COMBINED CAPILLARY FORCE AND STEP AND FLASH LITHOGRAPHY

Elisa Mele, Dario Pisignano, Luana Persano, and Roberto Cingolani

National Nanotechnology Laboratory of Istituto Nazionale di Fisica della Materia
Department of Engineering of Innovation
University of Lecce
Via Arnesano I-73100 Lecce
ITALY

Tel: +39-0832-298378 Fax: +39-0832-298238
E-mail: elisa.mele@unile.it
http://www.nnl.it

Photolithography is the dominant technology for patterning surfaces on micro- and nanometre scale. However, the cost of short-wavelength light source, required for realizing 100-nm-scale features, increases rapidly upon approaching higher resolution limits. Over the past decade, extensive efforts have been made to develop new patterning methods, which can replace photolithography, such as electron and ion beams, X-rays, scanning probes, soft and imprinting lithographies, self assembling, and atom lithography.

In particular, soft lithography is a set of techniques, which involves the use of an elastomeric stamp or replica to transfer a pattern to a substrate. The replica is prepared by casting the liquid prepolymer of an elastomer, usually poly(dimethylsiloxane) (PDMS), against a master with a patterned relief structure on its surface. In this way, multiple copies of the highly complex structures in the master can be faithfully produced with nanometre resolution. Among the techniques enable to reproduce patterns with high fidelity, which use both rigid and soft molds, we developed room-temperature nanoimprint lithography [1-3], and soft molding [4] on optoelectronic active organic materials.

Here we propose a technique that combines the key element of soft lithography, namely the use of an elastomeric stamp, with step and flash imprint lithography (SFIL). SFIL is a high-throughput, low-cost approach to generate 100 nm and sub-100 nm-scale patterns via *in situ* polymerization. SFIL is characterized by the use of a low viscosity, photo-curable liquid, which allows to carry out the imprint process at room temperature with low applied pressures, and by a transparent, rigid template, in order to obtain a complete exposure of the photopolymer. Nevertheless, the complete release of the imprint mold from the imprinted polymer required treatments of the template surface [5].

This limitation can be overcome by the use of a PDMS stamp. In fact, PDMS is chemically inert, thus not adhering irreversibly to the surface of the polymers, and can be easily released after photopolymerization. Moreover, the elastic characteristic of PDMS enables the replica to spontaneously wet the surface and make conformal contact with the substrate, without any external force, over a large area. We develop the SFIL by an elastomeric stamp for patterning organic materials. The template is exposed to UV light through its backside, thereby crosslinking the polymer at room temperature. The capillary effects force the photo-curable polymer into the void spaces of the features formed between the replica and the film. After polymerization, the replica is peeled off, and the pattern remains on the target. Our lithographic process is shown in figure 1.

The penetration of the solution into the recessed features of the PDMS mold is driven by capillarity and favoured by the low viscosity of the UV-curable polymer. In fact, the time, *t*, necessary for the filling process depends on the viscosity of the polymer, η, according to the equation:

$$t = \frac{2\eta z^2}{\gamma R \cos\Theta}, \qquad (1)$$

where z is the feature size, γ the fluid-air surface tension, *R* the hydraulic radius of the capillary, and Θ the contact angle between the liquid and the surface of the capillary.

Our technique therefore combines the advantages of both capillary-force and step and flash imprint lithography, allowing highly parallel, fast and cheap operation, easy alignment procedure by the transparent mold, and chemical flexibility. The application of this technique for patterning optically active conjugated compounds is also presented and discussed.

List of references

[1] D. Pisignano, M. F. Raganato, L. Persano, P. Visconti, R. Cingolani, G. Barbarella, L. Favaretto, and G. Gigli, Adv. Mater. 16 (2004) 525.
[2] E. Mele, D. Pisignano, M. Mazzeo, L. Persano, G. Gigli, and R. Cingolani, J. Vac. Sci. Technol. B, in press (2004).
[3] D. Pisignano, L. Persano, P. Visconti, R. Cingolani, and G. Gigli, Appl. Phys. Lett., **83** (2003), 2545.
[4] D. Pisignano, L. Persano, G. Gigli, R. Cingolani, F. Babudri, G. M. Farinola, F. Naso, Appl. Phys. Lett. 84 (2004) 1365.
[5] T. Bailey, B. J. Choi, M. Colburn, M. Meissl, S. Shaya, J. G. Ekerdt, S. V. Sreenivasan, and C. G. Wilson, J. Vac. Sci. Technol B, **18** (2000), 3572.

Figure 1