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The future of electronics is print

Fair warning: This issue contains a preponderance of information about printed electronics.

Imagine printing out electronic prototypes on your desktop printer. That would give a whole new meaning to JIT manufacturing. Two converging technologies will make this possible some day—the printing industry and the electronic materials industry. The world of printed electronics includes: thin film transistor circuits (organic and inorganic), sensors, photovoltaics, sound and power, displays (of all kinds), materials (conductors, semiconductors, substrates), and manufacturing techniques (reel to reel, printing, spin coating, etc.)

Low-cost disposable electronic technologies provide opportunities to develop products that will change our lives. Applications include electronic smart packaging, such as the changing product use packaging date, sensors on drugs and foods, signage and large area displays, photovoltaics, Radio Frequency ID (RFID), healthcare applications, flexible displays, electronic inks, organic electronics, low-cost laminar batteries, sensors, and circuits.

Printed electronics will make an impact in RFID, driven by initiatives such as Wal-Mart's mandate to its supplier base. As tag costs are driven down, applications like food and medicine item-level tracking, record storage, store shelving, food, and medicine tracking become possible. Imagine the tagging of three trillion consumer goods manufactured worldwide. The added benefit of flexible substrates with operational electronics opens up new doors in areas such as packaging and display screens where flexibility is desirable.

Components are shrinking and high-volume manufacturing capabilities are needed to meet demand. Roll-to-roll manufacturing of components is made possible through printed electronics, increasing the ability to reduce per unit manufacture cost, and further driving down system cost savings. Volume capabilities demand the printing press. Because of the increased functionality that comes with digital manufacturing, inkjet capability can be one of the key drivers of the cannibalization of higher-end markets in the future. As multi-system inkjet heads are brought online and throughput is increased, the changeover to new digital production can be justified.

Research firm IDTechEx found that organic electronics will be a $30 billion business in 2015 mainly due to logic, displays, and lighting. It will be a $250 billion business in 2025, with at least ten billion dollars in sales from printed logic/memory, OLED displays for electronic products, OLED billboards, signage, and non-emissive organic displays, OLED lighting, batteries, and photovoltaics, with sensors at that level. Almost all of these products will be printed, flexible, laminar constructions using similar processes. Important other products such as laminar organic fuel cells and organic electrostatic and RF protection are also in the forecasts.

IBM, Advanced Micro Device, Infineon Technologies, and Micron Technology are some of the companies that are part of an effort to shrink electronics through printing. Dubbed Invent, for the International Venture for Nanolithography, the effort will be based at Albany NanoTech, a research and development center affiliated with the State University of New York at Albany.

Lithography uses light to trace patterns of circuitry as chips are created on silicon wafers. Advances in lithography tools are crucial for chip makers to continue shrinking the size of transistors, which allow each chip to provide more calculating power and store more data. The most advanced chips in production have widths of 90 nanometers, or billionths of a meter, and companies expect to begin introducing 65-nanometer chips in 2007. To reach 45 nanometers, however, chip makers are contemplating a new technology called "immersion," which injects a film of water between a projection lens and the silicon wafer to focus light beams more precisely. To achieve widths of 22 nanometers, semiconductor companies are expected to take an even more radical step called extreme ultraviolet lithography, or EUV.

DID YOU HEAR?

- Electronic messages to the House of Representatives doubled to 99 million from 2000 to 2004. In the Senate, the number of e-mails tripled to 83 million during the same period. Ironically, most offices reply to some or all of their e-mail with postal letters (washingtonpost.com).
- Asked about their media consumption habits, 61 percent of the respondents said they spend more time on the Internet today than a year ago, with 32 percent saying they spend "much more time," and 29 percent claiming to spend "somewhat more time" online. 36 percent said they are spending less time today than a year ago watching television, 34 percent spend less time reading magazines, 30 percent devote fewer hours to reading newspapers, and 27 percent listen to less radio (Burst!Media).
- Credit card issuers are on track to send us 6 billion mail solicitations this year (Synovate).
- 30 percent of graphic arts firms are producing some type of Web-to-print applications; 10 percent of graphic arts firms are using Web-to-print to produce variable data or customized/personalized marketing materials (TrendWatch GA).
- U.S. workers squander over two hours a day at the workplace, with surfing the Web, socializing with co-workers, and simply "spacing out." This costs $759 billion in annual paid salary that results in no apparent productivity (America Online and Salary.com).
- Publishers are experiencing a dramatic shift in their revenue mix. 15 percent of total revenue this year will be from the Internet. Internet revenue has been growing at more than 30 percent a year. In 2002, Internet revenue was only 6 percent of total revenue (101communications CEO Jeff Klein).

