High-Throughput Transfer Imprinting for Organic Semiconductors

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Development of nanoimprint lithography has enabled high-throughput and high-resolution patterning over the optical limitation[1,2]. In recent years, thermal nanoimprint has been used to directly pattern functional materials such as organic semiconductors because heat and pressure used in thermal nanoimprint do not damage functional materials[3]. However, issues such as residual layer removal and mold contamination still limit the application of nanoimprint for organic semiconductor patterning. In this work, we developed a nanoimprint-based transfer imprinting technique to address the issue of throughput, residual layer removal and mold reusability.

The method of polymer transfer imprinting using soft polydimethylsiloxane (PDMS) film as carrier film for organic semiconductor patterning is schematically shown in Fig. 1. Compared to conventional thermal nanoimprint, the mold does not touch the organic semiconductors directly as shown in **Figure 1**. Regions of the PDMS carrier film will be selectively pressed by mold protrusions when a pressure is applied. At those regions, poly(3-hexylthiophene-2,5-diyl) (P3HT) film is pressed against the adhesive layer on the substrate, which will result in the selective transfer of P3HT from the PDMS to the substrate at those regions. Regions of P3HT that do not experience high pressure will remain on the PDMS carrier film, yielding residual-layer-free P3HT patterns on the substrate. Because the mold is not in contact with P3HT, the mold is not contaminated and can be used repeatedly. This technique can also be easily configured to enable roll-to-roll printing for high-throughput organic semiconductor patterning.

Using nanoimprint-based transfer imprinting, we achieved 50 μm line patterns in P3HT. **Figure 2** shows the patterns after imprinting. Imprinting is performed at 200 psi and 83℃. PDMS is spin-coated at 2500 rpm and the expected film thickness is around 20 μm. For the adhesion enhancing layer, diluted CYCLOTENE (BCB) is spin-coated at 3000 rpm and the expected thickness of the BCB layer is around 400 nm. **Figure 2** (a) shows the transferred P3HT pattern through optical microscope. **Figure 2** (b) is the optical microscope image of the PDMS carrier film after transfer imprinting. The light brown regions are P3HT stripes that are not transferred to the substrate and remain on the PDMS carrier film due to the absence of pressure at mold trenches. **Figure 2** (c) is the same P3HT pattern viewed in a fluorescent microscope. The sample is excited by UV light and the red lines are due to the fluorescence emission of the P3HT pattern. Dark regions between the red lines show P3HT between mold protrusions were not transferred and the residual-layer-free P3HT patterns are completely isolated. Further optimization of the transfer imprinting process and the modeling investigation of process resolution through multi-physics Comsol simulations will be reported.

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[1] S. Y. Chou, P. R. Krauss, and P. J. Renstrom, *Science*, 272, 85 (1996)
[2] Guo, L. J. *Adv. Mater.* 2007, *19*, 495–513.
[3] D. Cui, H Li, H. Park and X. Cheng, *J. of Vac. Sci. & Technol. B*, 26, 2404-2409, 2008.

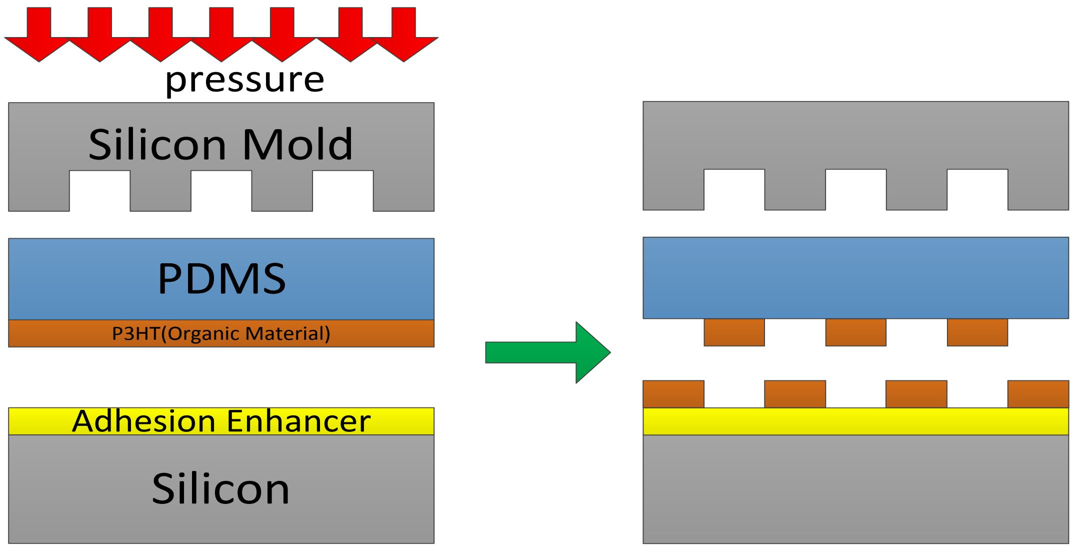

Figure 1: A schematic of patterning organic semiconductor by polymer transfer imprinting. Left: pressure is applied to the silicon mold, which transfers the pressure at mold protrusions to P3HT through the PDMS carrier film; Right: Regions of P3HT in contact with the adhesion enhancer due to pressure at mold protrusions are transferred to the substrate, while regions of P3HT that do not experience high pressure remain on PDMS.

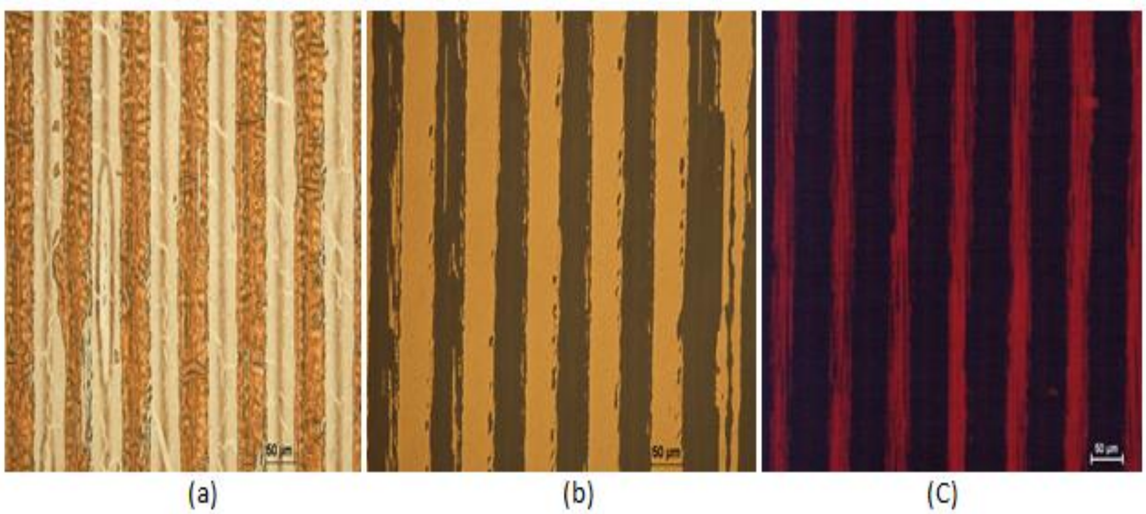

Figure 2: P3HT stripes of 50 μm patterned by transfer imprinting: a) optical microscope image of the P3HT grating on the substrate; b) optical microscope image of PDMS carrier film after transfer imprinting; c) fluorescent microscope image of patterned P3HT on the substrate.