Nanofabrication with high-resolution stamps

By John A. Rogers, Jana Zaumseil, and Matthew Meitl

Methods for nanofabrication are essential to scientific progress in many areas of biology, physics, chemistry, and materials science. They also form enabling technologies for applications that range from nanofluidic devices to sub-wavelength optical components, to molecular electronics and nanoelectromechanical systems (NEMS).

In some cases, it will be possible to use extensions of the highly engineered and spectacularly successful lithographic techniques that have been developed for microelectronics. In others, certain drawbacks associated with these techniques—high capital and operational costs; difficulty in forming features with sizes less than ~100 nm; capability for patterning only small areas in a single step—will prevent their use. As a result, a branch of research has recently emerged to study the possibility of performing nanofabrication with low-cost techniques that rely on advanced forms of embossing, molding, printing, and writing.

Although the basic approaches are not conceptually new, it is possible to extend their resolution into the nanometer range by incorporating advanced materials, chemistries, and processing techniques. The resulting methods possess remarkable patterning capabilities that make them suitable for devices and structures that would be difficult to realize with conventional approaches.

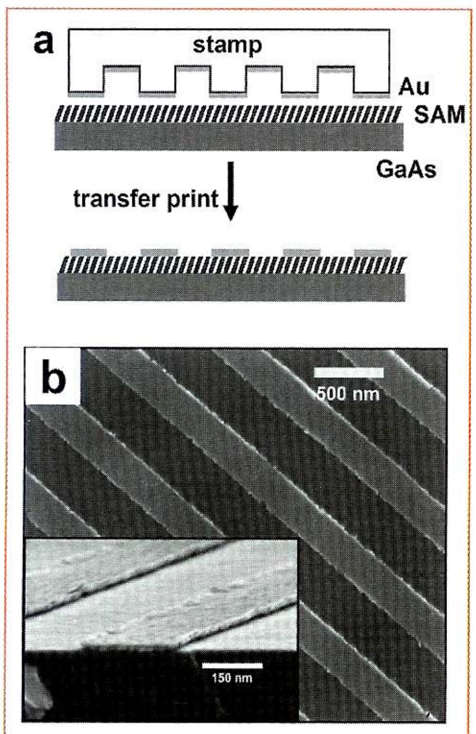

Fig. 1. **a)** Schematic illustration of nTP. **b)** Method forms 300 nm lines. *Source: Univ. of Illinois, Urbana-Champaign.*

nTP method

Our recent research has identified a purely additive contact printing technique that can, in a single step, form complex patterns with nanometer resolution. The method, which we refer to as "nanotransfer printing" (nTP), involves the controlled transfer of thin films of solid material "inks" from stamps onto substrates. Interfacial chemical bonding reactions, that form when the substrate and the stamp are brought into contact, control the transfer of these ink layers.

Fig. 1a (left) schematically illustrates the use of nTP with an organic self-assembled monolayer (SAM; 1-2 nm thick) surface chemistry to print patterns of Au on a wafer of GaAs. The stamp, which is formed by casting and curing a polymer against a reusable "master" structure, is designed so that the adhesion of Au to its surface is poor. Contact of the stamp to the substrate leads to the formation of covalent thiol bonds between the Au and the SAM. Removing the stamp leaves a pattern of Au in the geometry of relief features on the stamp.

The scanning electron micrographs in Fig. 1b show patterns of 300 nm lines and spaces that have formed. In this case, the stamp has nearly vertical sidewalls so that thermal evaporation with a collimated flux of Au yields an ink layer on the raised and recessed regions of the stamp but not on its sidewalls.

As a result, patterns that form upon printing have the geometry of the raised features on the stamp. By using conformal ink coatings on stamps with sloped sidewalls, it is possible to print, in a single step, certain types of 3-D nanostructures. The SEM in Fig. 2a (above) shows, as an example, arrays of printed Au nanochannels. Because nTP is additive (i.e., it does not involve etching or removal of material), it is easy to build complex multilayer structures. Fig. 2b shows a stack of 10 orthogonal nanochannel layers formed by printing multiple times. Here the SAM chemistry facilities transfer of the first layer; Au cold welding bonds subsequent layers. Structures of this type, which could be important in areas such as photonics or fluidics, are easy to produce by nTP, but would be challenging to construct using more established methods.

The nTP technique as well as recently developed writing, embossing, and molding methods have capabilities that can complement those of more conventional approaches to nanofabrication. When taken together with the wide variety of compelling uses for micro and nanostructures, they suggest that this field of study will continue to produce exciting results with broad technical and scientific significance.

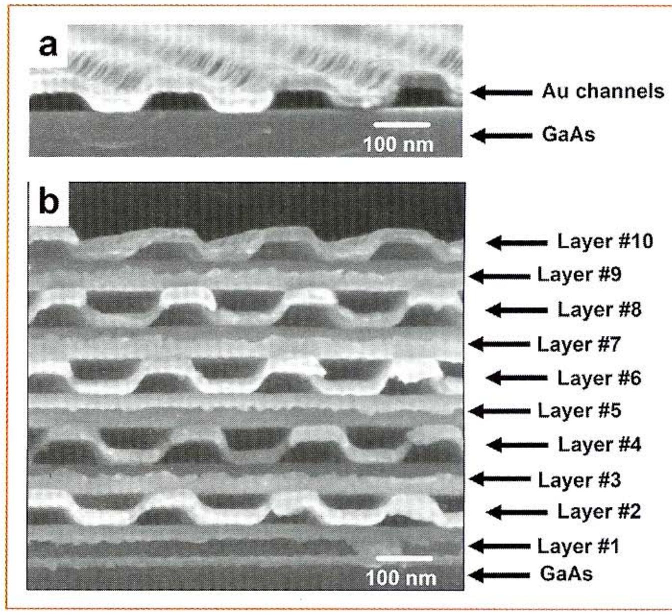

Fig. 2. **a)** Cross-sectional view of nanochannels formed by nTP. **b)** 10 layer stack of nanochannels formed by repeated printing. *Source: Univ. of Illinois, Urbana-Champaign.*

John A. Rogers will be giving a detailed technical presentation on "Nanofabrication with High-Resolution Stamps," at the Micro/Nano Conference sponsored by Micro/Nano Newsletter *and* R&D Magazine, *Oct. 14-15, Chicago, Ill. For information about the conference, contact Susan Beck, conference manager, at 630-288-8494 or e-mail her at sbeck@reedbusiness.com.*

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