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TECH SHORTS

A new product, Das Keyboard, has a 104-key keyboard with blank keys. Each key is weighted by location to be more or less resistant to touch. It takes less force to make the Z key register than it does the F. It's really for geeks who can touch-type without looking. Some of us need to peek.

University of Texas students at Austin found something missing from the undergraduate library: books. Almost all of the library's 90,000 volumes were dispersed to other university collections to clear space for a 24-hour electronic information commons. As more texts become accessible online, libraries have been moving lesser-used materials. In this case, the books are being moved within the university's library system, home to some 8 million volumes and growing by 100,000 a year. Basic reference books like dictionaries and encyclopedias remain. It may be that the library is not so much a space where books are held as where ideas are shared. More and more libraries are delivering material *to* the user as opposed to the user *coming into* the library to get it.

Researchers have teleported beams of light across a laboratory bench. In the book, "Teleportation: The Impossible Leap," author David Darling contends that "Teleportation is going to play a major role in all our futures. It will be a fundamental process at the heart of quantum computers, which will themselves radically change the world." Darling suggests that some form of teleportation and replication for inanimate objects seems inevitable, but whether humans can make the leap remains to be seen. Teleporting a person would require a machine that isolates, organizes, and tracks over a trillion *trillion* atoms that constitute the human body, then sends that data to another location for reassembly without messing up their physical and mental makeup. Scientists at Hewlett Packard created a quantum computer using switches of light beams rather than transistor-based devices. What's needed is hardware capable of making calculations billions of times faster than any silicon-based computer. The day of the "Beam me up Scotty" technology is in a future far, far away.

There is a war between competing next-generation optical disc formats to replace the DVD standard for delivery of software, entertainment, video, and games. The Blu-ray Disc Association, supported by Apple, Dell, H-P, Panasonic, Philips, Pioneer, and Sony, and HD-DVD, backed by NEC and Toshiba, are both formats for high-capacity optical discs. The competing formats are not compatible with one another. Blu-ray Disc supports 25 GB on a single-sided disc and 50 GB on a double-sided disc, while HD-DVD supports 15 GB on a single-sided disc and 30 GB on a double-sided disc. Hollywood movie studios have split on support. Backward- and cross-compatibility: the ability to play today's DVDs on next-generation players is an important requirement.

Flat screen volumes are not so flat

Flat-panel displays are built by international conglomerates such as Samsung, which is so big it flattened the top of an Asian mountain for one of its factories. The United States may dominate the chip industry, but it has only a minor role in flat panel production. Applied Materials in Santa Clara, CA gives the U.S. one advantage in flat panel manufacturing—it makes the machines that make the flat panels.

Demand for liquid crystal displays (LCDs) is skyrocketing because they are used in so many consumer products. So far in 2005, LCD sales have risen 130 percent over last year, while prices dropped 30 percent. The displays are used in cell phones, laptops, computer monitors, and TVs. Panels are a $73 billion worldwide market.

Each machine has up to five chambers where chemicals are deposited onto glass sheets and each machine can process 60 sheets of glass in an hour. The chambers heat materials to 698 degrees Fahrenheit. To complete the display, a manufacturer will sandwich liquid crystals between the two sheets of glass. The machines can handle glass sheets about 74 inches by 87 inches and can be cut into many smaller screens or used as one large TV. Some companies are selling LCD TVs that are 65 inches diagonally. To display an image, an electric current passes through the liquid, which causes the crystals to align so light can pass through them or not.

LCDs are only one technology used for flat screens. OLED (Organic Light Emitting Diodes) and other methods are also used. Printing components for displays and the potential to use flexible, lower-cost substrates creates a new set of opportunities. Inkjet printed displays are already being shown, such as Epson's 42-inch prototype OLED display.

