Selection of UV-Resin Molds Having Nanostructures for Thermal-NIL

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Recently, nanoimprint molds made of soft polymeric materials have taken center stage as a replacement of typical molds (e.g. silicon (Si)- or metal-based hard molds) due to their excellent demolding property during demolding and low fabrication cost [1]. However, these advantages are often sacrificed by their reduced replication fidelity associated with the low mechanical strength.

In this work, we will study replication fidelity of different polymeric molds, e.g. UV-resin molds copied from a Si master mold via UV-nanoimprint lithography (NIL) and their thermal imprinting performance into a thermoplastic substrates. Fist, in order to study UV-resins filing into sharp nanostructures in a Si master mold, nanochannels with different aspect ratio (AR) were fabricated by FIB milling (Quanta 3D Dual Beam, FEI) (Figure 1). Four different UV-resins were then replicated on a PET backbone substrate by exposing to flash-type UV light (250-400 nm) for 1 min at an intensity of ~1.8 W/cm^2. Two were home-made and high surface energy UV-resins, e.g. tri(propylene glycol) diacrylate (TPGDA) and poly(propylene glycol) diacrylate (PPGDA) and the other two were commercially available and low surface energy UV-resins, e.g. polyurethane acrylate (PUA) and hydrophobic PFPE (Fluorolink MD700) (Table 1). In order to study the performance of different UV-resin molds for thermal-NIL, lastly, imprinting was carried out at 160 ^{o}C and 5 MPa for 15 min in cyclic olefin copolymer (COC) substrates (1 mm thick COC6013 substrate, T_g=147 ^{o}C, TOPAS) with the replicated UV-resin molds having low AR patterns.

Reference:

[1] Wu, J.; Chantiwas, R; Amirsadeghi, A; Soper, S; Park, S; "Complete Plastic Nanofluidic Devices for DNA Analysis via Direct Imprinting with Polymer Stamps" Lab Chip 2011, 11, 2984-2989.

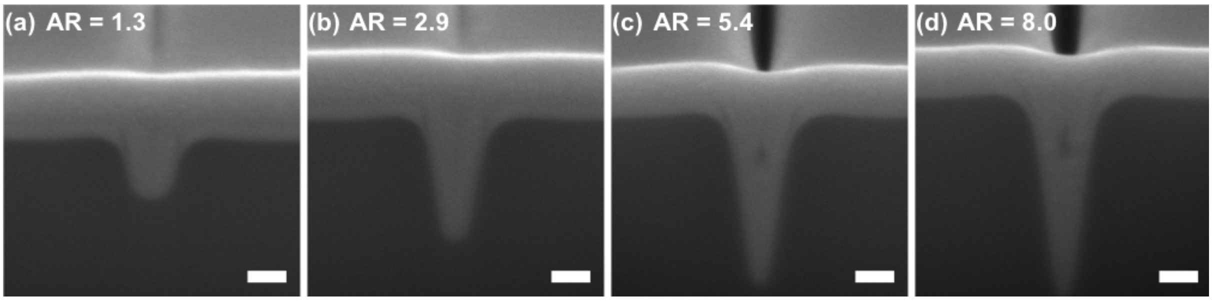

Figure 1. SEM images of cross-sectional profiles of nanochannels on the Si master with different aspect ratio. Nanochannels were milled by FIB rectangular mode, with 100 nm fixed setting width and setting depth ranging from 100 to 400 nm. When milled deeper by FIB, nanochannel cross-sectional profile changes from U-shaped to sharp tip V-shaped, which makes UV-resin solution hard to fill at the very bottom. SEM images were taken with a tilt angle of 52^o. The scale bar is 100 nm in white.

Table 1. Physical properties of UV-resins used in this study. The molecular weight is from monomers and Young's modulus and surface energy are from cured UV-resins. The viscosity of TPGDA and PPGDA is not sure but less than PUA and MD700.

UV-resin	Molecular weight (g/mol)	Viscosity (cps)	Young's modulus (MPa)	Surface energy (mN/m)
TPGDA	300	N/A	698	63
PPGDA	900	N/A	65	60
PUA	600-6000	241.4	4771	24.76
MD700	1600	850	10.5	12.7