Transparent hybrid polymer stamp copies with sub-50 nm resolution for thermal and UV-nanoimprint lithography

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The concept of mastering and fabrication of daughter stamps for mass fabrication in nanoimprint lithography (NIL) is not only a means to enhance the lifetime of the original, but also to reduce the effect of contamination and damage [1]. Recently a novel organic-inorganic hybrid polymer system was successfully used for the fabrication of NIL working stamps and commercialized under the name Ormostamp®. The UV-curable hybrid polymer offers, besides high transparency, high thermal stability, and can therefore be used for UV-NIL and thermal NIL (T-NIL), as well as for combined processes (TUV-NIL) [2,3].

Because of the high silicon content, the stamp surface can be permanently coated with silane based antisticking layers (ASL), which is a large asset in contrast to the polymer stamps used until now. To comply with the requirements for high resolution and structural fidelity, the oxygen plasma step needed for the surface activation prior to silane coating is considered as particularly critical. The organic component in the cured hybrid material is susceptible to the oxygen treatment which may lead to deterioration of surface hardness and loss of structural fidelity.

We have now investigated the material in terms of different requirements: Resolution has been pushed to below 50 nm (see 100 nm pillar and 40 nm line structures in Fig. 1). This was also a prerequisite to observe deterioration effects due to multiple ASL recoating steps. The stamps were produced from different masters. Transparent stamps were produced from silicon masters by direct casting of the viscous precursor on Borofloat® substrates. To avoid template fouling by silicon containing residues and preserve the tone of the original relief (0^{th} generation), a hot embossing step was performed in polycarbonate plates or in thin thermoplastic resists before the replicated pattern was copied into the hybrid polymer (2^{nd} generation). These stamps were imprinted into several materials (see Table 1) using T-NIL up to 180°C imprint temperature. Further investigations will show the effect of recoating on the loss in structural fidelity and the imprint temperature on the micro- and nanomolding capabilities.

[1] H. Schift, J. Vac. Sci. Technol. B **26**(2) (2008) 458-480.
[2] A. Klukowska et al., Proc. SPIE **6792** (2008) 67920J.
[3] A. Klukowska et al., accepted for publ. in Microelectron. Eng. (2009).

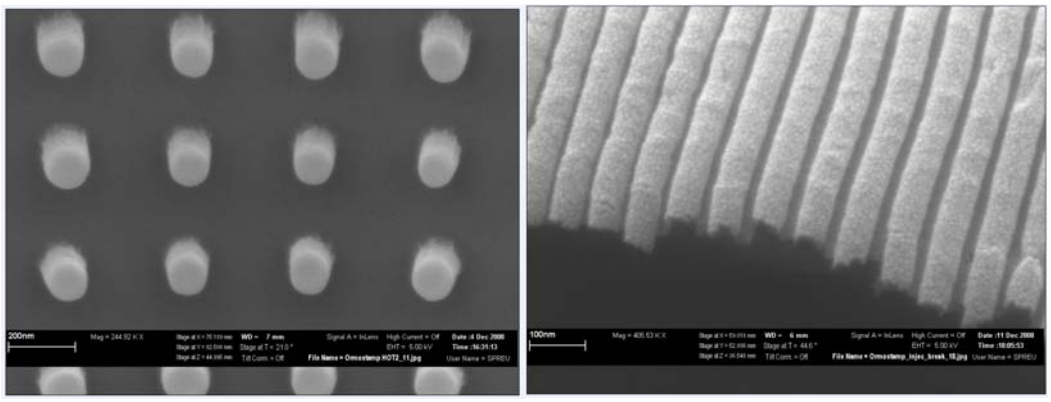

Fig. 1: Micrographs of hybrid polymer stamp copies replicated from a master fabricated by electron-beam (left side, 100nm pillars, 240nm height) and EUV-interference lithography (right side, 70nm period grating with 1.0×0.2 mm^2 array, coated with gold film for SEM).

Material	**Properties**	**Imprint parameters**	**Structure / Tone**	**Comments**
silicon master	silicon	-	0th generation	coated with ASL
PC	T_g=140°C	$T_{imprint}$=180°C	negative (1st gen.)	not coated
Ormostamp	viscosity	casting on Borofloat substrate (3 µm thickness)	negative (1st gen.) from silicon and positive (2nd gen.) from PC	no ripping during demolding observed
Imprint with Ormostamp replica		positive (2nd gen.) and/or negative (3rd gen.)		
mr-NIL 6000.3	T_g=40°C	$T_{imprint}$=110°C UV exposure t_{UV}=5s	positive (2nd gen.)	combined thermal and UV-NIL (TUV-NIL)
mr-I 7030	T_g=70°C	$T_{imprint}$=140°C	positive (2nd gen.)	5 imprints at moderate temperature
mr-I 8030	T_g=115°C	$T_{imprint}$=180°C	positive (2nd gen.)	$t_{imprint}$ = 20 min
PMMA	T_g=105°C	$T_{imprint}$=180°C	positive (2nd gen.)	$t_{imprint}$ = 20 min

Table 1: Comparison of different materials replicated with Ormostamp stamps. Multiple ASL coating steps were performed with a total plasma exposure time of 10 min. The exposure was done within a Jenoptik HEX UV-module with I = 2.8 mW/cm^2@ 365nm ($\Delta\lambda$=10nm) and 50 bar.