THIN FLEXIBLE COLOR ELECTRONIC—PAPER?

Fujitsu announced the joint development of the world's first film substrate-based bendable color electronic paper with an image memory function. The new electronic paper features vivid color images that are unaffected even when the screen is bent. An image memory function enables continuous display of the same image without the need for electricity. The thin and flexible electronic paper uses very low power to change screen images, thereby making it ideal for displaying information or advertisements in public areas. This new type of electronic media can be handled as easily as traditional paper.

Electronic paper, like real paper, is thin, flexible, and lightweight. It also boasts low power consumption because it does not require electricity except during screen image changes, making electronic paper well suited for advertisements or information bulletins in public places. Electronic paper is especially convenient for use on curved surfaces, such as posts and columns. Electronic paper can also be used in conjunction with mobile devices as an easy-to-read and portable display device. Many companies have r&d in this area.

Numerous R&D efforts are in progress in the field of electronic paper. However, thus far there had been no color electronic paper available that uses flexible film substrate capable of being bent without affecting the screen image and which features a memory function.

Key features of Fujitsu's electronic paper:

1. No electricity required for continuous display; minimal power consumption when changing screen image. An image memory function that enables continuous display of the same image even when electricity is turned off; therefore, no electricity is required for continuous display. Screen image can be changed using minimal electricity consumption equivalent to the weak radiowaves used in contactless IC cards. Fujitsu's new technology conserves energy by consuming only one one-hundredth to one ten-thousandth the energy of conventional display technologies.
2. High-level display performance. The new electronic paper is constructed of three displaying layers—red, blue, and green. No color filters or polarizing layers are required, and color is significantly more vivid than conventional reflective-type LCDs. Because the screen image does not require repetitive updates to be maintained, the screen does not flicker.
3. Flexible film substrate. The film substrate employing the new electronic paper can be flexibly bent and thus significantly widens the range of potential applications.

By leveraging the features of this technology, a wide array of applications are envisioned:

- Transit advertising, information displays on curved surfaces, and other public display applications that could take advantage of its light weight and flexibility. Information displayed can be updated based on the time of day, enabling more effective advertising and informational signage.
- Electronic shelf display tags, point-of-purchase displays, restaurant menus, and other in-store uses. Can also be used for pricing displays or product information displays that stand out in full color and can be readily updated.
- Operating manuals, work/task orders, and other short-term information displays will facilitate the trend toward paperless offices or factories.
- Text and/or images from mobile phones or other mobile devices can be transferred wirelessly to larger display screens for easy viewing.
- Use in the home can offer more convenient digital-media devices that can be carried from room to room.

