[Technology Report]

When Small Gets Big

Nanotechnology promises a new generation of microscoping power-saving and performance-boosting electronic devices. But will it really live up to the hype?

John Edwards | ED Online ID #15858 | June 29, 2007

Article Rating: **Not Rated**

George Malliaras and his colleagues recently had a bright idea—literally. As director of the Cornell University NanoScale Facility, he is among several researchers working on nanolamps—light-emitting microfibers no larger than a virus. The technology promises a new generation of flexible displays that can be integrated into a variety of products and perhaps even woven into clothing. "Here we have devices made out of fiber," Malliaras said. "You talk about textile, and your mind doesn't necessarily go to electronic devices."

Hot Or Hype?

Whether it's tiny fiber lamps, molecular-level memory circuits, or any of the hundreds of other small-scale innovations currently being investigated, nanotechnology has emerged as one of the most important research developments of the 21st century. Often compared to fundamental technological breakthroughs like the steam engine, the transistor, and the Internet, nanotechnology promises a new generation of innovative, power-saving, and performance-boosting electronic devices. It will also help electronics continue on its march toward ever smaller and denser devices.

"We're going to have to have some fundamental change in the way that we put electronic devices together if we're going to increase their performance in the years ahead," said Andrew Maynard, emerging-nanotechnologies chief science advisor to the Woodrow Wilson International Center for Scholars, a non-partisan think tank created by Congress. "Because we try to cram so much stuff into such small spaces, nanotechnology is the only going to find new solutions."

Vahé Mamikunian, a senior analyst at Lux Research, a market research firm for emerging technology, predicts that nanomaterials will b billion market by 2014 while sales of nano-enabled products will become a $1.82 trillion market by that same year. "As nanotechnology will open up a new paradigm of electronics where electronic products will become even more ubiquitous," Mamikunian said.

Lofty sales projections and comparisons to breakthrough technologies of the past led a number of critics to accuse nanotechnology boo hyping the field's prospects. Mamikunian acknowledges that while some researchers may be inflating their projects' importance to attrac venture capital or government funding, his research finds that plenty of hard-nosed business cash is flowing into the field. "There has be almost equal amount of corporate funding," Mamikunian said. "That's not something that is generally vocalized."

According to Mamikunian, big businesses ranging from electronics giants like Intel and Motorola to chemical powerhouses such as BAS are intensely interested in nanotechnology. "Companies of these sorts are looking at nanotechnology as a way to further the progress o industries they are active in," he said. "They're serious about nanotechnology."

Cellular Level

Molecular-level storage is one promising area of nanotechnology. In 1959, physicist Richard Feynman predicted that it should be possit to store all of the Encyclopedia Britannica on the tip of a needle.

Although this goal hasn't yet been reached, joint nanotechnology research at the University of California at Los Angeles (UCLA) and the Institute of Technology (Caltech) may give storage technology a big shove in that direction. These institutions' researchers created a me the size of a white blood cell that contains the capacity to store the Declaration of Independence. The device's 160-kbit capacity makes densest memory circuit ever created.

Lit Up

On the other side of the country at Cornell University, scientists are continuing to investigate nanotechnology's potential as a cheap and electronic light source. Made from a compound based on the metallic element ruthenium, the researchers' nanolamps are smaller than t wavelength of the light they emit.

Using a technique called electrospinning, the researchers spin the fibers from a mixture of the metal complex ruthenium trisbipyridine ar polymer polyethylene oxide. The fibers give off orange light when excited by low voltage through micropatterned electrodes, like a tiny li *(Fig. 2)*. The synthetic fibers are just 200 nm wide. Malliaras compares the production technique to pouring syrup onto a pancake locate spinning table.

As the "syrup" (a solution containing a metal complex-polymer mixture in solvent) is poured, it forms a spiral pattern on the "pancake," a containing micropatterned gold electrodes. A high voltage between a microfabricated tip and the substrate ejects the solution from the ti a jet that's stretched and thinned. As the solvent evaporates, the fiber hardens and lays down a solid fiber on the substrate.

