Fabrication of Mesas with Micro- and Nanopatterned Surface Relief used as Working Stamps for Step & Stamp Imprint Lithography

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Step and Stamp Imprint Lithography (SSIL) often needs stamps where the structures are placed on a macroscopic mesa with a few µm height. This enables to print defined areas with sharp borders [1]. If the active stamp area is only a few mm^2 large, as it is often in thermal step and repeat NIL, e.g. when high imprint pressures for achieving low imprint times and homogeneous residual layers are needed, these mesas are defined by photolithography and subsequent etching. We have now used the concept of combined nanoimprint and photolithography (CNP) and a double stamp copying process, in order to fabricate working stamps with defined mesa structures in an easy, straightforward process [2].

As demonstrated in our previous work, we generate a mixed pattern of nano- and microstructures by imprinting and exposing a thick SU-8 layer through a locally transparent mask mold (see Figure 1) [3]. The imprinted structure represents already the final mesa with a surface relief on top of it. For the generation of a working stamp in a material with desired properties, this structure needs be replicated two times. For this purpose the UV-curable organic-inorganic hybrid polymer Ormostamp® from micro resist technology GmbH has proved to be a good choice [4]. Because of the high silicon content, the stamp surface can be permanently coated with silane based anti-sticking layers, which is a large asset in contrast to polymer stamps used until now. Figure 1 illustrates the process route for the fabrication of mesa stamps. A 30 µm thick SU-8 layer on a silicon substrate is pre-baked for 5 min @ 65 °C (1a), imprinted with a CNP mold for 15 min @ $T_{imprint}$ = 100 °C and F = 5 kN (b) in a Jenoptik HEX03 thermal NIL machine with UV-module, exposed using a 50 mJ/cm^2 dose (c) and post-baked for 5 min @ $T_{imprint}$. The non-exposed resist areas are removed in PGMEA (d). According to the used Cr mask pattern, this results in 30 µm high resist areas (0.05×0.05 mm^2 up to 10×10 mm^2) with steep slopes. The macroscopic mesa shows micro- or nanopatterned surface relief on top. The shape of mesas can be further improved by using a SU-8 double layers..

After silane coating (F_{13}-TCS), a drop of Ormostamp® precursor is dispensed on the sample and a 0.7 mm thick Borofloat substrate is placed on it (2a). The stack is gently pressed at 300 N in the HEX03. The 50 µm Ormostamp® layer is then flood exposed through the Borofloat substrate with a dose of 600 mJ/cm^2 (b). After demolding at room temperature (c), the replicated substrate is hard-baked for 30 min @ 130 °C on a hot plate. To retrieve the original polarity of the mesa, this procedure is repeated using the negative polarity substrate as a stamp (3a-c). Figure 2 reveals the surface relief which is preserved over the two replication steps. In the future this process can be further simplified by exposing the Ormostamp material directly by CNP.

The working stamps are suitable e.g. for the easy fabrication of large area stamps. This is proven by VTT using their SET NPS 300 step & repeat NIL machine. Here, a single mesa on a silicon die (10×10mm^2) is imprinted in a 325 nm thin layer of mr-I 7030E using 10 N for 30 sec at a stamp temperature of 140 °C (substrate: 70°C)– see AFM micrographs in Figures 3 and 4.

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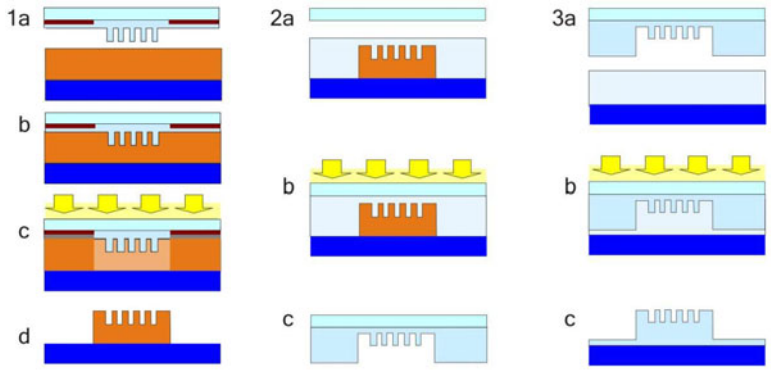

Figure 1 Process route for fabrication of Ormostamp® mesas with surface relief on top.

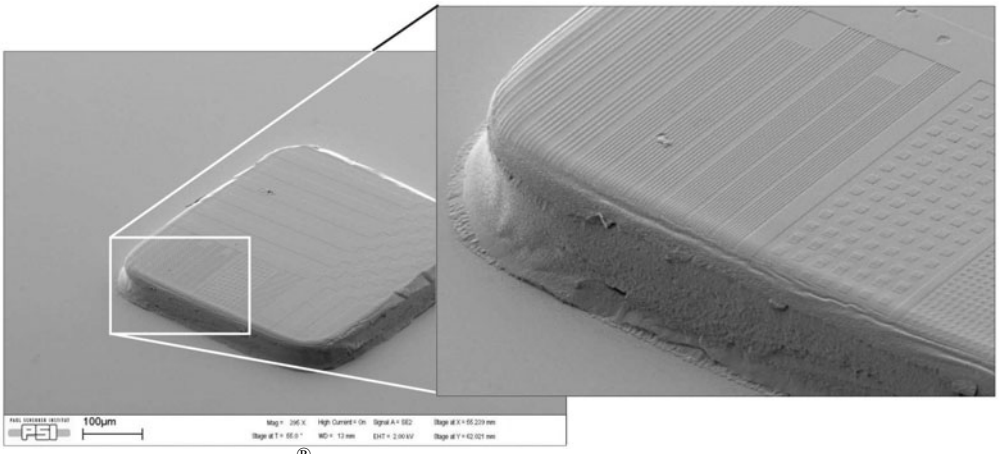

Figure 2 Single Ormostamp® mesa structure after two copying steps (original polarity).

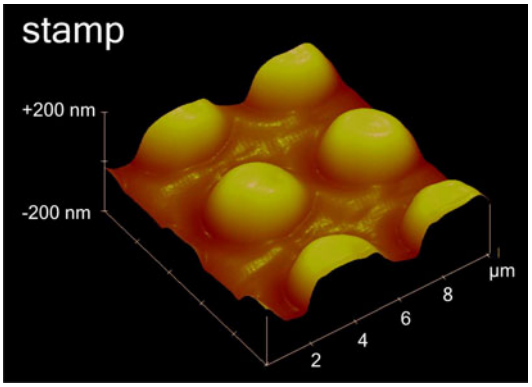

Figure 3 AFM micrograph of surface relief on top of Ormostamp® mesa working as molding structure.

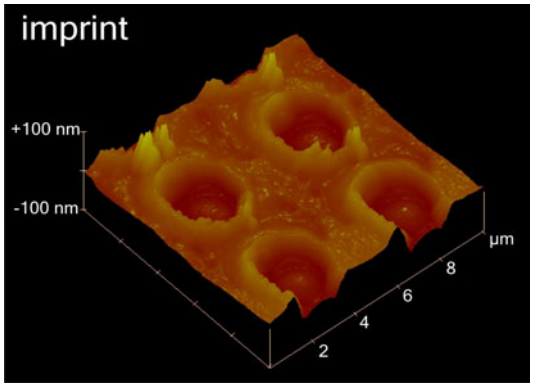

Figure 4 AFM micrograph of imprinted structure in a 325 nm thin layer of mr-I 7030 using step & repeat thermal NIL.