The Truly Integrated Circuit is Printed and Flexible

Dr Peter Harrop, Chairman, IDTechEx

 For 40 years, so called integrated circuits have integrated little more than transistors, diodes and sensors assembled onto one piece of material. Now there are much more highly integrated circuits arriving where most electrical and electronic components are co-deposited on flexible substrates. Those flexible substrates are key, because this new electronics will be affordable and desirable on everything from apparel to human skin and electrical and consumer packaged goods, where surfaces are only rarely flat.

Savvy designers, seeking to use the new electronics to create "The iPod of labels", or some other blockbuster product, think of the flexible substrate as part of functioning of the product. For example, there as flexible films that emit and detect ultrasound, act as loudspeakers or change shape under an electrical field. The latter use electroactive polymer film and the recent purchase of Artificial Muscle Inc AMI by Bayer MaterialScience is a nice reminder that there are plenty of exits for venture capitalists backing these new printed electronics companies.

Stretchable electronics

AMI polymer films, with printed stretchable electrodes, are used in the development, design and manufacture of actuators and sensing components. They offer significant advantages over traditional technologies used in this area. They provide touchscreen panels in consumer electronics with "awareness through touch" by creating authentic tactile feedback, just like a conventional keyboard. This innovative technology has significant application potential, particularly for electronic devices like smart phones, gaming controllers and touchpads. AMI initially targeted products for a range of applications including valves, pumps, positioners, power generation, snake-like, self-aiming camera lenses and sensors. With the emergent need for haptics in consumer electronics, particularly in touchscreens, AMI used EPAM™ to create the Reflex™ brand of haptic actuators. These products are targeted at a wide range of consumer electronics including smartphones and other portable electronics, computer peripherals, gaming controllers and touchpads.

Meanwhile, MC10 Inc, a company formed to commercialize stretchable electronics, has recently made a licensing agreement with the University of Illinois at Urbana-Champaign. According to the terms of the agreement, MC10 Inc. will gain access to technology contained in patents dealing with stretchable silicon technology from Professor John Rogers' laboratory. The venture-backed startup is currently developing processes and applications that enable high performance electronics to be placed in novel environments and form factors. MC10's approach transforms traditionally rigid, brittle semiconductors into flexible, stretchable electronics while retaining excellent electrical performance. Stretchable silicon allows for a degree of design freedom capable of expanding the functionality of existing products whilst providing a platform on which new microelectronic-enabled applications can be developed.

Surgery

In a completely different approach, the electroactive devices of Artificial Muscle AB in Sweden, with stretchable printed electrodes, make surgeons' tools snake through the human body. Researchers at Purdue University have created a magnetic "ferropaper" that might be used to make low-cost "micromotors" for surgical instruments, tiny tweezers to study cells and miniature speakers. Control and monitoring electronics and electrics can be printed onto this new smart paper. The material is made by impregnating ordinary paper - even newsprint - with a mixture of mineral oil and "magnetic nanoparticles" of iron oxide. The nanoparticle-laden paper can then be moved using a magnetic field.

"Paper is a porous matrix, so you can load a lot of this material into it," said Babak Ziaie, a professor of electrical and computer engineering and biomedical engineering.

The new technique represents a low-cost way to make small stereo speakers, miniature robots or motors for a variety of potential applications, including tweezers to manipulate cells and flexible fingers for minimally invasive surgery.

"Because paper is very soft it won't damage cells or tissue," Ziaie said. "It is very inexpensive to make. You put a droplet on a piece of paper, and that is your actuator, or motor."

cPaper

Kimberley Clark is one of the latest to announce a smart substrate suitable for printed electronics. Its cPaperTM is paper impregnated with carbon rather than the more expensive carbon nanotubes and it can be used as heating elements, electrodes in printed supercapacitors and supercabatteries and in many other applications.

Organic impregnated conductive paper

In a different approach, the University of Uppsala in Sweden may be on the way to improved printed batteries. It is developing a novel nanostructured high-surface

area electrode material for energy storage applications composed of cellulose fibers of algal origin individually coated with a 50 nm thin layer of polypyrrole. Results show the hitherto highest reported charge capacities and charging rates for an all polymer paper-based battery. The composite conductive paper material is shown to have a specific surface area of 80 m2 g?1 and batteries based on this material can be charged with currents as high as 600 mA cm?2 with only 6% loss in capacity over 100 subsequent charge and discharge cycles. The aqueous-based batteries, which are entirely based on cellulose and polypyrrole and exhibit charge capacities between 25 and 33 mAh g?1 or 38?50 mAh g?1 per weight of the active material, open up new possibilities for the production of environmentally friendly, cost efficient, up-scalable and lightweight energy storage systems.

Paper-e

Also newly arrived is the Paper-e of the New University of Lisbon, which is an inspired way of printing transistor circuits by making the gate of the transistor the paper substrate itself. Interestingly, these transistors, made with the superior, new zinc oxide based printed semiconductors ,have much better characteristics than one would expect at first sight and the physics of this is currently being clarified. Needless to say, all the above smart papers for printed electronics can be environmental and biodegradable.

Printed smart shelf

Plastic Electronic GmbH in Austria specialises in capacitive printed electronic structures. For example, its smart shelf consists of polymer film that deforms when things are placed on it and the crossbar conductive patterns on both sides monitor the change in capacitance and thus the position and relative weight of what is on the shelf. Now NTERA, Inc., a leader in all-printed, flexible, colour change display technologies, and plastic electronic GmbH, have entered into a license agreement to develop advanced printed electronics products using NTERA's flexible printed electrochromic displays.

Piezo flags and eels

Polyvinylidene difluoride PVDF and its derivatives are made into ferroelectric ink used to print non- volatile rewritable random access memory on flexible film. It can also form a film itself that forms a smart substrate for printed electronics, examples being electret microphones and energy harvesting "flags" and, under the water, "eels".

Smart barriers

Barrier layers to protect delicate printed organic photovoltaic and OLED displays are receiving close attention. Hugely improved barrier layer substrate film is announced by DNP & 3M Display & Graphics Business Lab and companies such as DELO are developing barrier adhesives and inks to go over the patterns printed on these barrier films and to seal encapsulation.

Edible and transparent electronics

Edible printed electronics from Eastman Kodak and Somark Innovations is initially intended to be applied directly to food, pharmaceutical tablets and meat but edible substrates will also be needed, preferably leveraging the electronic functions. Then there is the new discipline of transparent electronics being pursued by Hewlett Packard, Cambridge University in the UK and Fraunhofer ISC in Germany for example.

The largest event on the subject

The largest event on the subject is Printed Electronics Europe and many of the above organisations will be presenting as well as other leaders from across the world. The event will run 13-14 April in Dresden, Germany and includes two full days of conference and exhibition, Masterclasses, and Company Tours. For full details and to register, visit www.IDTechEx.com/peEUROPE [1].

Links:
[1] http://www.IDTechEx.com/peEUROPE