Malliaras notes that the tiny light-emission devices can be made with simple fabrication methods. Compared with traditional high-resolut lithography methods, electrospinning requires almost no fabrication and is simpler to do. "What this work shows is that you can have for materials, and processing metals that are traditionally not associated with electronic devices, yet can be used to yield electronic devices

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Linear Arrays

A growing number of electronics researchers are fascinated by the potential of single-walled carbon nanotubes—one-atom thick sheets of graphite rolled into seamless cylinders. These tiny objects have attractive electrical properties and physical features. But incorporating single-walled carbon nanotubes into scalable ICs has proven to be a challenge, largely because of difficulties in manipulating and positioning the tiny objects and in achieving sufficient current outputs.

Engineers at the University of Illinois, Lehigh University, and Purdue University studied this problem and developed an approach that uses dense arrays of aligned and linear nanotubes as a thin-film semiconductor material. According to John Rogers, a University of Illinois professor of materials science and engineering, the nanotube arrays can be transferred to plastic and other unusual substrates.

To create the arrays, the researchers begin with a wafer of single-crystal quartz, upon which they deposit thin strips of iron nanoparticles. The iron acts as a catalyst for the growth of carbon nanotubes by chemical vapor deposition. As the nanotubes grow past the iron strips, they lock onto the quartz crystal, which then aligns their growth *(Fig. 3)*.

According to William Dichtel, a project researcher, the new memory is based on a series of perpendicular nanowires, similar to a tic-tac- with 400 bottom wires and another 400 top wires crossing the bottom *(Fig. 1)*. Sitting at each crossing of the tic-tac-toe structure, and se storage elements, are approximately 300 bistable rotaxane molecules. These molecules can be switched between two different states. I crossbar junction can be addressed individually by controlling the voltages applied to the appropriate top and bottom wires, forming a bi nanowire crossing.

A rotaxane is a molecule with a dumbbell-shaped component, consisting of a rod section and two stoppers, encircled by a ring. It has th to be a molecular abacus. The molecule can act as a switch by inducing the ring to slide from one side of the rod to the other. "It's not ju storage of charge, like most of today's memory devices use," Dichtel said. "There are actually molecules which respond to applied volta molecules switch from one state to another."

The bistable rotaxane molecules used in the crossbar memory can be switched at very modest voltages from an "off" (low conductivity) "on" (high conductivity) state. The stoppers for the rotaxane molecules are designed to allow the molecules to be organized into layers t single molecule thick, after which they're incorporated into the memory device. The 160-kbit molecular memory was fabricated at a dens billion bits per square centimeter—a density predicted by Ditchel for commercial memory devices by approximately 2020.

"One of the most exciting features of this research is that it moves beyond the testing of molecular electronic components in individual, device formats and demonstrates a large, integrated array of working molecular devices," Dichtel said.

The resulting linear arrays consist of hundreds of thousands of nanotubes, each approximately 1 nm in diameter, and up to 300 µm long nanotubes are spaced approximately 100 nm apart. The arrays function as an effective thin-film semiconductor material in which a char independently through each of the nanotubes. In this configuration, the nanotubes can be integrated into electronic devices in a straight fashion by conventional chip-processing techniques.

"Our approach has been not to figure out how to grow electronically identical tubes everywhere, or to position or control the location of a individual tube, Rogers said, "but to instead make a thin form that consists of very well aligned arrays of individual tubes." The research technique to build and test a variety of transistors and logic gates, as well as to compare the properties of nanotube arrays versus indivi nanotubes.

Rogers notes that nanotube arrays aren't likely to replace silicon, but could be added to a silicon chip and exploited for special purposes speed operation, higher power capacity, and linear behavior are a few options for enhanced functionality, and they can also be used for that silicon can't easily support, such as flexible devices.

Nano Now

Mamikunian believes that nanotechnology, and the new and enhanced products the field promises to generate, will open an almost end fresh opportunities for the electronics industry. Furthermore, the field's benefits won't only be limited to major industrialized nations. "A lo developing countries are looking at nanotechnology as a way to leapfrog from where they are today to become more of a player in the la of commercialization and manufacturing," he said.

According to Mamikunian, enough progress is being made in nanotechnology research that the field is on the verge of becoming mainst the next five years or so you'll begin to see this transformation where the terms 'nano' and 'nanotechnology' will fade away and it will be 'technology,'" he said.

Maynard agrees with Mamikunian, adding, "One thing is certain, and that is that the next generation of electronics has got to rely on our engineer at the nanoscale."

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