High Aspect-ratio Nanograting Formation on Liquid Resists by a Continuous Mold-assisted Direct-write Process

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Nanograting structures have been intensively investigated as key functional elements in many practical devices ranging from optoelectronics to energy harvesters. Previously we showed a novel Dynamic NanoInscribing (DNI)[1] technique that can create seamless large-area nanograting structures at high speed. In DNI process, a slice of rigid (e.g., Si, SiO_2) grating mold mechanically inscribes a solid metal or polymer surface to create nanostructures continuously. However for very dense gratings, the elastic recovery occurring in plastically deformed solids after removing the mechanical load makes it difficult to achieve sharp and deep grating profiles in the final structures, which are highly desired in applications such as metal wire-grid polarizers.

Inspired by the simplicity of the DNI process, we have developed a new nanograting patterning technique by adopting curable liquid resist materials to the DNI process. Resist lines are delineated as the grating mold is moved across the liquid surface as depicted in Figure 1. Upon curing the resist patterns will remain fixed and are completely free from the elastic recovery effect observed in the regular DNI process. This has made continuous high aspect-ratio nanopatterning possible with excellent process durability. In our experiment a UV-curable epoxy-silsesquioxane (SSQ)[2] possessing great coating/demolding characteristics, is used as a liquid resist. After spin-coated on a transparent polymer substrate, the liquid resist surface is made contact to the edge of a SiO_2 grating mold under slight pressure. The mold is heated up to 80-90 °C at which the viscosity of SSQ is reduced to facilitate the DNI patterning. The patterned SSQ grating lines are promptly cured by a UV light.

Whereas a relatively large pressure is required in regular DNI to 'inscribe' nanopatterns on a solid substrate by plastic deformation, in our new process the liquid resist can readily 'infiltrate' the openings in the mold gratings upon contact. The filling of mold spacings by the liquid resist is maintained as the DNI proceeds, realizing continuous formation of nanogratings that do not undergo elastic recovery upon UV curing (Figure 2). It resembles nanoimprinting of liquid resist, and therefore can ensure faithful formation of high aspect-ratio structures. Due to its simplicity and continuous operation, this technique may open a way to mass-produce large-area, high-quality nanogratings at low cost.

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[1] S. H. Ahn and L. J. Guo, Nano Lett. **9**, 4392 (2009).
[2] C. Pina-Hernandez, L. J. Guo, and P.-F. Fu, ACS Nano **4**, 4776 (2010).

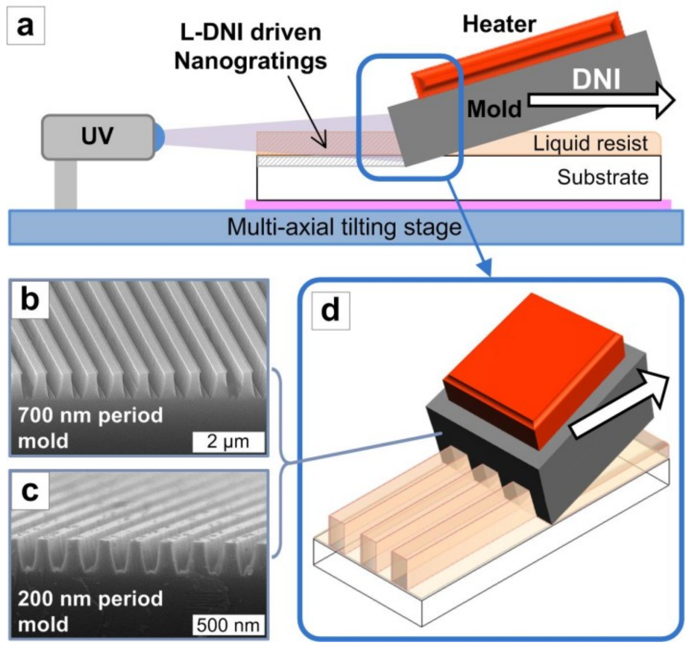

Figure 1: Experimental Setup of Mold-assisted Direct-write Process using Liquid Resists: (a) A schematic drawing setup depicts that a slice of SiO_2 grating molds (b) or (c) makes contact to a liquid SSQ coated substrate. The continuous nanogratings are formed as the DNI proceeds as shown in (d). UV light illuminates the contact point and cures the resist lines instantly.

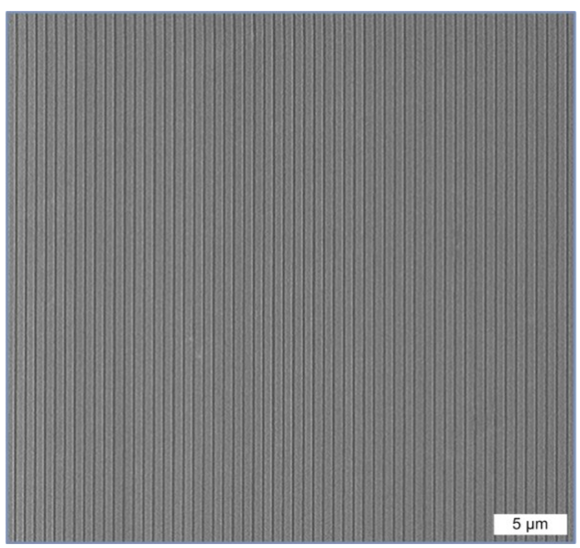

Figure 2: Nanogratings Formed on Liquid Resists by DNI: The SEM image of 700 nm period SSQ gratings formed on a PET substrate at 80 °C shows uniform and continuous nanopatterns.