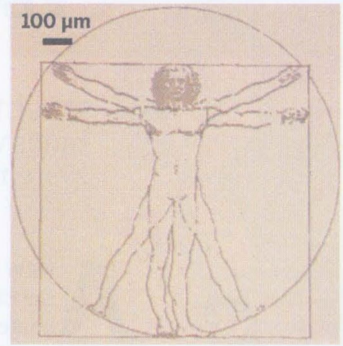
# PRINTING ON THE NANOSCALE

**NANOTECHNOLOGY:** Method exploits electrified liquid jets for high-resolution patterning

**ELECTRICALLY CHARGED JETS** of liquid lie at the heart of a novel printing method that can be used to form complex patterns with nanoscale features from a variety of inks on nearly any type of surface, according to a team of researchers based in the U.S. and South Korea (*Nano Lett.*, DOI: 10.1021/nl903495f). The study demonstrates a versatile technique for patterning surfaces with positively and negatively charged microscopic regions of arbitrary shape—an advance that may lead to new methods for fabricating electronic devices and controlling their properties.

Xerography is a decades-old printing technology based on electrostatic attraction between a charge pattern "drawn" with light on a photoconducting surface (a photocopier "drum") and oppositely charged toner particles. Efforts to increase xerography's spatial resolution from the tens-of-micrometers range led to demonstrations in the past few years of new procedures based on scanning-probe tips and elastomeric stamps. Those techniques offer ways of printing with resolution on the 100-nm scale but are limited to materials with specific charge-storage capabilities.

In contrast, the new method, which also offers nanoscale printing resolution, can be used with a wide variety of inks and printing surfaces. To demonstrate that versatility, the research team printed patterns of dots and lines—as well as microscopic images of classic artwork—with polymers, DNA solutions, and suspensions of silver nanoparticles and nanowires. The widths, diameters, heights, and other characteristics of the patterns range from a few micrometers to about 100 nm.




NANO LETT.

**WRIT SMALL**
Da Vinci's "Vitruvian Man," shown in this micrometer-scale optical micrograph, was reproduced with positively and negatively charged jets of a polyurethane ink.

In the new printing method—which was developed by Jang-Ung Park, Sangkyu Lee, and John A. Rogers of the University of Illinois, Urbana-Champaign; Ungyu Paik of Hanyang University, Seoul; and coworkers—an ink solution forms a meniscus at the tip of a nozzle with a micrometer- or nanoscale opening. Applying a voltage between the nozzle and the printing surface causes ions to accumulate at the meniscus surface and forces tiny jets of liquid to the printing surface. The droplets deposited in that way retain an overall net charge—positive or negative—depending on the applied voltage.

The team showed that the applied bias can be switched "on the fly" during printing, which enabled them to form complex patterns with combinations of charge polarities. The group exploited that flexibility to customize the performance characteristics of silicon nanomembrane transistors by depositing charge (positive and negative) in selected regions of the device.

University of Minnesota electrical and computer engineering professor Heiko O. Jacobs says the work reported here is unlike anything else he has seen so far in this field. "With this method, you can spray an area or a domain to build up a layer of charge with good lateral resolution and then study how this charge impacts the surrounding environment," he says. The method "could be applied to anything from cell cultures to integrated circuits," he adds.—MITCH JACOBY

## FLAME RETARDANTS Chemtura signs bromine agreements with Albemarle

Chemtura, the specialty chemical maker now under Chapter 11 reorganization, has signed a series of agreements and settled a lawsuit with Albemarle to help pave the way for a restructuring of its business in bromine derivatives.

Under the agreement, Albemarle is signing over its 17% stake in a bromine-rich brine field in Union County, Ark., that is managed by Chemtura. The transfer consolidates Chemtura's ownership of the field, according to Anne Noonan, Chemtura's vice president of flame retardants. The field is the most productive in South Arkansas, she says, and among the most competitive in the world.

As part of the deal, Albemarle will manufacture the plastics flame retardants tetrabromobisphenol A, decabromodiphenyl oxide, and decabromodiphenyl ethane for Chemtura. Albemarle will also supply Chemtura with *n*-propyl bromide and sodium bromide.

In addition, the companies are settling an eight-year-old lawsuit in which Albemarle accused Chemtura of infringing its patents for decabromodiphenyl ethane flame retardants and bromine vacuum tower technology.

As part of the settlement, the companies have cross-licensed rights to market decabromodiphenyl ethane, a substitute for the flame retardant decabromodiphenyl ether (decaDBE). Chemtura, Albemarle, and Israel's ICL Industrial Products pledged last month to phase out decaDBE as part of an EPA initiative because of concern over its potential impact on human health (C&EN, Jan. 4, page 10).

"The settlement saves both companies a lot of money on litigation," Noonan says. "And it allows for the redeployment of resources toward what brings value."

Chemtura intends to quickly deploy decabromodiphenyl ethane to customers that want to protect plastics such as high-impact polystyrene.—ALEX TULLO