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Printed Electronics

A new industry, in its embryonic stage today, can shape the future of printing, as well as just about every other industry on the planet.

By Jack Kenny

At Arizona State University, in Tempe, AZ, USA, is a research program called the Flexible Display Center. The center is working with the US Army to develop new information displays that will deliver high performance. They will be rugged, lightweight, ultrathin and compact, be made in any shape, and utilize low power. The electronics used to create the images on the displays will be printed on. The use of the future tense here is somewhat misleading. These displays exist today in prototype form.

At Clemson University, in Clemson, SC, USA, researchers from several different departments have been at work developing conductive polymer ink systems, work that has resulted in the filing of US patents. According to Jay Sperry, of the Department of Graphic Communications, the university is in a position to collaborate with advanced materials and engineering technologies to bring package printing and display to a level that involves many projects including organic light emitting displays. This work has attracted allied packaging industries and some large consumer product companies. Retail use? Nobody's talking.

PolyIC, a German joint venture between Leonhard Kurz and Siemens, is manufacturing thin, flexible chips that are inexpensive, simple and disposable. These are added to functional inks to build electronics, replacing metal circuitry, replacing three-dimensional works in ways barely dreamed of a decade ago. "We are trying to bring electronics where there is none today, and to make it disposable," says Wolfgang Mildner, managing director of PolyIC.

[Farther into the future medical scientists might be printing organs — laying down layer upon layer of organic material via application equipment similar to inkjet. This isn't so farfetched: experiments in printing small vessels is under way. It might seem like science fiction, but so did Star Trek 40 years ago. Now every kid has a flip phone.]

Unlimited potential

Printed electronics is the application of conductive and electronic components onto a material by means of a printing process. It might not occur on a conventional press, but the applied product will be liquid or semi-liquid in form, and will cover a substrate in a pattern.

The uses for such technology are almost unlimited, and the benefits are numerous. Lighting, displays, batteries, communications devices, sensors — these consume power and raw materials that are expensive today. If the circuitry is printed on a thin substrate, the cost is reduced, the weight is reduced, the disposability might be enhanced, and the ubiquity of the devices will grow.

Some of these products are in production today. Consider the work by Pelikon, a UK company that manufactures a flexible plastic display. Chris Fryer, the chief technology officer, says that the printed displays can be cut to any shape and are 10 times thinner than an LCD. "They can be sited in places and on products not previously possible," he says. At an IDTechEx conference on printed electronics in December, Fryer said that the versatility of the printed electronics on the displays enables the product to become more user friendly.

As an example, Fryer referred to the remote control device accompanying the home entertainment centers manufactured by Universal Electronics. The center lets the user control up to eight distinct electronic devices, and conventional remotes can and do appear cluttered with buttons. The display created by Pelikon for the entertainment center's remote shows only eight icons, one for each main function. When touched, the controls for that function alone — the television, perhaps — appear on the screen. If another system is required — the surround-sound, for example — a touch of that icon will illuminate only those controls. All of this takes place on one small panel.

Printed remote control displays designed by Pelikon.

Fryer said the company has developed a display for microwave ovens that also takes the dizzying complexity away from the operator's view and permits actions that are more simply directed by a select few visuals.

Developments in papers and plastic substrates can make new printed electronics opportunities possible. Papers themselves soon are expected to reveal displays — imagine the shelves in the grocery store when labels begin competing in motion. Displays will appear on credit cards and other security products. Indeed, the security industry will be a major customer of printed electronics.

The list of potential users appears to include everyone: healthcare and pharmaceutical, security, automotive and aviation, manufacturing and logistics, retail, and military of course.

The military often is a mover in new technology. At Arizona State's Flexible Display Center (FDC), work is in

progress for printed electronic displays to replace the entire cockpit screens in fighter jets. Sophistication is necessary, as is lightweight and easily disposable (replaceable) components. The soldier, the single combat unit, also will benefit. The 150 pounds of equipment carried by a special operations soldier can be drastically reduced if metal and other components are replaced by printed electronics. Work is in progress on this as well, according to Gregory Raupp, director of the FDC.

“These displays will provide soldiers with real-time mission updates, logistical information and detailed maps,” Raupp says. “They will download data or maps from a satellite to clarify a squadron’s position or provide details on the location of enemy forces. Once the size of the display has been increased (today it’s 4" in diameter, and planned for 12" by 2008), work will focus on applying advanced touch screen elements.

“Enabling soldiers to add or write data on the display is definitely a future target,” adds Raupp. “The display will be lightweight, consume very little power, and will be rugged and able to withstand high levels of heat and vibration.”

Conventional polymer films are used as the main substrate material, but Raupp says that thin layers of stainless steel will also be tested. Stainless steel is much more flexible than plastic and can be cut to a near transparent layer.

