer manufacturers, primarily for use in office applications.

In 1999, the first printhead manufacturing Xaar was acquired by MIT, an existing licensee. MIT was integrated into Xaar and became Xaar's dedicated manufacturing facility at Järfälla, Sweden. Xaar's product portfolio has expanded considerably since this acquisition.

In 2003, Xaar introduced its first full production printhead incorporating its unique, patented greyscale technology. The Xaar 318 is manufactured in Japan by Xaar licensee Toshiba TEC and offers photographic-quality printing with no compromise in speed.

In 2007, Xaar launched the revolutionary Xaar 1001 printhead with TF Technology delivering a significant step forward in inkjet reliability. The company confirmed its position as a market-leader in the innovation of digital inkjet printing.

In 2012, Xaar announced the launch of the Xaar 1001 GS12, allowing ceramic tile manufacturers to achieve deep colour intensity for bolder tile colours and effects. The Xaar 1001 GS12 gives the same ink coverage as the established Xaar 1001 GS6, but at double the print speed.

http://www.xaar.co.uk/

Xerox Corporation

Once self-styled as "The Document Company," Xerox has grown from offering multifunction document machines to now also being an outsourcer of business processes (BPO), such as customer care and claims filing operations, and IT functions, such as infrastructure, cloud computing, and application services. Its document equipment is used not only in the office but also in mass-printing production settings. It serves customers in both the private and public sector. Major subsidiaries include office equipment and services provider Global Imaging Systems.

Xerox has two main segments, which essentially divide about 90% of sales: services (BPO and IT and document outsourcing) and technology (products, supplies, and related service and financing). The $6.4 billion acquisition of Affiliated Computer Services (ACS) helped drive Xerox's outsourcing business in 2010, overtaking the technology side of the business in 2011 to become Xerox's largest segment; it grew from $3.5 billion to $10 billion to account for nearly half of sales. The company's other, smaller business lines include paper, wide-format systems, GIS network integration, and electronic presentation systems; together they make up less than 10% of sales.

BPO constitutes 55% of services, with document outsourcing taking a third, and IT outsourcing bringing in 12%. BPO addresses common enterprise functions such as HR and tech support, as well as offering support for financial services, healthcare, transportation, retail, travel, insurance, and more. IT outsourcing focuses on mainframe server environments, network, and desktop, but also includes other functions such as remote infrastructure management and utility computing, among others. Document outsourcing offers managed print services and communication and marketing services. Xerox's technology segment is made up of mid-range products (nearly 60% of the segment), small and midsized business offerings (about 20%), and its high-end portfolio for graphic, communications, and large clients (about 20%).

Xerox serves more than 160 countries, with about two-thirds of sales coming from the US, and 25% from Europe. It holds a 25% stake in its joint venture with FUJIFILM, Fuji Xerox, which serves the Pacific Rim with document processing products.

Among Xerox's acquisitions has been the purchase in 2012 of e-discovery technology provider Lateral Data for $30 million. In 2011 it picked up digital document products distributor Concept Group and print software and consulting services provider NewField IT as part of an effort to expand its presence in the UK, particularly in the small and medium-sized business market. It expanded in the Benelux region that year with the acquisition of customer care provider Unamic/HCN. Xerox didn't ignore its home turf either, bringing in The Breakaway Group (cloud-based electronic medical record adoption) and Education and Sales Marketing, LLC (student financial and enrollment management) that year, both headquartered in Colorado.

www.xerox.com/