Tuesday, December 19, 2006

Making Nanoelectronics for Displays

A new way to print devices made of diverse materials could prove to be an invaluable tool in making nanoscale electronics and optics.

By Kevin Bullis

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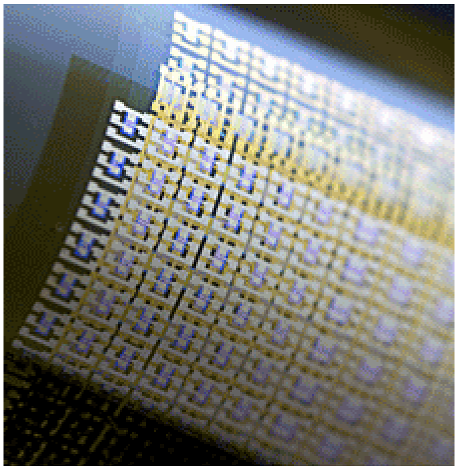

A new method of printing layers of high-performance transistors on a sheet of plastic could lead to flexible electronics.
Credit: John Rogers, University of Illinois, Urbana-Champagne

A new, inexpensive way to make nanoscale electronics could lead to, among other things, better displays, more-compact and higher-performance cell phones, and small wide-angle night-vision systems that mimic the structure of the human eye.

John Rogers, professor of chemistry and materials science and engineering at the University of Illinois, Urbana-Champaign, and his coworkers have developed a printing technique that allows them to combine a wide variety of inorganic structures, such as single-walled carbon nanotubes, assorted nanoscale wires, and ribbons made of gallium arsenide or silicon, to create multilayered, high-performance optical and electronic devices. They can also print on flexible or curved surfaces.

"This is a lovely and remarkably complete piece of work, and [it] provides probably the best method to date" for integrating dissimilar materials onto one platform, says James Heath, professor of chemistry at Caltech. It has been a challenge to do this in part because the manufacturing processes, including high-temperature deposition, that are needed for some materials can damage others. Rogers's method makes it possible to process incompatible materials separately but then combine them using a low-temperature process onto a variety of surfaces, including flexible plastic ones.

Rogers's method, which is described in the current issue of *Science*, begins with the fabrication of nano- and microstructures, such as an array of semiconducting silicon nanowires, using conventional techniques. The researchers then press a soft stamp onto these structures, and when the stamp is peeled away, the structures stick to it, much as dust will cling to a strip of tape. The nanostructure-bearing stamp is then pressed onto another surface that is covered with a glue-like polymer. Once this polymer cures, it adheres to the nanostructures more strongly than to the stamp: when the stamp is lifted off, it leaves the nanostructures behind, still ordered in the same configuration in which they were originally patterned. This is then repeated for the other structures.

Once the nanostructures are in place, the researchers use conventional techniques to deposit electrodes and other structures to make working devices, such as transistors. Different nanostructured materials, such as carbon nanotubes, can be printed next to the first ones on the same surface.

The method can also be used to make multilayered systems. After the first layer of devices is printed, the researchers coat it with a thin layer of the polymer glue. This serves to anchor the next layer of devices, as well as insulate between the layers. Because the polymer is thin, small holes can easily be etched into it to allow connections between selected devices in different layers.

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By making it possible to easily integrate dissimilar materials onto one surface, the method could lead to smaller, more compact devices. Many electronics and optoelectronics already rely on different types of materials to perform different functions. For example, a cell phone might use high-performance gallium-arsenide semiconductors to handle high-frequency radio signals, but it might also use less-expensive conventional silicon for data processing. In the past these couldn't be easily incorporated into a single chip. One option--mounting chips side by side on a circuit board--wastes space and makes it necessary to build long, performance-degrading connections between components. In other methods, such as building up layers of wafers or depositing different materials on the same chip, the temperatures used to process some materials can limit the sorts of materials that can be combined. This can also make it impossible to place the electronics on some types of flexible surfaces, such as polymers.

The method could have an impact on various aspects of the display industry. Today's flat-screen LCD televisions are made in enormous, expensive chambers in which the electronics that control individual pixels in the display are formed on large slabs of glass. Rogers says his technique could make it possible to form these electronics in smaller batches in less expensive machines. His process could then transfer the electronics section by section to the displays to cover the glass surface. The smaller batches would also make it possible to create higher-performance silicon in these electronics, Rogers says, which would improve the response time of LCDs.

Improving LCDs is only the first step. Rogers says the technique could make it feasible to build televisions using bright and colorful light emitting diodes (LEDs) of the type used in the enormous screens at sports arenas. Because the printing method would make it easier to integrate the materials needed, the LEDs could be much smaller and more tightly packed than these large-format displays. And since the printing technique can make high-performance devices on flexible substrates, it could pave the way to roll-up LED displays.

The ability to print onto a curved surface could also make it possible to mimic the compact structure of the human eye, which could lead to smaller night-vision equipment, Rogers says.

Semprius, a University of Illinois spin-off based in Research Triangle Park, NC, has an exclusive license on the technique. Much work remains to be done to demonstrate that the device can scale up from making a handful of devices to reliably making millions for displays and night-vision systems. But Takao Someya, professor of engineering at the University of Tokyo, says that unlike past methods, which have been stymied by costs, Rogers's method offers "an ideal solution."

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