PRINTING ELECTRONICS REPORT
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ET TRENDS

NEWS

Is PE Real or Wishful Thinking? - Printable Electronics (PE) is viewed by the net-geeks as just another "almost there" thing. But engineers see PE as emerging technology with a real future, but with serious challenges if it is to get beyond niche status. According to the popular website, Engadget, the latest PE group, which includes scientists from DuPont and Organic ID, has reportedly **"fabricated a printing plate used to print the source-drain level of an array of thin-film transistors,"** essentially solving some of the low-resolution constraints seen on prior competition. The goal is to eventually posses the ability to "print large, flexible circuits using machines similar to printing presses," and while it seems to be a ways from commercialization, initial testing and comparisons to more traditionally created transistors have produced glowing results. Source: Engadget.

EDA for Organic Displays - The UK Trade & Industry has awarded a Fast Track grant to help development of EDA software for use in organic-based electronic applications. [This area of displays is able to utilize Printed Electronics (PE) and this grant can be viewed as indirect support. Cambridge Display Technology (CDT) won Fast Track grant to develop electronic design automation software (EDA) for use in organic TFT-based (OTFT) electronic applications. This will be important in the development of displays using TFTs, in particular flexible displays based on plastic substrates. The project will extend the use of EDA software to organic semiconductor (OSC) materials, and accelerate the development of low-cost fabrication techniques for organic displays on both flexible and rigid substrates. It will enable the faster development of advanced structures, devices and circuits and expand the application space for organic electronics. The grant, for approximately $500,000 was awarded by the UK Department of Trade and Industry's Technology to a small consortium led by CDT. Partnering with CDT is Silva co International, one of the leading providers of technology computer aided design (TCAD) and EDA simulation software. This is an important stepping stone in the transition of low-cost organic electronics from the laboratory onto production, according to CDT. Other significant projects announced recently include the metal deposition techniques and the computational fluid dynamic (CFD) simulation. The CFD project further demonstrates that CDT is building a strong position in the fundamental expertise required for development of low cost organic and flexible P-OLED displays. Source: ElectronicStalk.

