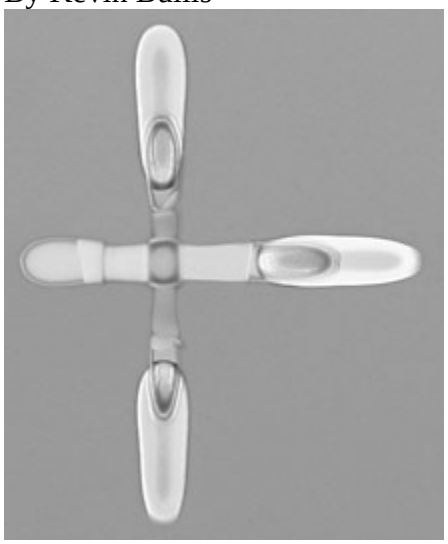
Printing Cheap Chips

Kovio's new technology for printing inorganic transistors could lead to large-area displays and ultracheap smart cards.

By Kevin Bullis



Printing processors: Printed transistors such as this one could bring microchips to everyday objects. Different inks are used for various parts of the transistor, which include the electrical contacts, the source and drain (top and bottom), and the controlling gate.
Credit: Kovio

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After years in "stealth mode," a company founded to commercialize technology originally developed at MIT's Media Lab has announced a new process for printing transistors for memory and logic chips, as well as analog devices for radio. Since the technology uses commercial printing equipment such as inkjet printers, it could be a cheap and easy way to make high-performance microchips.

The first products made by the company, Sunnyvale, CA-based Kovio, will likely be disposable smart cards for public transportation, which could be available by the end of next year. Eventually, the technology could help enable a range of applications, including wall-sized displays.

Kovio is one of a number of companies developing ultracheap alternatives to conventional microchips by replacing conventional photolithography methods with printing techniques. Such processes produce larger transistors than conventional chip-making methods--a printed chip might have a thousand transistors, rather than hundreds of millions--and won't likely compete with the microchips used in computing or consumer electronics. But because printed electronics are cheap to make, they could lead to the use of microchips in a large range of common objects, as well as large displays that cover, for example, an entire wall.

What sets Kovio apart from most printed electronics companies is that it uses inorganic semiconducting materials, such as silicon, rather than organic materials such as conducting polymers. Although they cost a bit more, the inorganic transistors have 100 to 1,000 times better performance than organic transistors, says Vivek Subramanian, who works on printed organic electronics at the University of California, Berkeley and is a technical advisor to Kovio. Organic materials are cheaper and can be easier to work with, but inorganic materials, and the processing techniques Kovio has developed, make it possible, for example, to produce radio devices that switch at speeds fast enough to meet current RFID standards.

Amir Mashkoori, Kovio's CEO, says the company can print memory and energy-efficient CMOS logic devices, as well as analog circuitry for radios, to make RFID tags that cost less than a nickel. To do this, they've developed a variety of inks, including nanocrystalline metals for electrodes and connections between devices, doped silicon semiconductors, and insulating materials. Kovio's process makes use of several types of commercial printers, including inkjet models. The printing is followed by a curing process. Kovio estimates that its system requires just 5 percent of the materials and a quarter of the electrical power used in conventional chip-making processes, with equipment that costs a third as much.

Within five years, the cost for some applications could fall to just a penny a piece, Mashkoori says--cheap enough for stores to replace barcodes with RFID tags. Such tags could make tracking inventory much easier. Eventually, consumers may be able to read the tags with their cell phones to confirm that a product complies with their dietary restrictions or to keep a tally of the cost of items in their basket. Items could be paid for by walking past a reader and accepting the charges.

The higher performance of inorganic devices could also prove useful for organic LED-based displays, says John Rogers, professor of materials science and engineering at the University of Illinois at Urbana-Champaign. Printing techniques are effective at distributing transistors over large areas, which is why they are good for making large

displays. Indeed, Rogers suggests printed electronics may ultimately prove most suited to large-area applications.

Kovio's process was originally based on research by Joseph Jacobson, a professor at MIT's Media Lab. (See "Print Your Next PC.") His goal in part was to develop a printing process that used low temperatures compatible with plastic substrates, which could be useful for producing some types of flexible displays. For this he developed inks made with semiconductor nanoparticles that melt at lower temperatures than the bulk form of the semiconductor materials. He cofounded Kovio in 2001, and the company almost immediately went into stealth mode as it developed the technology for commercial applications. But over the years, at the urging of potential customers, the company put more value on device performance than on low-temperature processing. The new methods use higher-temperature processing of the materials after printing--these can still work with a flexible substrate, Subramanian says, but it must be a metal foil, rather than plastic.

The trade-off came in part because of the need to make RFID tags that work with current radio-frequency standards. At first the company could only print radios that worked in the kilohertz range, says Walter Bonneau, a senior vice president at San Diego-based Cubic Corporation, which supplies smart-card systems for major transit systems. But RFID standards demanded megahertz-range devices, he says. Switching to higher temperatures and higher performance devices made it possible to reach the necessary frequencies.

The switch helped persuade Cubic to sign a development and supply agreement with Kovio. (Kovio also announced such an agreement with Toppan Forms in Japan.) The technology could be perfect for replacing magnetic stripe cards, Bonneau says, which are currently used for disposable limited-use passes, with faster, more reliable smart cards. Current contactless smart cards of the type used by frequent travelers on major transit systems can cost as much as $5 a piece to produce. But Kovio's technology could soon lead to nonmagnetic smart cards that cost a nickel.