Flat and highly flexible composite stamps for nanoimprint, their preparation and their limits

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Replica stamps for nanoimprint have become more and more relevant in the past years. These replica stamps can reduce the process costs substantially; furthermore flexible replica stamps may open up new possibilities. In addition to enabling conformal contact between stamp and substrate, even with non-flat samples[1], one important option is to reduce the size of a particle-induced imprint defect[2,3]. Another option is to minimize demolding forces during separation by sequential demolding (rolling mode)[4].

The flexibility of such replica stamps is controlled by the modulus and the thickness of the stamp. However, flexibility is restricted by practical aspects. A small modulus limits the structure size and aspect ratio due to pattern collapse and a very thin stamp may be complicated to handle. Therefore composite stamps are a good alternative. These flexible composite stamps consist of a structured top layer and a flexible supporting backplane and, optionally, some additional layers in between. Because of shrinkage due to crosslinking or preparation at elevated temperature these stamps are often bended at room temperature (see Fig. 1a), which hinders an easy use. Bending can be minimized by use of a thicker backplane, as e.g. with SCIL stamps; unfortunately, this counteracts flexibility.

In contrast, our concept relies on the correct choice of the preparation parameters with regard to the properties of the stamp materials involved, namely the coefficient of thermal expansion (CTE) and the shrinkage due to crosslinking. In our procedure (see Fig. 1b), the shrinkage of the top layer during crosslinking is counter-balanced by the higher thermal shrinkage of the backplane during cool-down, when the right process temperature is chosen, resulting in a flat stamp.
In order to quantify the potential of such highly flexible stamps (see Fig. 2) for technical use we address the suitability to reduce the size of particle-induced imprint defects. Therefore particles of a well-defined size are dusted across the coated substrate before imprinting with different contact pressures. With increasing pressure the risk of stamp failure increases; as sketched in Fig. 3, the top layer may break when extended beyond a specific material characteristic, the "elongation at break". The respective limits are identified experimentally as well as theoretically.

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[1] T. Köppelmayr et al, Surf. Topogr.: Metrol. Prop. 3, 024003 (2015)
[2] L. Chen et al, J. Vac. Sci. Technol. B 23, 2933 (2005)
[3] B. Li, J. Zhang and H. Ge, Appl Phys A 110,123 (2013)
[4] T. Shiotsu et al, J. Vac. Sci. Technol. B 31, 06FB07 (2013)

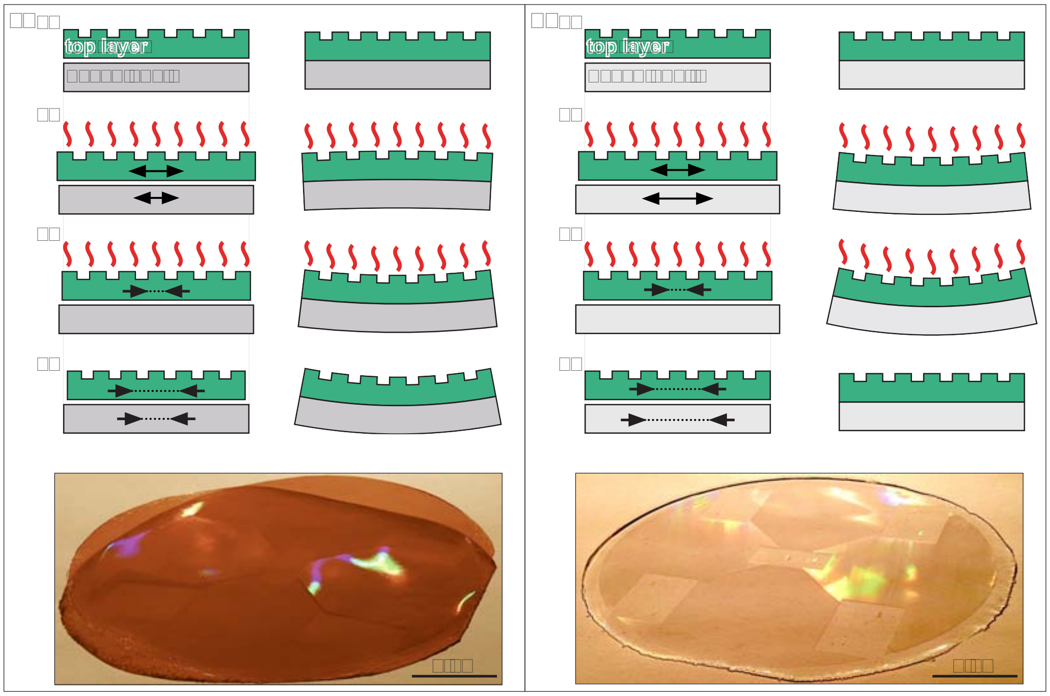

Fig. 1. *Issue of thermal crosslink of the top layer on backplanes with different CTE.* a) The CTE of the backplane is higher than the one of the top layer and b) vice versa. For both cases, the left hand sketches indicate the dimensional changes if the layers were separate (see arrows). The right hand sketches indicate the real situation (both layers in contact) with bending showing up. The four situations sketched are: 1. Initial situation, room temperature (before crosslinking of the top layer), 2. after heat-up, 3. after crosslink of the top layer and 4. after cool-down. The photographs give typical results. Top layer 20 µm OrmoStamp with backplanes a) 125 µm PI and b) 300 µm PDMS.

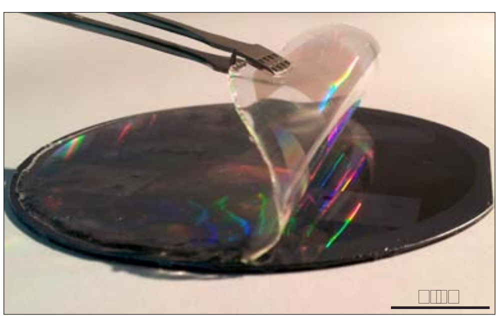

Fig. 2. *Benefits of the flexibility of the composite stamp.* The stamp (20 µm OrmoStamp on 300 µm PDMS) allows easy separation from the substrate by peeling.

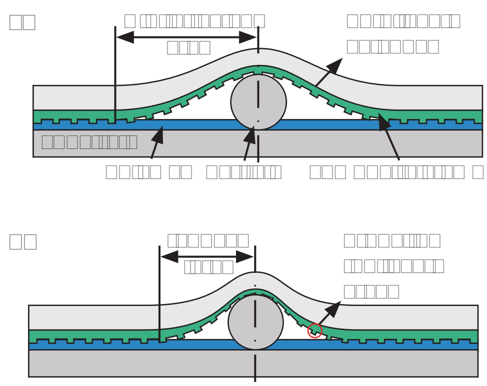

Fig. 3. *Potential stamp damage due to particles.* a) Low contact pressure, b) increased contact pressure.