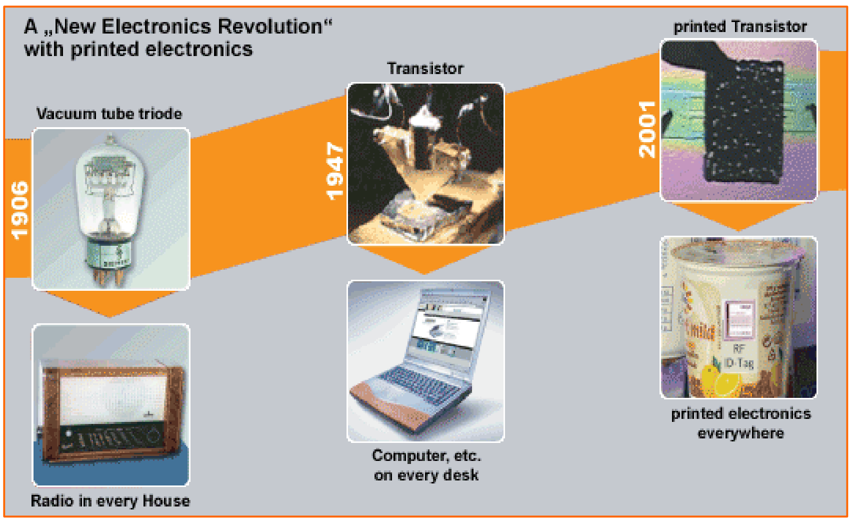
TECHNOLOGY

Printed Electronics Future - ***[Printed Electronics may be emerging, but the definition is already getting murky and hype is starting to muddy the waters - and that is unfortunate].*** NanoMarkets forecasts that between 2007 and 2013, about 15,000 printers will ship to factories doing Printed Electronics (PE). They go on to say that capital equipment suppliers targeting this niche will be challenged to output high-volume/low-cost printing systems using gravure, flexography, or offset methods; small R&D, laboratory, or educational printers, most likely ink jet; and screen printers for the thick-film printed electronics that dominate the initial market. [Based on my own experience of running silver ink on flexo, and other graphic printers, these methods do not work well, primarily because the ink deposit is way too thin compared to screen printing. [***But screen printing is unique among the popular methods for ability to control thickness and to apply thick deposits***]. By 2013, NanoMarkets sees 75% of printed electronics manufacturing lines using high-volume thin-film methods, with screen printers occupying 18% market share. More than 70% of systems used for R&D and prototyping will be ink-jet printers. Manufacturing capacity globally is expected to hit 400-million m^2, producing product for a $40-billion market. PE blurs the distinctions between components and PCBs. ***[This is what PE is all about, printing the conductors and components. If only the PCB traces are printed, then its only PTF technology].*** Traces, shielding, dielectrics, conductors, and semiconductors can, in theory, all be deposited onto substrates ranging from flexible plastics to paper to clothing fibers. ***[And rigid substrate, as well]***. Printed electronics may integrate with traditional electronics assembly techniques, increasing market penetration. Kovio is developing printed silicon electronics and thin-film technologies that enable integration with existing and emerging assembly techniques. Kovio's manufacturing techniques combine printing processes borrowed from graphics fields with silicon-based semiconductor capabilities.

MATERIALS

Printable Electronics (PE) Materials - While the semiconductor industry pursues more complexity, the large market for simple devices seems to have been forgotten. RFID tags, for example, store just 100 bits of information. Displays and sensor arrays are more desirable if they are larger. Nanometer-scale transistors can help display quality, but do little to improve the parameters that matter most to customers. These kinds of applications are over served by conventional CMOS manufacturing. Printing of electronics differs from conventional CMOS manufacturing in several important ways. The most important difference, and the basis for PE’s potential cost advantage, is that it is a low temperature, processing at atmospheric pressure. PE is compatible with essentially any substrate material, with existing industrial applications using materials as diverse as corrugated cardboard, paper, metal foil, and plastic film. The second important characteristic is that it is an additive process; CMOS uses etching and additive. PE materials utilization approaches 100% since materials deposited on the substrate are not removed. Finally, many of the printing methods are roll-to-roll processes.

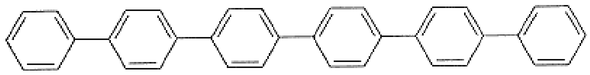
Many small volume printers are batch-oriented, single sheet devices, but roll-to-roll printing’s high throughput gives it the most significant cost advantage. Continuous processes allow only limited time-usually only seconds-for annealing and in situ chemical reactions. Printed electronics require functional inks with conducting, insulating, and semicon-



ducting properties. Different printing methods require different viscosities and hardening characteristics. Inkjet printing needs low viscosity inks that can form individual droplets at the printhead. Flexographic printing transfers ink from a reservoir, to a roller, to a flexible printing plate and inks must be viscous enough to coat all of these surfaces evenly, and mechanically robust enough to tolerate the resulting shear stress. But conventional printing methods cannot yet meet the resolution requirements of even simple electronic circuits. The smallest printed features are about 10µm, although many would prefer submicron features.

