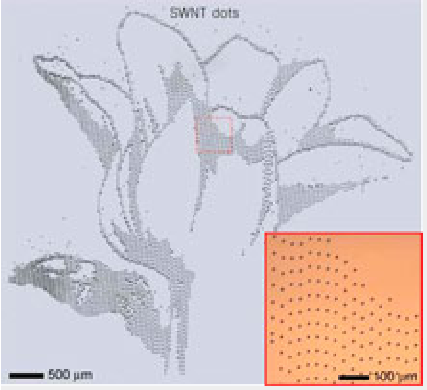
Thursday, September 13, 2007

Nanoscale Inkjet Printing

E-jet printing of precise structures out of various materials could prove to be a valuable tool in nano manufacturing.

By Duncan Graham-Rowe



Nano printing: This image shows a picture of a flower printed using a novel electrohydrodynamic inkjet printer. Each dot is just eight micrometers in diameter and made up of single-walled carbon nanotubes.
Credit: University of Illinois, Urbana Champaign

A new type of inkjet printer has been developed that can precisely print dots of various materials just 250 nanometers in diameter. The inkjet printer could make it possible to rapidly synthesize complex nanoscale structures out of various materials.

"The goal is to do manufacturing," says John Rogers, a professor of engineering at the University of Illinois, Urbana Champaign. The new printers can use a broad range of materials for manufacturing novel devices, from plastic electronics and flexible displays to photovoltaic cells and new biomedical sensors, says Rogers.

The researchers have demonstrated that the new inkjets can print very precise patterns of electrically conducting polymers and carbon nanotubes; they have also shown that DNA can be printed without damaging it. "It's hard to do this with traditional silicon fabrication techniques," says Rogers.

Often the nanomaterials needed to make ultrasmall biomedical devices and nanoscaled polymer-based electronics are in solution, which means that they don't lend themselves to traditional microfabrication techniques. Because of this, printing is an attractive alternative, in terms of both cost and complexity, says Heiko Wolf of IBM Zurich Research Labs' Nanoscale Structures and Devices Group, in Switzerland.

But patterning structures at the nanoscale has so

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far proved challenging. "Conventional inkjets are limited to resolutions of about 25 micrometers," says Rogers.

Traditional inkjets work by pushing ink out of a nozzle to form droplets, either by heating the ink or applying physical pressure to force it out. While this works fine on the micrometer scale, issues of surface tension and fluid flow start to become a barrier when researchers try to go smaller. "The smaller the nozzle size, the harder it is to get fluid to flow through it," says Rogers. "So the amount of force you need to apply increases disproportionately."

To overcome this, Rogers and his colleagues use a different approach, called electrohydrodynamic inkjet (or e-jet) printing. "We pull the fluids rather than push them," he says.

This involves using electric fields to create the droplets and relies upon there being a certain amount of electrically charged particles, or ions, within the fluid. Capillary forces pull the fluid from its reservoir to form a semispherical droplet hanging from its rim, like a drop of water on a faucet.

By using electrodes to create an electric field between the nozzle tip and the substrate upon which one wants to print the material, it is possible to make the droplet conical, says Rogers. "Ions accumulate at the surface of the fluid, at the apex of the cone," he says. This concentration of ions allows the tip of the cone to break away and form a droplet that's just a fraction of the volume of the cone.

"You can generate droplets that are smaller than the nozzle diameter," says Rogers. "You're really just pinching off droplets. It's only at the very tip of the cone that the droplets are formed."

[1] 2 Next »

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« Back 1 [2]

Thursday, September 13, 2007

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Continued from page 1

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Using this approach, Rogers and his colleagues have shown that they can print lines of a material 700 nanometers wide or individual dots just 250 nanometers in diameter.

In addition to the size of the droplets, the spatial accuracy is also improved, says Rogers. He and his team discovered quite serendipitously that the field used to create the droplet also helps guide the charged droplet toward the target substrate. "That was kind of a bonus," Rogers says.

Electrohydrodynamic printers have been used in the past, says Howard Taub, associate director of HP Labs, in Palo Alto, CA. The novelty here is the high resolution, he says.

But, says Taub, what these new e-jets make up for in resolution they lack in speed. The high voltages required to generate the fields can be difficult to pulse in order to print quickly. Regular printers can eject droplets on the order of between 10,000 and 100,000 times a second. Rogers's e-jets, on the other hand, operate at around 1,000 times a second.

One solution is to use arrays of inkjet heads, says Taub. But this can lead to further problems, he says: "The droplets are going to interact with each other because they are charged. So you'd have to keep them spaced out."

Rogers says that his group is working on the speed issue. He and his colleagues have already shown that nozzles can be placed as close as 250 micrometers without droplets interacting. They are now working with several manufacturers to commercialize the technology.

« Back 1 [2]

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