Fabrication of Large-area Flexible Roll-to-Roll Nanoimprint Molds with Sub-100nm Features Using Step-and-Repeat Duplication, Bonding and Lift-off

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Roller nanoimprint-lithography (RON)[1] is becoming a major focus in research and development, because of its advantages in large-area, high throughput and low cost. In RON, a large-area flexible mold with nanopatterns plays an important role. However, often the master molds are made by a direct-write method (e.g. electron, ion, or photo-lithography), which in general has a small pattern area. Therefore, a step-and-repeat method should be developed to create large area molds from a small-area master mold. Here, we present a fabrication of large-area flexible roll-to-roll molds with sub-100 nm features by step-and-repeat duplication (with a small-area master mold) and bonding and lift-off of the duplication. This method is fast, reliable and low-cost.

For the master mold, we used a silicon mold. For the final large-area daughter mold, we used PFPE (Perfluoropolyether) as the mold surface material, because of its low surface energy, fast curing, and resistance to common solvent[2]; and 175μm flexible PET (Polyethylene terephthalat) film as the mold substrate. The large-area mold fabrication consists of (Fig. 1): first, nanoimprint by the master mold to form a reverse-tone pattern in imprint resist (NXR-1025 from Nanonex) on silicon substrate as the 1st-generation daughter mold. Then in the fabrication of 2nd-generation daughter mold, a 35μm-thick PFPE pre-polymer was coated on the surface of 1st-generation daughter mold, and was UV cured. The backside of the PFPE film was then glued onto the PET substrate by UV-curable glue. After bonding, the 1st–generation daughter mold was easily peeled off due to the low surface energy of PFPE, leaving only PFPE film on the PET substrate.

Fig. 2a shows an example of the final mold, which has 6 blocks -- each replicated from a 1.5-inch square master mold that has 400nm-pitch nano-gratings with sub-100nm line width. Line widths on original master mold and final replicated mold are 94 nm and 97 nm, respectively (Fig.2b-c). The deviation is only 3%, indicating that the mold duplication has a high fidelity.

In addition, our method has other three advantages: (a) The 1st-generation mold is reusable (Fig. 2d-e), since it can be separated from the duplicated PFPE easily; (b) Parallel duplication: a master mold can produce many 1st-generation molds, with which we can simultaneously perform duplications to achieve high throughput; (c) The mold size can be easily scaled up. By now we are able to duplicate 4” mold (and larger) into large-area flexible PET substrate.

In summary, our work develops a fast and low-cost way to fabricate large-area flexible molds for roller imprint with high-fidelity and high-throughput.

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[1] H. Tan, A. Gilbertson, S. Y. Chou, *J. Vac. Sci. Technol. B*, 1998 (16), 3926.
[2] S. S. Williams, *et al*, *Nano Lett*. 2010 (10), 1421.