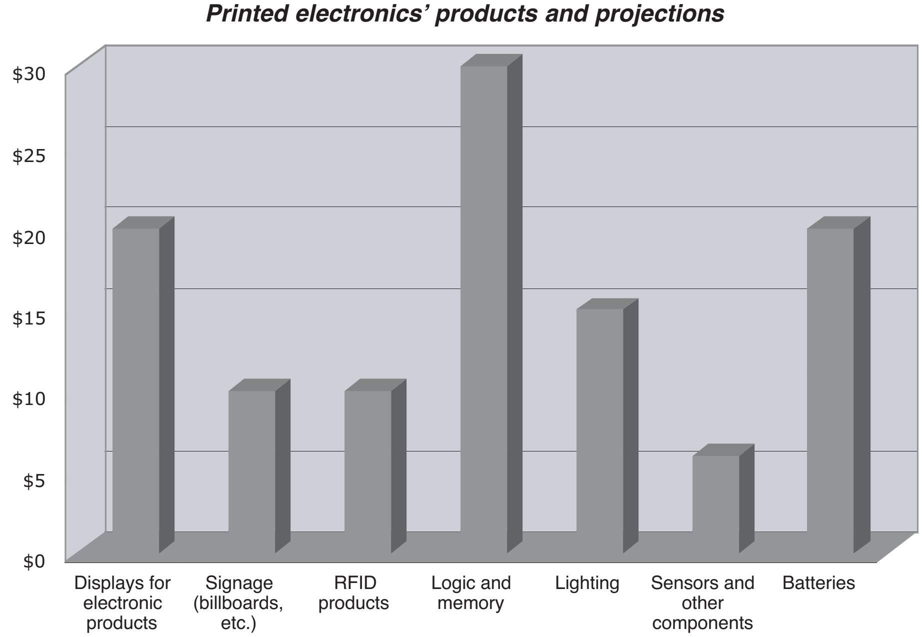
Printing DNA gives life to new chips

A group of scientists believes it has a nanoprinting technique that could lead to the mass production of DNA-based chips. Professor Francesco Stellacci of the Department of Materials Science and Engineering at the Massachusetts Institute of Technology has named a new DNA printing method "supramolecular nanostamping." The technology allows fragile single strands of DNA to assemble themselves on a surface to create a nanoscale duplicate of an original complex DNA pattern. The duplicate can then be used as a master to replicate additional copies of the DNA pattern.

It prints all DNA sequences at the same time, ultimately forming an information-rich pattern on a surface. Such patterns are found today on DNA microarray chips, which are made up of hundreds of thousands of dots representing DNA molecules of known sequences. Those sequences are used to analyze a person's genetic code in order to predict the onset of cancer or a couple's likelihood of having a child with a genetic disease.

DNA microarrays require over 400 printing steps. Stellacci's method requires just three printing steps, so it could bring the cost of such chips down from $500 to less than $50. At that price, routinely using the chips in many kinds of medical procedures and providing widely available genetic diagnostics would be feasible. Cost reductions would also carry over to lower costs for many kinds of procedures. A working prototype is expected in a year. Then, low-cost mass production of microarrays could make DNA analysis as commonplace as blood testing, which could lead to advances in disease detection and more.

Printed electronics' products and projections



In Billions of dollars, 2005-2010. Source IDTechEx and others.

Palaverous paper

Picture a card a little larger than a standard post card and as thick as two sheets of card stock with bumps on it. Press a little embossed button and talk to the card. Press another button and it plays the audio back—you have palaverous (talkative) paper.

Toppan Forms, a division of Toppan Printing, has a line of "Smart Media"—a term they use to encompass smart cards, RFID, audio paper, smart point-of-purchase, and smart shelf displays. They predict a $54 billion worldwide market for these digital products between now and 2010.

Their enabling printing expertise includes web handling of multiple stocks, ink jet printing, screen printing, flexo printing, offset printing, bonding, laminating, and registration.

To use Audio Paper, you push the "Record" button, speak and record for 20 seconds. You then push the "Play" button to play the recorded message. The recording stops when the "Play" button is pushed again. Audio Paper delivers a personal "Voice Message." Audio Paper can be used for greeting cards (birthday, holiday, etc.), message cards with gifts/parcels, postcards from trips, or instructions for the blind. There is a play-only version for business-to-business applications, such as direct mail (junk mail that speaks), music promotions, and sales promotional tools.

Toppan Forms' thin circuit manufacturing and assembly are the core production technologies. These printing and manufacturing technologies include: Printable Micro-Battery, Switch, Circuits, Sensor, Display, Capacitor, Resistor, and Transistor.

Protein semiconductors

Israeli researchers have created self-assembling organic semiconductors. Unlike inorganic silicon semiconductors, organic materials are naturally self-assembling. All the complex development and growth experienced by living things evolved from the self-assembly of atomically precise organic materials. Semiconducting proteins, called "electronic peptides," could enable lighter, cheaper, lower-power, flexible electronics.

By linking electronic peptides in protein chains like conventional polymers, organic semiconductors can both emit and detect light. It is predicted that emitting electronic peptides will enable foldable, color organic-LED displays with a higher resolution than possible with inorganic methods. The self-assembling methods for detectors could enable large-scale, flexible solar cells. Both displays and solar cells made from electronic peptides could be extremely flexible and easily rolled up like a blanket.

The research team's electronic peptides were synthesized following the same formula that nature uses to repair living cells—building up molecules consisting of long protein chains by assembling them from amino acids, which are the basic building blocks of life. While most organic materials quickly degrade when exposed to changes in humidity or temperature, the ultraprecise electronic-peptide material was found to be as durable as silicon devices. Currently, the researchers and a manufacturing company are attempting to integrate the electronic-peptide material into the normal fabrication lines used to create silicon chips.

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