Plastic electronics: a neat solution

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Printed electronic test circuit manufactured on a flexible plastic substrate at the Cavendish Laboratory, University of Cambridge. Credit: Enrico Gili

(Phys.org) -- A breakthrough in the development of a new generation of plastic electronic circuits by researchers at the Cavendish Laboratory brings flexible and transparent intelligent materials – such as artificial skin and interactive playing cards - a step closer.

The sense of touch is something we take for granted. The sensitive nerves in our finger tips generate a flow of information to our brains that enables us to do things that require extraordinary precision. Reaching out for an object in the darkness, we are able to tell in a split second what we're touching and how to respond. Artificial skin with the ability to process information – such as texture and temperature – has long been the holy grail of researchers working on the next generation of electronics. Artificial skin, which has potential in areas such as robotics, and other products are now within our grasp as the result of recent research into the exciting field of plastic electronics.

Initially discovered in the late 1970s, plastic electronics is an expanding technology that is bringing us a myriad of products incorporating flexible and transparent electronic circuits in which the active materials are deposited as printable inks onto polymer-based substrates using various printing technologies. Rather than relying on conventional, rigid and brittle silicon chips to process information, plastic technology relies on novel organic materials which can be printed, just as coloured inks can be printed on paper. Plastic electronic circuits have the potential to be printed in a small laboratory containing one or two printing tools, whereas state-of-the-art microchip factories are about the size of three football fields and require purpose-built facilities.

However, the full commercial potential of plastic electronic circuits has been hampered by their lower speed and by the requirement of high supply voltage (of the order of 100 V), which meant that they were unable to compete with conventional silicon-based electronics especially in off-the-grid applications, which are the most attractive for this technology.

A breakthrough by researchers at the University of Cambridge's Cavendish Laboratory lays the foundation for plastic electronic circuits that are fast, flexible and have low power consumption – as well as being cheap and relatively straightforward to produce. Physicists Dr. Auke Kronemeijer and Dr. Enrico Gili, working in the Cambridge team led by Professor Henning Sirringhaus, have developed a technology based on solution-processed organic semiconductors that will find a wide range of applications in everyday life – from radio frequency identification (RFID) tags on supermarket packaging to transparent displays embedded in car windscreens displaying vehicle speed or satellite navigation directions.

Put simply, the new technology provides a simpler way to fabricate plastic electronic circuits with relatively high performance. Dr. Kronemeijer said: “Our research shows that it’s possible to produce electronic circuits using a new class of ambipolar organic materials that simplify considerably the fabrication process compared with more traditional materials. Typically, to fabricate high performance plastic electronic circuits you need two different active materials. Our technology obtains the same result using only one material. This is an ink that can be printed and requires little more than room temperature to reach its peak performance. Conventional silicon chips, on the other hand, typically require more than 1000degC to be fabricated. The robustness and flexibility of our new material opens up the possibility for developing all kinds of intelligent products such as clothing items that interact with their wearer.”

Countless reports have predicted a future in which we will enjoy roll-up TV screens in our homes and buy phones with rollable display screens. But so far, these products have been restricted by the reliance of plastic electronics on high voltage power supplies which makes them cumbersome and impractical. Typically such circuits would operate at a speed of a few hundred Hz and would require input voltages of several dozens of volts – while the consumer would expect the devices to have embedded printed batteries able to supply all the power needed. The new circuits developed by Drs Kronemeijer and Gili exhibited the fastest operation published to date using this class of materials (a few hundred KHz) and reduced the power supply requirements by approximately one order of magnitude so that they can already be operated using a standard 9 V battery.

The physicists are confident that they will be able to reduce the power supply requirements further to make this technology suitable for ubiquitous electronic devices incorporating printed power supplies. This was achieved by using new ambipolar organic materials developed by

Dr. Martin Heeney's team at Imperial College, London, exhibiting carrier mobility in excess of 1 cm2/Vs. Moreover, these materials conduct both electron and holes, making the use of two different materials (such as in complementary logic circuits) redundant.

The integration potential of the new technology will open up possibilities for the production of entirely new products as well as lighter, more flexible versions of existing products. Dr. Gili explained: "Take an item such as a hand held solar powered calculator. This requires several discrete components contained in a bulky casing, such as a solar cell, back-up battery, silicon chip and LCD display. Using plastic electronic technology, all these components could be integrated on a single plastic substrate by simply printing different inks in different areas. Moreover, the end result would be a transparent piece of flexible plastic performing similar operations to the original, bulky calculator. Although the circuitry may not be powerful enough to perform very complex calculations, this opens up a multitude of novel applications, such as interactive playing cards or self-powered customisable business cards."

Forty years after the introduction of microchips which have revolutionised our life with consumer products such as computers, mobile phones and TVs, it's hard to remember a world without them. Will this new generation of plastic electronics replace the technologies used in the day-to-day products that we have come to rely on? Dr. Gili said: "The new technology has broad applications in areas such as display technology and ubiquitous sensor networks. It is not likely to replace silicon chips in computational-hungry applications such as PCs, but is has the potential to open up a whole new range of exciting applications of plastic electronics which will be cheaper and easier to manufacture, flexible and easy to customise."

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