The center’s work will not be enjoyed only by the military. “The FDC was established to accelerate commercialization of flexible displays and to provide new, early capability to the army,” says Raupp. “The FDC has created a one-of-a-kind partnership to enable rapid development of dual-use flexible display technology and transition to the military and commercial world.”

Beyond silicon

Raghu Das, CEO of IDTechEx, an education and consulting company based in England, says that the two key benefits of printed electronics are the low costs of materials and manufacturing, and that circuits can be deposited onto flexible substrates such as plastic film and foils.

Das says that while silicon based components are dominant, other semi-conductive materials are being developed. “Now more than 50 companies, from start-ups to blue chips, are working on alternatives by using the semi-conductive properties of other materials, such as organic semiconductors (e.g., conductive plastics) and inorganic semiconductors (e.g., carbon nanotubes). Organic semiconductors, the most popular of the flexible electronic options so far, are based on large or small molecule plastics which are conductive. They can be deposited to form a functional transistor, and ever more functional and complex circuits. They can be printed using high resolution printing processes such as inkjet printing, lithography, gravure; and unlike silicon, other components such as batteries, sensors, displays, etc., can be printed using similar materials and processes.”

Two other printing processes, flexo and screen, will figure in the mix. GSI Technologies, of Burr Ridge, IL, USA, has been manufacturing batteries for several years using screen printing for the application of the components. The company also produces RFID tags and labels using proprietary screen printing equipment.

“Printed electronics,” Das continues, offers the possibility of using electronics in applications where the cost of silicon would have made it impossible or where silicon properties — such as size or rigidity — are inadequate. Suitable applications include either ‘small area’ electronics, such as electronic sensors and the changing use-by date on a pack of meat or medicines; ‘large area’ electronics, such as billboard size electronic displays, solar cells, lighting and sensors; or where flexible circuits are needed, for example: displays for computers, signage and posters where the flexibility of the display adds much needed robustness.”

Peter Harrop, chairman of IDTechEx, says that the impact of printed electronics on society will be immense. “Transparent solar cells will be on watches by year end and vast areas of printed flexible photovoltaics will be available within the next few years. Polymer alternatives will have lower efficiency but often be lower in cost. Announcements have yet to be made,” he adds, “but we have identified several companies that will be commercializing polymer solar film in 2007.

“Light emitting moving color displays, vehicle and room lighting on flexible substrates, the electronic book and many forms of disposable electronics are near to mass rollout. An example of a Sony e-book developed with e-ink electrophoretics is on the market. Some new versions are flexible and use printed polymer thin film transistor circuits Plastic Logic as back plane drivers. Working samples of these have been widely available in 2006. None of them require a voltage to retain the image.

Last year, Harrop says, drug packs with printed sensors and sometimes printed batteries were produced. “These have unique electronic identification and they record which pill was removed when, because 50 percent of patients take their medication incorrectly. Initially they are being used to improve drug trials, such as the National Institute of Health trial of Azithromycin and a Novartis trial this year.

“We already have flexible, electroluminescent color displays from billboards to animated watch backgrounds. In 2007 we will see improved versions selling in very large numbers.”

Toys and power grids

According to IDTechEx, the potential markets for low cost printed and thin film photovoltaics vary from

feeding national power grids to use on smart packaging and toys. “We need photovoltaics that are one tenth of the manufacturing cost and installation cost of today’s silicon solutions and with none of their supply shortages,” Harrop says. “Within reason, it will not matter if the replacement has a larger footprint, particularly if it is flexible and/or transparent. If its efficiency is 5 to 10 percent vs. double or treble that for silicon, it will not matter in most applications because the other benefits will prevail. For example it can go over a window or conform to the shape of a vehicle. However, it is a challenge to achieve the 10,000 hours life necessary for an entry level printed product and 50,000 hours for mainstream use. The same can be said of OLED displays, signage and lighting on flexible film, but progress is being made and products are starting to sell.”

An OLED (organic light emitting diode) is made not of semiconductors but of carbon based molecules. That factor, scientists say, could potentially eliminate the LED’s biggest drawback — size — because carbon molecules are much smaller. OLED flat panel displays are said to be brighter, thinner, lighter, and faster than the normal liquid crystal display (LCD) in use today. And they require less power to run.

According to Harrop, they have great potential in the printed electronics field for years to come. Work with OLEDs is in progress worldwide, at military research facilities as well as at Motorola, Xerox, Merck, Honeywell, and more.

A future niche

For some — such as GSI — printed electronics is here already. For others in the narrow web converting field, the field provides immense potential. Converters are eager for that new and profitable niche, and while this particular embryonic industry certainly appears daunting, its arrival is all but certain.

Already an association has taken shape to further the cause of printed electronics. The Organic Electronics Association (OE-A) was founded in 2004 by more than 60 members from seven European countries and the US. The OE-A’s first annual report takes a realistic view: “Although this technology has a huge potential, market forecasts are bright and first products have entered the market — materials, equipment, processes, and applications have to be developed and improved.”