Large-area Roll-to-Roll and Roll-to-Plate Nanoimprint Lithography and Analytical Models for Predicting Residual Layer Thickness

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A continuous roll-to-roll nanoimprint technique can provide a solution for high-speed large-area nanoscale patterning with greatly improved throughput; furthermore, it can overcome the challenges faced by conventional NIL in maintaining pressure uniformity and successful demolding in large area printing. In our previous work,[1,2] we presented fabrication of metal wire-grid polarizers done by continuous roll-to-roll imprinting of nanoscale structures (70 nm and 300nm linewidth gratings) on a shallow flexible plastic substrate (10 mm width) using a flexible fluoropolymer mold and fast thermal curable PDMS[3] and a liquid UV curable epoxysilicone resist.[4]

In this work, we demonstrate large-area (4" width) continuous imprinting of nanoscale structures by using newly developed 6"-capable roll-to-plate / roll-to-roll apparatus (Fig. 1), which can be directly applied to many potential applications. 300 nm linewidth grating patterns are continuously transferred on either hard glass substrate (roll-to-plate mode, R2PNIL) or flexible plastic substrate (roll-to-roll mode, R2RNIL) with greatly enhanced productivity (Fig. 2). In addition, residual layer thickness, which is critical in optical applications, as a function of several imprinting parameters such as roller pressure and speed, is thoroughly investigated and an analytical model has been developed to predict the residual layer thickness in dynamic R2PNIL process (Fig. 3).

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[2] S. H. Ahn, J.-S. Kim, L. J. Guo, *JVSTB*, 25, (6), 1388-2391, 2007

[3] C. P.-Hernandez, J.-S. Kim, L. J. Guo, and P.-F. Fu, *Adv. Mater*. 19, (9), 2007

[4] X. Cheng, L. J. Guo and P.-F. Fu, *Adv. Mat.*, 17, 1419-1424, 2005

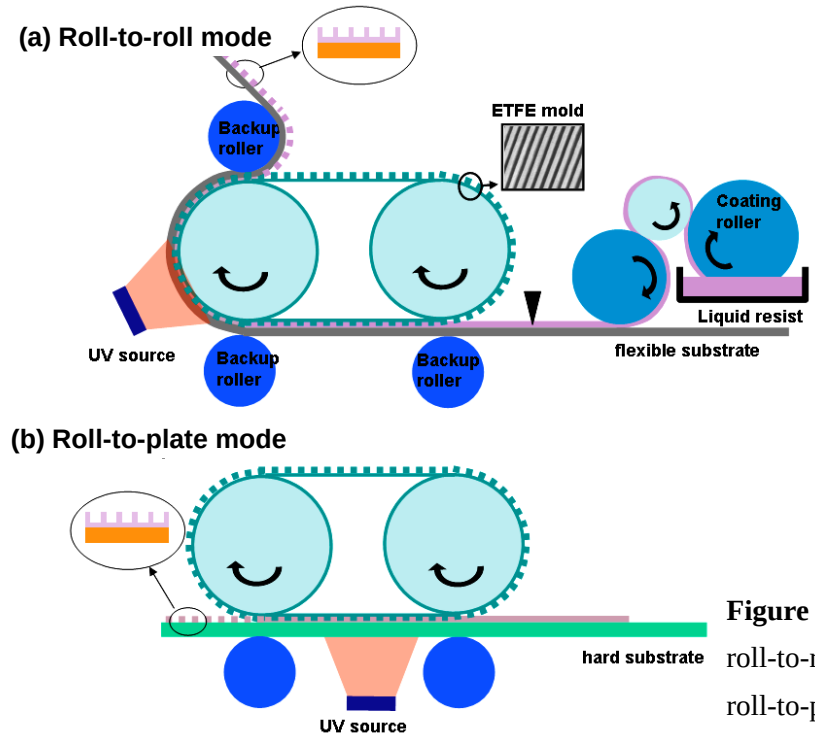

Figure 1. Schematics of roll-to-roll NIL (A) and roll-to-plate NIL (B).

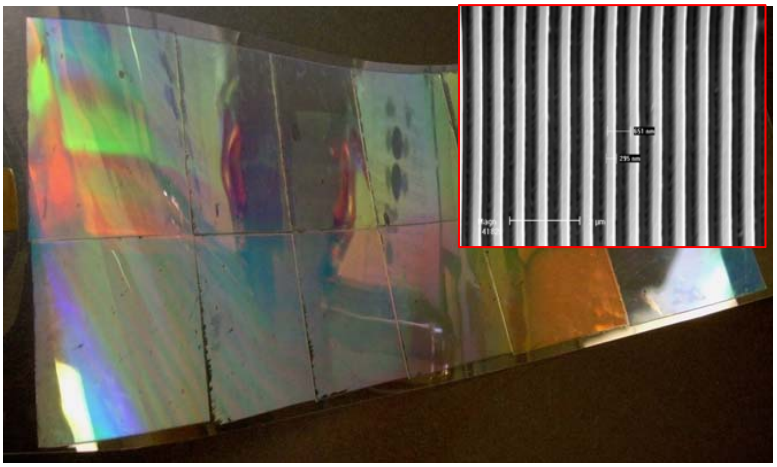

Figure 2. Photograph of a 4" by 12" area, 700 nm period grating pattern imprinted on a PET substrate.

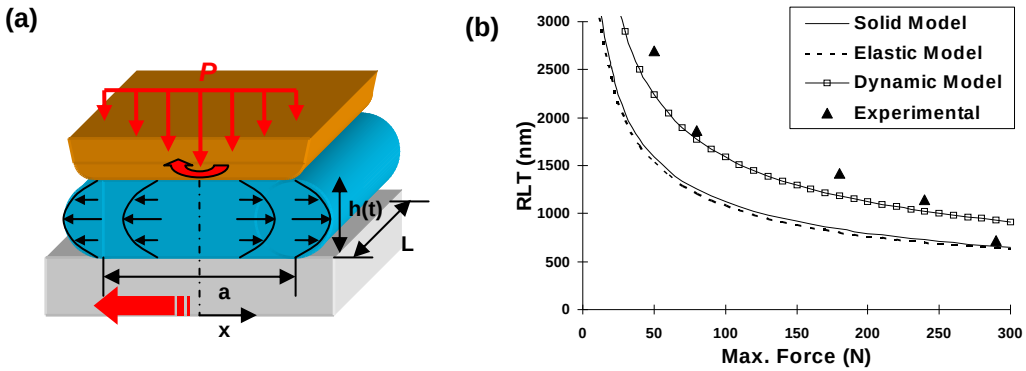

Figure 3. (a) Schematic of dynamic R2PNIL squeezed flow model and (b) plot of residual layer thickness vs. rolling force.