Materials & Deposition: The most mature group of electronic inks are probably metallic inks and they have been used for several decades. Metallic inks are composites of metal particles in a media but have higher resistance than a conventional wire due to the gaps and interfaces between particles. Forming consistent film is difficult because the metal particles tend to agglomerate and settle out of solution, especially in low-viscosity inks. Some are trying nanoparticle suspensions followed by sintering that can occur at a lower temperature; some will fuse at below 150oC. Inkjet printing has been used in much of the research on printable electronics, including much of the work on printable metals. Yet some argue that inkjet printing is not an ideal technology for high-volume IC manufacturing because of low throughput and various printing problems. Thin dielectrics and low-voltage operation are especially important for RFID tags, which are constrained by the voltage that can be induced through the antenna. Suitable dielectric materials are readily available-many different polymers have been used-but it can be difficult to create a thin enough layer that is also continuous. One common approach to the deposition of thin continuous dielectric films depends on self-assembled monolayers (SAMs) composed of molecules in which one end preferentially bonds to the substrate, while the other is repelled by it. Thus, the material coats the substrate with a uniform, aligned monolayer. Dielectrics are often deposited as blanket films, with a SAM serving either as the dielectric by itself or as an adhesion layer to ensure a uniform spray deposition. Patterned SAMs can also be used to produce selective deposition of other materials. A stamp can be used to patterned areas with the appropriate monolayer. An organic semiconductor or conductor preferentially adheres to the prepared region, but rinses off the untreated areas of the substrate. Very small feature sizes can be achieved with stamping. “Soft lithography,” as this stamping of SAMs is known, is potentially compatible with roll-to-roll processing: the stamp resembles the soft plate used in flexure printing. Though initial research has been promising, it is not yet known how susceptible to defects the stamp will be since it could distort mechanically, or particles could embed themselves in the soft surface. Some wear and tear is likely; the stamp lifetime under use conditions is not yet known.

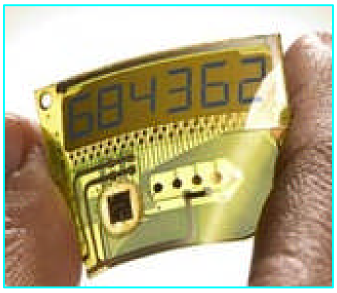
Most printed electronics researchers assume that only organic semiconductors can achieve the desired process simplicity and cost. Many different organic semiconductors exist, but all share a conjugated carbon backbone, in which single and double carbon bonds alternate. Conduction occurs by hopping between adjacent chains. The best carrier mobility is achieved in structures where the backbone chains of adjacent molecules are parallel to each other. Many organic semiconductors dissolve more rapidly, so many researchers have attempted to improve the mobility of these compounds. Attempts to develop solution-processable pentacenes (preferred electronic properties) have met with some success. One approach depends on a soluble pentacene precursor, converted to pentacene after deposition. Another modifies the pentacene molecule to improve solubility. Source Solid-State Technology.



Materials Market - Organic, inorganic, and composite materials can be used to construct various forms of printed electronics. Organic printed electronics will create a $300-billion industry in 2027, but is just over $1-billion in 2007 according to IDTechEx. The total market encompassing the well-known organics, inorganics, and composites, and could reach $48.18-billion in ten years, if manufacturing techniques using conductive inks to produce PCBs and flex connectors, or organics and composites to print sensors and OLEDs, meet the potential that has been appraised at the R&D level. Inorganics could lead to higher-performance conductors and printed batteries, quantum-dot devices, and highly mobile transistors, according to IDTechEx. While organics, particularly OLEDs, are leading the printed manufacturing industry, inorganics are poised to make the jump from thin-film traditional manufacturing systems to truly printed, truly flexible assemblies. [***They may be forgetting CTF - Ceramic Thick Film that is a very mature technology***]. Commercial potential and technical progress are high, IDTechEx reports, and companies producing flexible displays with up to eight printed inorganic layers and printed photovoltaics based on copper, indium, and gallium diselenide will lead inorganics in attracting market share, if printing techniques advance to keep up with organics. Composites also garner attention, as inorganic materials are added to printable organics in nanoparticles.

