Continuous fabrication of polymer waveguides with smooth sidewalls by Dynamic Nano-Inscribing (DNI) and NanoChannel-guided Lithography (NCL) processes

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Micro and nano photonics devices, such as micro-resonators, communication network multiplexers, and optical buffers, require on-chip interconnects using optical waveguide. Chip-to-chip interconnects using waveguide or fibers are also becoming necessary to solve the bandwidth challenges. Developing a scalable waveguide fabrication technique is therefore of great need. Low propagation loss in optical waveguides is one of the most important requirements. Waveguide loss is the sum of many factors including material absorption, Rayleigh scattering, substrate leakage and sidewall roughness; among which sidewall roughness is a dominant one in the micro-fabricated waveguides[1]. Nanoimprint Lithography (NIL) provides a solution to produce the waveguide structures from the trench mold at high precision and low cost[2], but the sidewall roughness (e.g., scallops, jags) inevitably emerging on the original trench mold surface during RIE is also left on the stamped waveguide structures in conventional NIL.

To address these issues, here we utilize our newly developed processes, Dynamic Nano-inscribing (DNI)[3] and NanoChannel-guided Lithography (NCL)[4], which can create seamless linear line or grating structures at high speed in a continuous fashion under 2-D contact. To fabricate polymer waveguide using DNI and NCL, a well-cleaved waveguide mold (i.e., trenches fabricated on Si) typically heated (~80 °C) and tilted (~15-45°) slides over either a softer solid polymer (in DNI) or liquid resist-coated substrate (in NCL) under conformal contact with slight pressure (Fig. 1a), to mechanically extrude the rib arrays continuously.

Both DNI and NCL can produce seamless and infinite long waveguide structures that have ideally smooth sidewall (Fig. 1c,d) regardless of the roughness existing on the original trench mold. This can significantly reduce the waveguide loss. Also, aided by the use of liquid resist layer, NCL enables higher aspect-ratio structures needed for certain applications. Currently we use epoxy-silsesquixane (SSQ, index ~1.5) as a waveguide material that is formed on a perfluoroalkoxy (PFA, index ~1.34) substrate that function as undercladding for SSQ waveguide. More studies on various materials and detailed waveguide performance will be presented at the conference.

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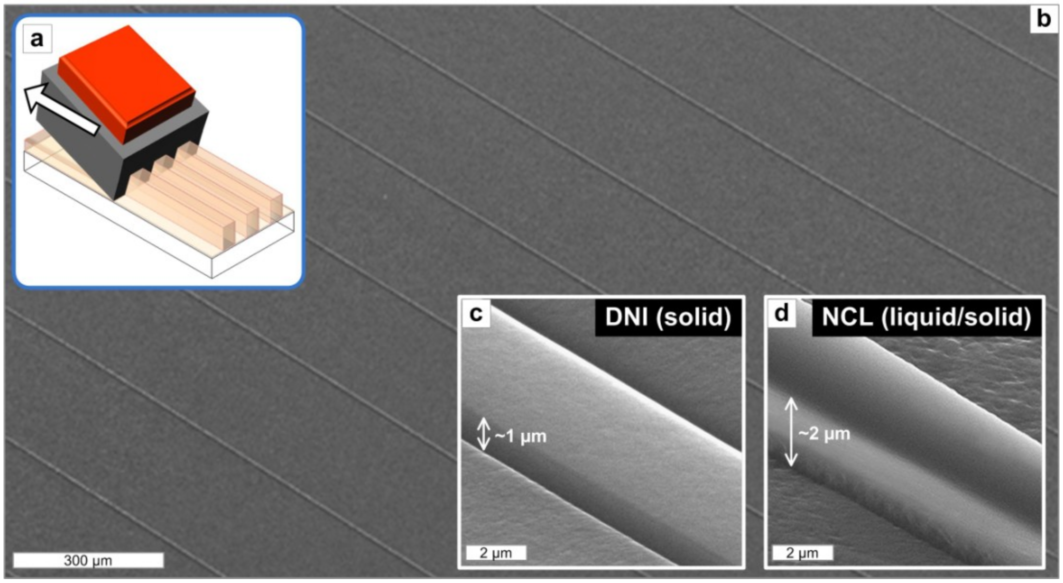

Figure 1: Waveguide arrays fabricated by DNI/NCL process: (a) A schematic drawing of DNI/NCL setup where a cleaved Si trench mold typically heated and tilted makes contact to the polymer substrate and continuously create rib waveguide structures at high speed. (b) Waveguide arrays fabricated by the DNI/NCL process. Enlarged views of the individual waveguides fabricated by the (c) DNI and (d) NCL processes, respectively, clearly show the ideally smooth sidewall surface that can help reduce the optical loss. Attributed to the use of liquid resist in NCL, the waveguide with higher aspect-ratio can be made which may further improve the quality.