High-resolution thin templates can be used to imprint both photonic-crystal and patterned media devices on full wafers and disks.

Step and flash imprint lithography (S-FIL®) is a unique method for printing sub-100nm geometries.1–3 For high-resolution alignment, the S-FIL process uses field-to-field drop dispensing of UV curable liquids for step-and-repeat patterning. Several applications, including patterned media, photonic crystals, and wire grid polarizers, are better served by a full substrate patterning process because alignment specifications are minimal.

Lithographic requirements for both photonic crystal and patterned media devices are extremely challenging. Each presents unique problems for a more conventional optical projection approach. Photonic crystal lattices typically require pitches considerably less than 1:1. In addition, the patterns are most effective with the application of long-range ordered arrays, as opposed to the repeating cell structures printed by reduction scanners for CMOS devices. Patterned media, too, is particularly demanding because of the feature sizes that are necessary to achieve the storage densities required for manufacturing beyond the current technology of perpendicular recording. The first insertion opportunity for patterned media is expected to be at features with a half-pitch of <20nm. A feature size comparison between the International Technology Roadmap for Semiconductors (ITRS) for dynamic random access memory (DRAM) storage and magnetic storage is shown in Figure 1(b). Presently, a 17nm half-pitch for DRAM circuits is scheduled for production in 2018. This feature density represents an approximate starting point for bit-patterned media and has an anticipated entry point around 2010.

We present a methodology for creating a thin template suitable for either full wafer or disk imprinting. Dense arrays of holes with half pitches as small as 21nm were imaged using an S-FIL approach. Finally, we detail a process for replicating a master template.

Template fabrication and imprinting
A lift-off process was employed in order to achieve resolutions better than 28nm. All patterning was done on 150mm diameter fused silica wafers. Charging during electron beam exposure can be addressed by either applying a conductive topcoat on top of the e-beam resist, or by depositing a conducting layer underneath it. In this study, we used the latter method. To generate the template relief images, patterns were exposed using a Vistec VB6 100 keV Gaussian beam writer. A polymethyl methacrylate (PMMA) resist was chosen for positive imaging. After development, a thin chromium layer was evaporated, followed by a lift-off using dichloromethane. The remaining chromium features served as a hard mask for the etch into the fused silica.

Imprinting of the template pattern was performed by using a Molecular Imprints Imprint1100 full-wafer imprinting system (Figure 2). A Drop-on-Demand™ method was employed to dispense the photo-polymerizable acrylate-based imprint solution.

Continued on next page
The template was then lowered into liquid contact with the substrate, displacing the solution and filling the imprint field. UV irradiation through the backside of the template cured the acrylate monomer. Figure 3(a) depicts 25nm and 21nm half-pitch arrays of pillars as defined on the template. Figure 3(b) shows a scanning electron microscopic image of the imprinted features. As expected, those that were resolved on the template faithfully reproduced during the imprint process.

**Template replication**
Creating a master template is only the first step towards solving the template supply issue for either patterned media or LEDs. It is likely that several hundred imprint tools will be needed to produce the required number of patterned GaN coated wafers (in the case of LEDs) and disks (for patterned media). Each imprint tool, in turn, will need multiple copies of a template to ensure defect-free imprinting over the course of a particular design rule. As a result, thousands of replicate templates will likely be required. Given that writing a master may take several days, the industry is faced with two problems. First, writing all the required templates in a reasonable time frame is a challenge. In addition, the cost for every e-beam written template is exorbitant.

A better approach is to create a master template and use the imprint tool to form replicates. This technique has recently been demonstrated for photonic crystal arrays. The methodology is reviewed below.

The tone of the master template is maintained by employing an SFIL/R\textsuperscript{TM} (reverse tone) pattern transfer process.\textsuperscript{5,6} The steps are depicted in Figure 4. To create the replicate template, the patterns are imprinted onto an organic transfer layer and chromium coated 6-inch fused silica wafer. A high-silicon-content resist, Silspin\textsuperscript{TM}, is spun on to planarize the organic monomer material. Continued on next page
Following an etch back, the monomer and transfer layer are patterned using the SilSpin as a hard mask. The resist and monomer stack then serve as a masking layer for the chrome and fused silica etches. The remaining monomer and chrome are then removed to create a thin conformal replicate template. Figure 5 depicts an imprint from (a) the master template and (b) from a replicate.

A viable patterned media product will require techniques for achieving even greater pattern densities. Feature image placement on the master template must also be improved. In presenting a method for fabricating replicate templates, we have not discussed inspection techniques to qualify master templates. Electron beams may be used for inspection, and further research will clarify how such an inspection system can be applied at dimensions at or below 18nm.

**Author Information**

**Douglas Resnick, Gerard Schmid, Mike Miller, Gary Doyle, Chris Jones, and Dwayne LaBrake**  
Molecular Imprints Inc. (MII)  
Austin, TX

Douglas J. Resnick received his PhD in physics from Ohio State University and is an MII vice president.

Gerard Schmid received his PhD in chemical engineering from the University of Texas at Austin and is an MII Senior Template Scientist.

Mike Miller received his BS from the University of Texas at Austin and is an MII Senior Template Engineer.

Gary Doyle received his MS in physics from the University of Connecticut and is an MII Senior Etch Process Engineer.

Chris Jones received his BS in chemistry from the University of Southern Mississippi and is an MII Senior Applications Engineer.

Dwayne LaBrake received his PhD from Loyola University of Chicago in chemistry and is the MII Director of Applications.

**References**