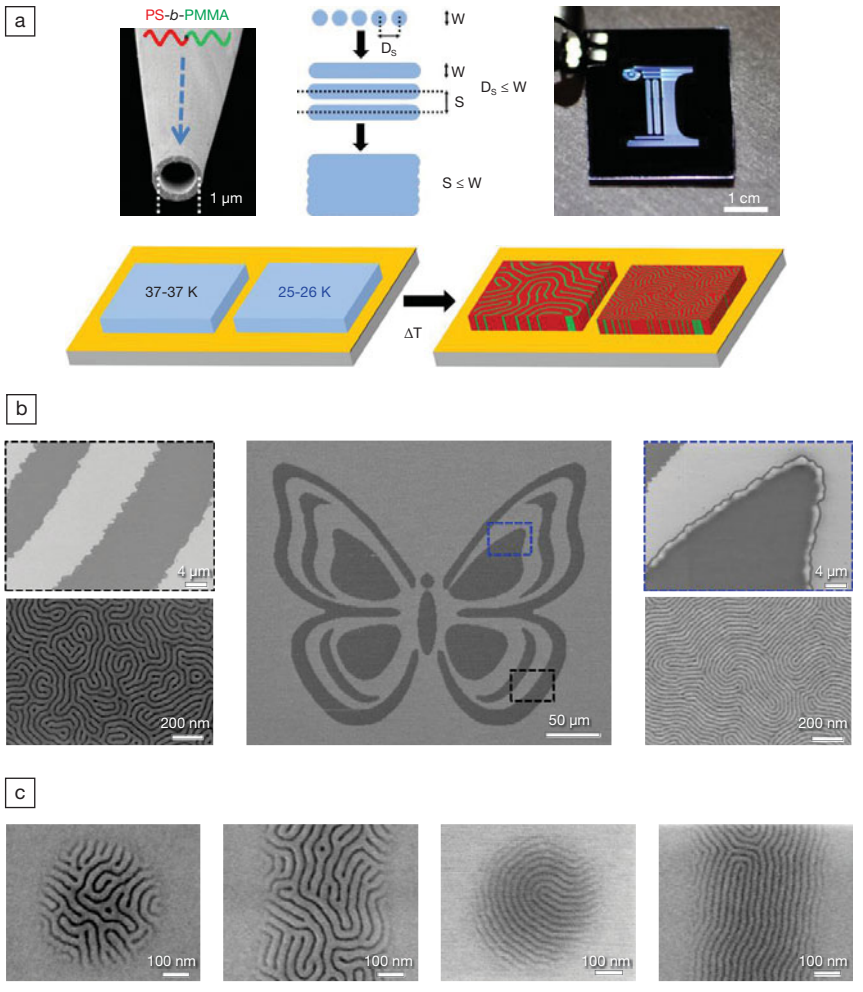
Nano Focus

Electrohydrodynamic jet printing enables BCP nanolithography

While block-copolymer (BCP) lithography has the potential to revolutionize manufacturing processes in the semiconductor industry, various challenges remain before this technique can become a widespread tool for nanolithographic applications. For example, BCPs in the form of spin-cast films do not allow independent control over the periodicity, size, and morphology of the nanoscale BCP domains, or the ability to pattern multiple BCPs into user-defined domains in a controlled manner.

Addressing these problems, researchers from the University of Illinois at Urbana-Champaign, the University of Chicago, Argonne National Laboratory, and Hanyang University in South Korea have now demonstrated a new electrohydrodynamic jet printing method to prepare BCP thin films. The technique allows rapid, ultrahigh resolution patterning of BCPs with different molecular weights and compositions, where the molecular weight of the BCPs, for example poly(styrene-block-methyl methacrylate), determines the periodicity of the nanoscale domains. The research team, led by Heejoon Ahn, Paul Nealey, and John A. Rogers, demonstrated that the pitch (i.e., the spacing of BCP features) can be continuously varied from <20 nm to several cm, making this type of approach useful for general applications in nanolithography.