IDTechEx

Limitations abound for market saturation, and PE likely will remain a niche of electronics assembly for several years. Manufacturing technique, substrate, and deposited materials are crucial, and the trend is toward collaboration. Materials, chemical, printing, plastics, and related companies can cooperate to bring product to market faster, though the logistics may be exceedingly difficult. The industry will be tested to bring its considerable quantity of IP into end markets efficiently and with profit, particularly in consumer applications, where time-to-market is expected to be swift and product design flexible. ***[There's a lot of old technology in this area, so there may be some IP surprises - and disappointments - and eventual litigation since early PE was not patented, but discoverable records exist in the public domain].*** Other challenges facing printed electronics rest in raw materials. Current-generation printed electronic products and R&D incorporate large amounts of rare materials, for both organic and inorganic inks, according to Das. Without improvement, this situation could destabilize within 15 years. ***[This area needs a serious effort].*** Success in printing could revitalize mature manufacturing regions, in particular Japan, the U.S., and Europe. Government projects, interest in lower-power/energy-efficient products, regulations on toxic substances in manufacturing and end products, and concentrations of university and laboratory research in these regions fuel development, and

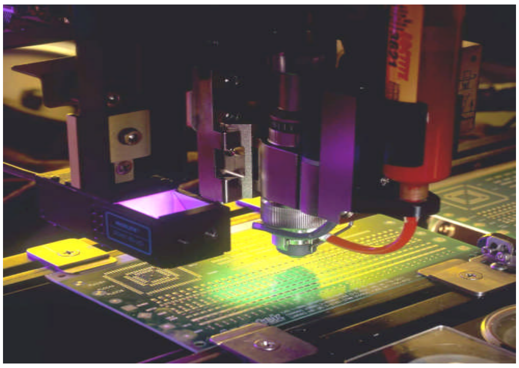


early manufacturing facilities are co-locating with IP hotspots. Plastic Logic, a Cambridge, U.K.-based company located its manufacturing facility for e-readers, devices with flexible displays that mimic a newspaper or book page, in Germany. Japanese universities are leading the R&D movement, and Tokyo-based manufacturer Konica Minolta Holdings will develop and ship OLEDs for General Electric within three years, IEEE's Spectrum NA reports. Research on carbon nanotubes (CNTs) for printed and transparent electronics is underway in Japan and the U.S., NanoMarkets reports. IDTechEx concurs that the majority of development and fledgling production is occurring in the U.S., Europe, and Japan and East Asia. In 2007, 56% of market spending is coming from East Asia, the analyst company states, and end markets will be strongest in Europe and North America. One could expect, however, to find manufacturing migrating to lower-cost regions as the technology matures, R&D lessens, and high-volume manufacturing equipment brings products to commercial markets. Sources: SMT Magazine and company websites.

