Improved printing provides higher resolution, versatility

By James E. Kloeppel
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By combining electrically induced fluid flow with nanoscale nozzles, UI researchers have established new benchmarks for precision control and resolution in jet-printing processes.

"We have invented methods for an electrohydrodynamic jet (e-jet) printing process that can produce patterns and functional devices that establish new resolution benchmarks for liquid printing, significantly exceeding those of established ink-jet technologies," said John Rogers, a Founder Professor of Materials Science and Engineering, and corresponding author of a paper accepted for publication in the journal Nature Materials, and posted on its Web site.

This type of e-jet printing could be used for large-area circuits, displays, photovoltaic modules and related devices, as well as other wide-ranging application possibilities in security, biotechnology and photonics, Rogers said.

The success of this effort relied critically on an interdisciplinary team of materials scientists, chemists, mechanical engineers, electrical engineers and physicists within the university's Center for Nanoscale Chemical Electrical Mechanical Manufacturing Systems, a nanoscale science and engineering center funded by the National Science Foundation.

"As an industrial process, this work opens up the possibility for low-cost and high-performance printed electronics and other systems that involve materials that cannot be manipulated with more common

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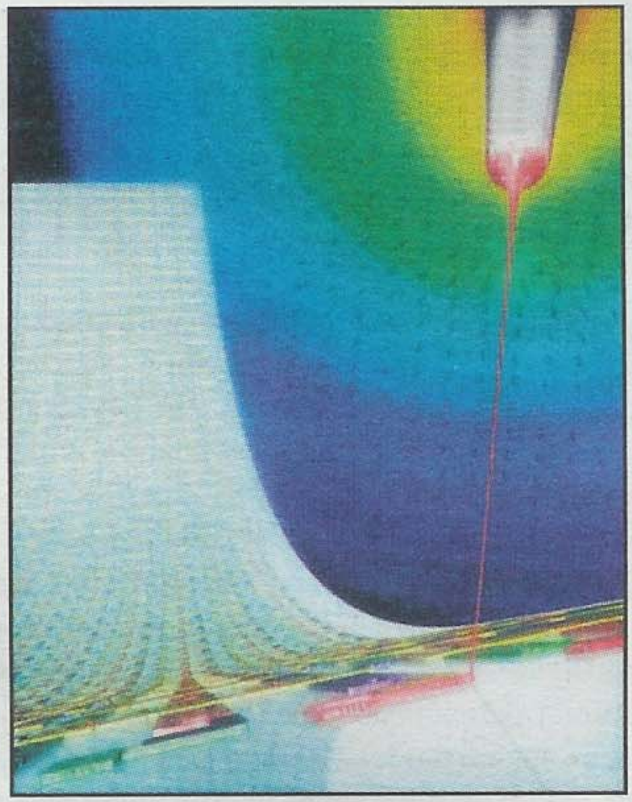

E-jet printing *Electric-field induced jets of functional organic electronic inks from nanoscale nozzles forms the basis of a technique, which researchers refer to as e-jet printing, to pattern electronics on flexible substrates.*

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patterning methods derived from microelectronics fabrication," said Placid Ferreira, the Grayce Wicall Gauthier Professor of Mechanical Science and Engineering, the director of the center and a key member of the team.

"The neat thing is that we find that this extremely high-resolution form of e-jet printing can also be used for diverse systems, such as printing microarrays of DNA spots for bioanalysis, or printing carbon nanotubes and other classes of nanomaterials that are difficult to pattern in other ways," said Rogers, who also is a researcher at the Beckman Institute and at the university's Frederick Seitz Materials Research Laboratory. "These capabilities are taking our research in new and exciting directions."

Unlike conventional ink-jet printers, which use heat or mechanical vibrations to launch liquid droplets through a nozzle, e-jet printing uses electric fields to pull the fluid out. Although the concept of electric-field induced flow is not new, the way the research team has exploited this phenomenon with nanoscale nozzles and precision control of electric fields to achieve unprecedented levels of resolution is an important advance.

The researchers' e-jet printing head consists of a gold-coated microcapillary nozzle (with a diameter as small as 300 nanometers) mounted on a computer-controlled mechanical support. An organic, Teflon-like coating on the gold ensures the ink flows cleanly out the nozzle toward the target. Tiny droplets of ink eject onto a moving substrate to produce printed patterns. Lines with widths as narrow as 700 nanometers, and dots as small as 250 nanometers can be achieved in this fashion.

As a demonstration of electronic device fabrication by e-jet printing, thin-film transistors that use aligned arrays of single-walled carbon nanotubes as the semiconductor and e-jet-printed source and drain electrodes were printed on flexible plastic substrates. The transistors were fully operational, with properties comparable to similar devices fabricated with conventional photolithographic methods.

The team also demonstrated that e-jet printing could be extended to a wide variety of functional organic and inorganic inks, including suspensions of solid objects (such as nanoscale silicon rods) with resolutions again extending to the submicron range.

Because the nozzles are routed directly to reservoirs of inks, e-jet printing has the capability to deliver large volumes of ink to a surface, and offers the ability to perform preprocessing on the inks before printing, Rogers said.

The existing e-jet printer can print text, drawings and images in a fully automated fashion. Current research seeks to improve the printing speed by incorporating large-scale nozzle arrays, and to explore the fundamental limits in resolution.

"The work represents an important milestone in the development of liquid-jet printing technology," Rogers said, "which creates many exciting possibilities."

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