(a) Schematic illustration of the electrohydrodynamic jet printing process including a scanning electron microscope (SEM) image of the end tip of a glass capillary nozzle coated with Au/Pd (top left), a printing pattern (top center), an example of a large-area pattern (top right), and the printing-annealing sequence, which results in block-copolymer (BCP) self-assembled nanodomains. (b) SEM images of irregular printed pattern with subsequent nanostructure self-assembly. (c) Individual nanometer-sized dots and lines using different molecular weight BCPs to achieve self-assembly into different morphologies, such as lamellae and lines. Reproduced with permission from *Nature Nanotech*. **8** (2013), DOI: 10.1038/nnano.2013.160. © 2013 Macmillan Publishers Ltd.

As reported in the September issue of *Nature Nanotechnology* (DOI: 10.1038/NNANO.2013.160; p. 667), the research team was able to print regular or irregular patterns and independently control the periodicity, size, and morphology of the nanoscale structures by using electrohydrodynamic jet printing (see Figure). In contrast, traditional spin-casting of BCP thin films allows only for uniform, unpatterned coatings. An applied electric field between the inkjet nozzle and the substrate determines the droplet size (as small as ~100 nm). Inks of dissolved BCPs can then be printed onto large-area substrates as either individual droplets or continuous streams of BCP, and the size, location, and geometry of the desired patterns can easily be defined. BCP self-assembly then leads to the formation of nanoscale domains within the features of the printed patterns. The processes of nanoscale self-assembly can be guided by printing onto chemically or topographically structured substrates as a route to an even higher degree of control over the three-dimensional hierarchical patterning.

The entire electrohydrodynamic jet printing process is automated and under complete computer control, thereby providing the levels of precision in ink flow, pattern registration, and other parameters necessary for realistic nanomanufacturing on an industrial scale.

"Jet printing provides control of thickness at the molecular scale, and lateral resolution at the 100 nm scale, in arbitrary geometries; self-assembly does the rest," said Rogers. "We find that this combined use of 'top down' and 'bottom up' approaches in nanolithography can work remarkably well."

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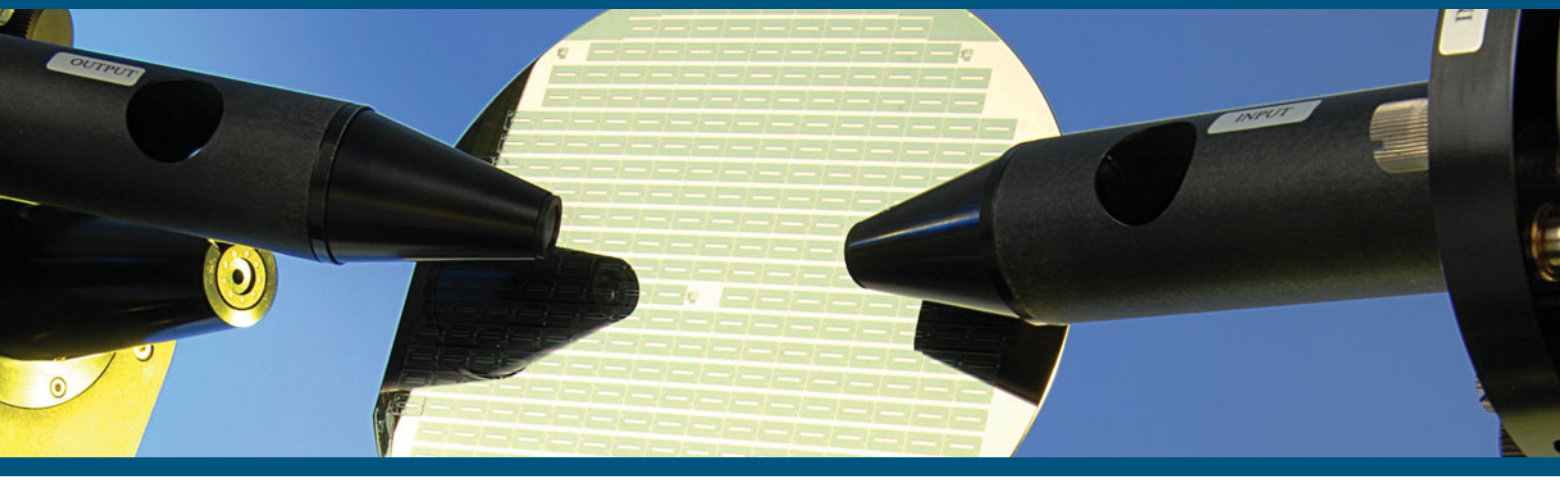

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