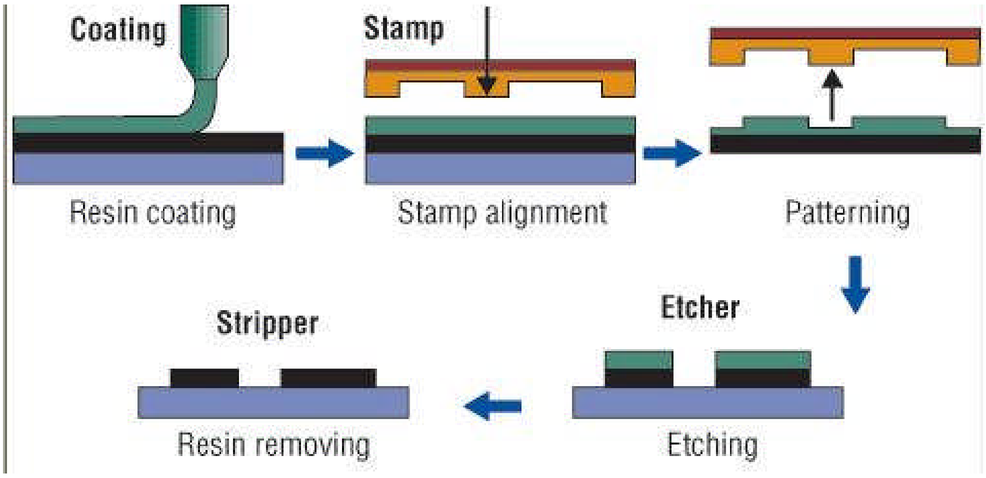
TECHNOLOGY

First PE Badges - PE badges, in the form of organic RFID circuits, are set to be used in a field trial at the Organic Electronics Conference (OEC-07) in Frankfurt, Germany later this year. The circuits are the first printed low-cost organic tickets, according to Cintelliq Ltd. (Cambridge, England), organizer of the conference, and have been developed under the auspices of PRISMA, a collaborative research project on printed smart labels with European Union funding. The tickets are set to be manufactured by printing company Bartsch GmbH and plastic electronics developer PolyIC (Fuerth, Germany). During this first field trial, it is planned to use organic tickets to collect statistical data. Four reader stations developed by PolyIC and about 1,000 organic tickets converted by Bartsch are set to be used to monitor the flow of attendees during the two-day conference and exhibition. The field trial is expected to support the development of a wider range of printed RFID applications, in public transportation and logistics. Source: EE Times Europe.

Inkjet for LCD Production - The LCD is composed of a number of parts including backlights, polarizers, glass, liquid crystals, and color filters, each of which requires numerous unit processes to manufacture. The cost is has a high proportion of component and material content; 68% of the total cost for a 40-in. LCD TV. Competition in the LCD industry has forced FPD prices to drop over the past two years, but component prices have been reduced accordingly and this has squeezed margins. LCD panel makers have probably reached their limit in cutting panel costs by adjusting each part price. They are now placing more focus on methods and technologies to trim costs in the manufacturing process. One area of R&D focus is the application of an inkjet printing process. Inkjet processing is currently under development for creating the TFT array, color filter, and alignment layer fields. TFT-LCD uses conventional lithography but the goal is to achieve cost reduction with nanoimprinting technology. Nanoimprinting is a way to form TFT patterns with ink jetting, the same basic method used in seal affixing. However, to jet-print an array of micro-scale TFT patterns, system designs, polymeric TFT pattern materials, patterning molds, and coating

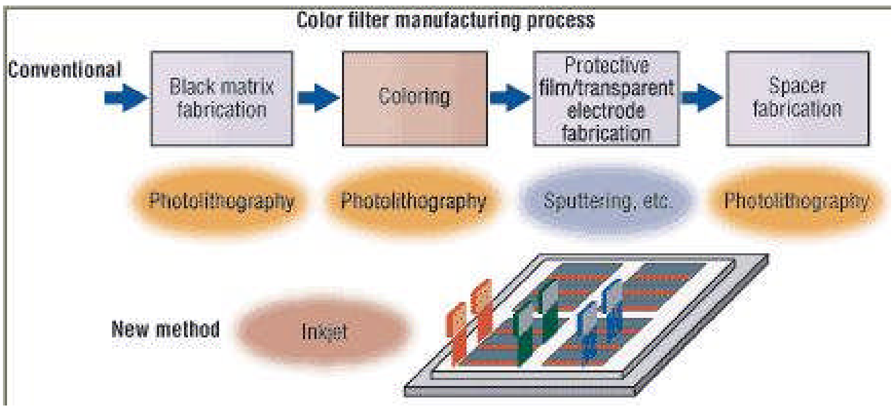


machines for stamping, stripping, and printing, all should be introduced simultaneously. LG.Philips LCD is developing nanoimprinting method called the anti-photo exposure method (APEM) **- *[See Figure].***



