Cleaning Defects of Soft UV-Nanoimprint Molds for High Aspect-Ratio Features

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Keywords: nano-imprint lithography, stamp fabrication, polymer molds, high aspect ratio, pattern collapse, UV-NIL, working stamp

Nanoimprint lithography (NIL) is a patterning technology which offers diffraction unlimited resolution and the replication of three-dimensional features. The use of UV-assisted NIL (UV-NIL) enables a synthesis of specialised functional resists and the use of NIL as a direct patterning method. The produced structures can be part of MOEMS structures which often do not require highest resolution but high aspect ratios features.
For the patterning using UV-NIL different mold materials like fused silica or polymers, which can be casted from a master structure, have been proposed. Polymers can offer a low surface free energy as intrinsic material property which supersedes additional anti-sticking coatings[1]. The usually low Young's modulus of polymers enables the imprint on uneven substrates or over particles[2] present. Apart from these key benefits, some drawbacks arise. The low Young's modulus enforces mold cavity deformation especially of patterns with large lateral dimensions during imprint (sagging). The cleaning of polymer molds is necessary to get rid of particles or uncured resist residuals. Similar to the pattern collapse occurring in the development of resist in other lithography technologies[3], the mold patterns can collapse or brake (cf. Fig. 1). This paper reports on pattern defects of soft polymer molds for UV-NIL which occur during cleaning with different cleaning agents. Thereby the materials investigated experimentally are PFPE (Fluorolink MD 40, MD 700; Solvay Solexis) and Ormostamp (micro resist technology GmbH)[4]. The structures considered are part of a planar micro-optical system and exhibit a Bragg reflector in a waveguide (cf. Fig. 2) with various feature depths. A three-dimensional simulation of the structures has been implemented in a finite element model validated using the experimental data (cf. Fig. 3). The simulations also include data for commonly used PDMS and fused silica. Capillary forces turned out to be the major root cause of pattern defects occurring during mold cleaning. The predicted faults include lateral feature collapse, ground collapse as well as feature fracture. Two ways to solve the problem can be concluded. Firstly the contact angle between any kind of cleaning agent and the mold material has to be kept to 90° or above. Secondly, the Young's modulus and the elongation at break have to be sufficiently high. This leads to a demand for ultra-stiff soft mold materials for the replication of high aspect ratio MOEMS features.

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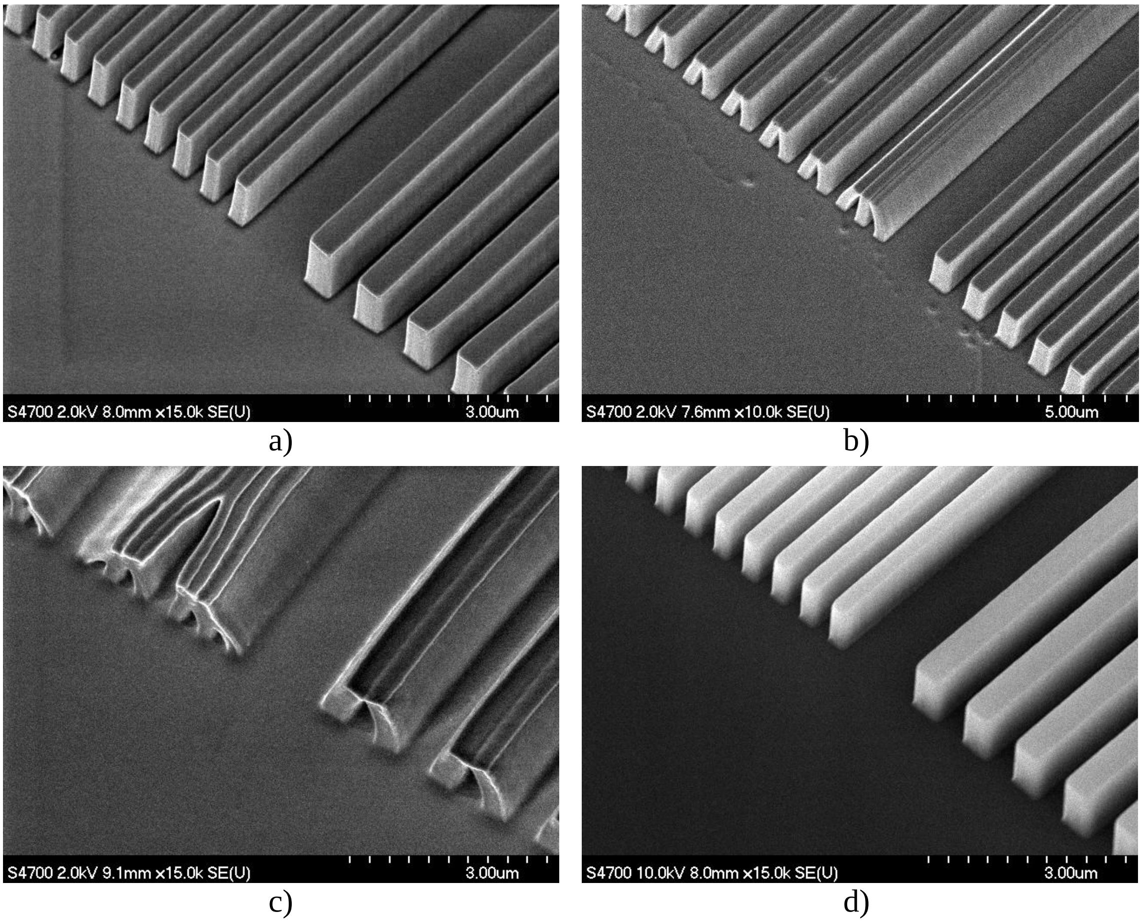
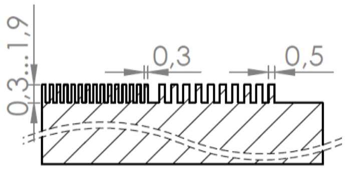


Figure 1: SEM micrograph of 300 nm and 500 nm hp structures out of MD 700 before cleaning (a) and after cleaning: MD 700 (b), MD 40 (c) and Ormostamp (d)



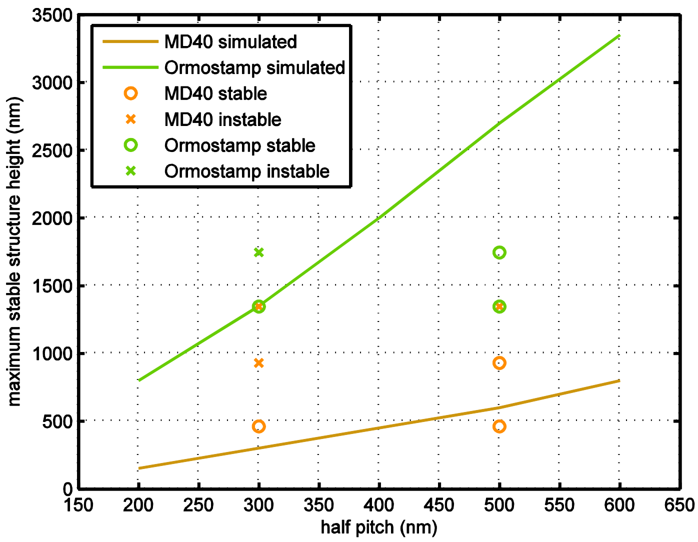


Figure 2: Layout of the produced features (dimensions in µm)

Figure 3: Calculated stability curves for different mold materials and the measured points of feature stability