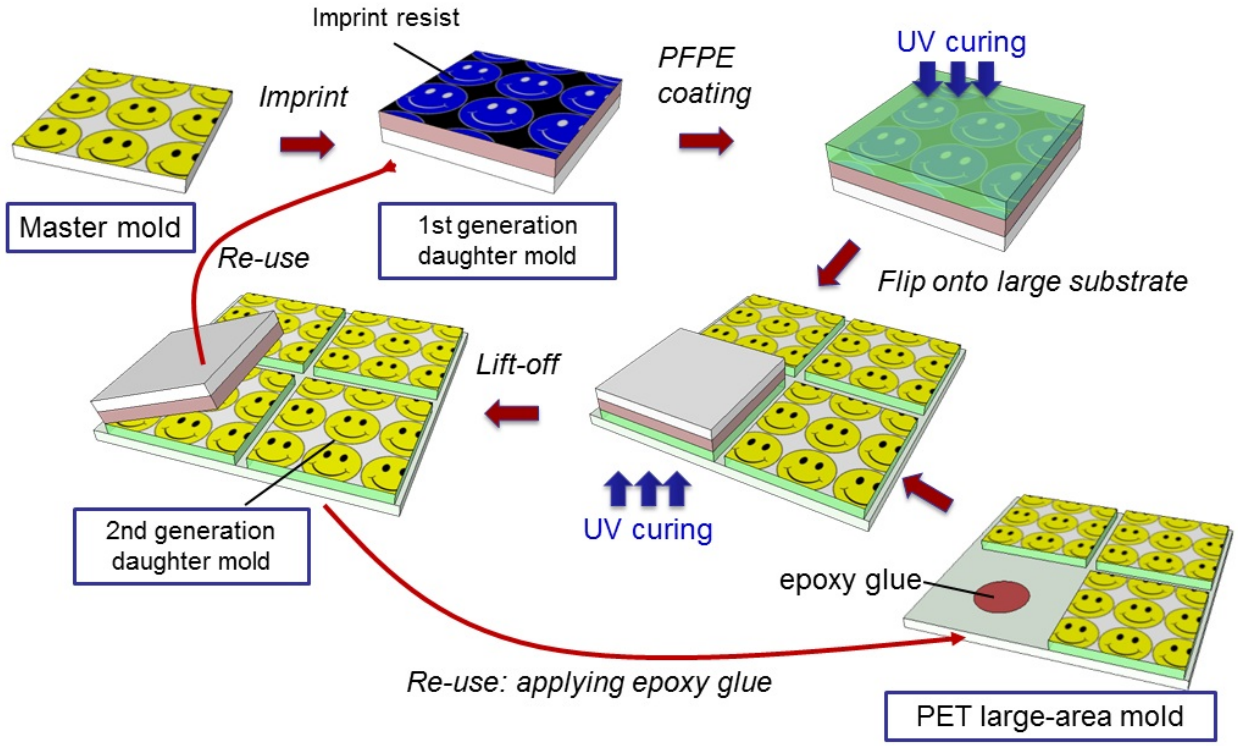

Fig. 1. Schematic of step-and-repeat method to form large-area flexible mold on PET substrate

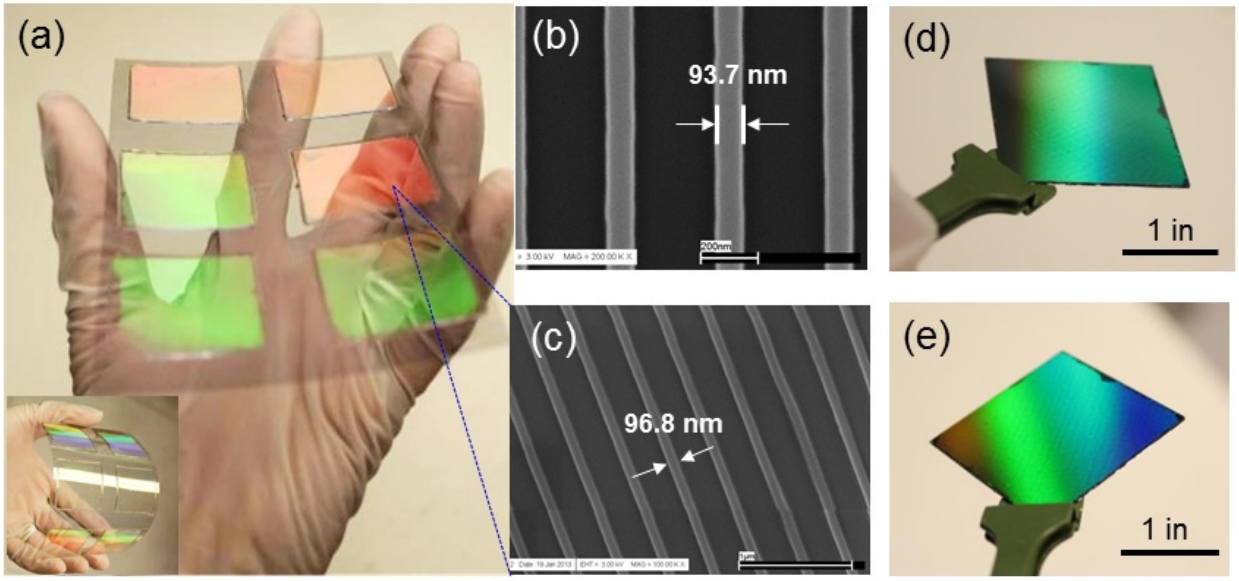

Fig. 2. Demonstration of step-and-repeat method to fabricate large-area mold. (a) final flexible mold consisting of 2 × 3 blocks; (inset) mold bending (b) nanopatterns from original master mold; (c) nanopatterns from replica on PET substrate; (d) 1st -generation daughter mold before PFPE coating; (e) 1st -generation daughter mold after PFPE peeling off.