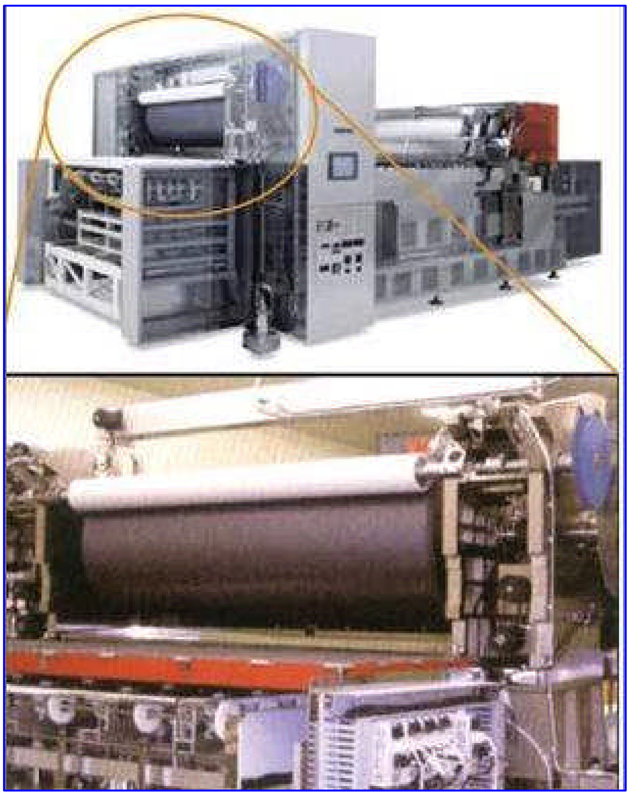
The use of APEM may be able to cut production costs, and here's why. The traditional photolithography process involves the exposure process for pattering that consumes photoresists and developers. But, the imprinting method eliminates the need for the exposure process and only uses the resists to lower material costs. In addition, the simple use of molds for printing, instead of masks, in the exposure process enables huge savings in facility expenditures.

The TFT patterning process will require equipment development, however, especially precision coating devices. The most important equipment is the stamper that will form fine patterns. Equipment companies are currently developing a process that hardens the polymer with evenly distributed contact using air pressure or simply the weight of the stamper. Ink jetting can also produce the color filter **[See Fig]**



Inkjet for color filters reduces material consumption, equipment costs, and substrate transportation. However, inkjet technology also requires co-development efforts for materials, systems, and equipment. Some printing issues include new ink technologies for better color reproduction, surface energy adjustment technologies between ink droplets and the substrate surface, printing precision technology enhancement to drop ink onto a desirable area, and technology for fine adjustment of the amount of ink droplets.

The LCD industrial appears to be switching to printing technology for coating the glass substrate with polyimide (PI) used for alignment layers. Today, alignment layer are applied by the spin-coating method. However, as the industry trends to larger substrates, the spin coating method doesn't provide layer uniformity over the large area and this can have a high scrap cost.



Ink jetting is an attractive solution for alignment layer coating and is currently under development. The new method is non-contact and vision systems will provide the precision alignment. However, since the new approach requires uniform PI on substrates, more development of both equipment and materials is needed to meet the demanding criteria. Japan's Nakan Corp. is a leader here. **[See Fig - Nakan's alignment layer printing/coating system].**

Development of inkjet printing technologies can reduce the cost of FPD manufacturing. This can also enable a roll-to-roll manufacturing process that will advance the emerging flexible display area. Source: Solid-State Technology.

CONFERENCES

Organic Electronics Conference to Break All Records - The OEC-07 (Frankfurt, Germany, 24-26 September 2007) conference sold out all exhibition space already sold months before the event, the speaker program is already filled and peer-review papers doubled compared to 2006. The 5-year old conference is set to be the biggest in its history. Organic Electronics Association (OE-A) is a sponsor and the key industry association for organic electronics. OE-A will talk about the expansion of its worldwide activities and the updated roadmap for organic electronics. They will also show projects of members and demonstrators that combine a large number of organic electronic modules with the objective of off the great potential of the technology. Organic Electronics Association is a working group within the German Engineering Federation (VDMA) and was founded in December 2004.The conference will cover all aspects of organic, flexible and printed electronics as well as organic semiconductor technologies. Presentations will come from BASF, Degussa, Dai Nippon Printing, DuPont, Kodak, LG.Philips, Merck, Siemens, Sony, and Samsung, as well as from organizations exclusively focused on organic electronics such as Cambridge Display Technology, CENAMPS, E Ink, Konarka, Nanoident, Novaled, OLED-T, Plextronics, PolyIC, Polymer Vision, printed systems, Sumation and Thin Film Electronics. Source: www.oec-europe.com.

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