Combining UV-nanoimprint lithography and inkjet printing for the fabrication of monolithic micro-optical components

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The application of advanced technologies such as for the manufacturing of specific µ-optical elements is often associated with high costs. As an example, microlenses with unique features - specified focal distances or shapes - can be inkjet-printed based on pre-patterned substrates. [1] The inkjet printing (IJP) of such elements in high throughput fabrication and low-cost applications may be hampered by its processing time due to the lack of parallelization.

A possible solution is the combination of nanoimprint lithography (NIL) approaches [2] with IJP as it enables the parallelized manufacturing of multiple monolithic components by replication. In addition, monolithic components are expected to show improved optical behavior and higher reliability. In this paper the combination of microlenses arrays (MLAs) IJP, containing lenses with individual characteristics, and their UV-NIL high-throughput replication into commercially available optical polymers is presented for the first time.

The microlens shape control is possible by confining inkjet-printed cross-linkable inks [3] onto substrates with pre-patterned platforms as recently described. [4] As depicted in Figure 1, the required masters are produced by photolithography leading to platforms with a nominal height of 7 µm and diameters ranging from 50 µm to 300 µm (Step 1). Subsequently, a transparent working stamp is produced by UV-casting (Step 2). The coating with an anti-sticking layer enables easy de-molding. The following UV-NIL replication leads to substrates made of OrmoComp® or PDMS (Step 3). The IJP step follows the process described in [4] but achieving herein convex MLAs with individual-lens characteristics (Step 4) which are replicated into a working stamp - of OrmoStamp® - with inversed pattern polarity (Step 5). Then, the final UV-NIL replication can be performed leading to convex monolithic MLAs (Step 6). The described process allows high-throughput fabrication of OrmoComp® or PDMS MLAs while preserving their shape and optical characteristics. Exemplary master substrates of OrmoComp® and PDMS are shown in Figure 2. A typical inkjet-printed MLA and its focal plane are shown in Figure 3. A replicated working stamp is shown in Figure 4a and the final monolithic MLAs in Figure 4b (OrmoComp® MLA example). Optical characterization has been performed and will also be presented.

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[2] H. Schift, J. Vac. Sci. Technol. B **26**, 458 (2008)
[3] A. Voigt, et al. , Microelectron. Eng. **88**, 2174 (2011)
[4] L. Jacot-Descombes, et al. , J. Micromechanics Microengineering **22**, (2012)

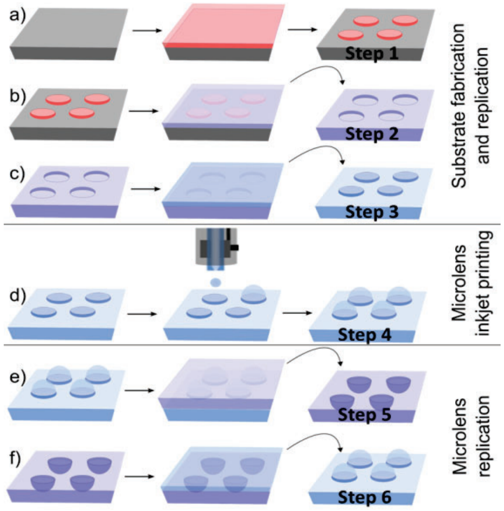

Figure 1: Process flow steps for fabrication of a)-c) platforms and d)-f) lenses: a) Master structures in positive photoresist on silicon wafers; b) Working stamps; c) Replicated platforms; d) MLAs on platforms by IJP (convex lenses) e) Microlens stamp (concave lenses) and f) Monolithic MLA replication (convex lenses).

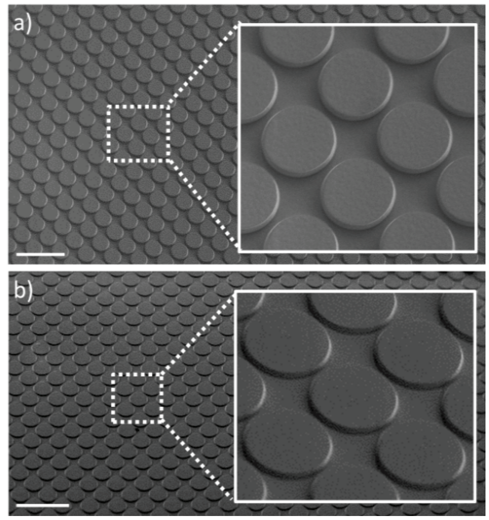

Figure 2: Step 3; Tilted SEM images of pre-patterned replicated substrates involving 100 µm in diameter platforms of a) OrmoComp® and of b) PDMS. The scale bar is 300 µm.

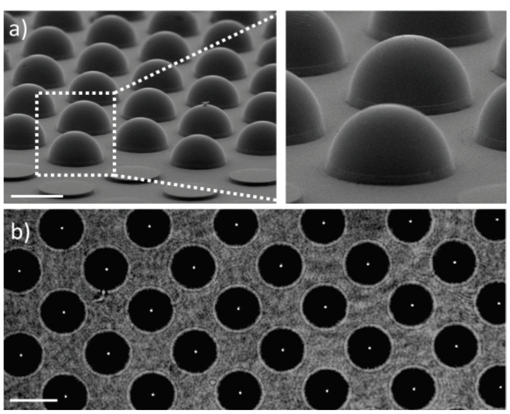

Figure 3: Step 4; a) SEM of an inkjet printed MLA, b) Optical image recorded on a CCD camera of the microlens focal plane in near field. The scale bar is 100 µm.

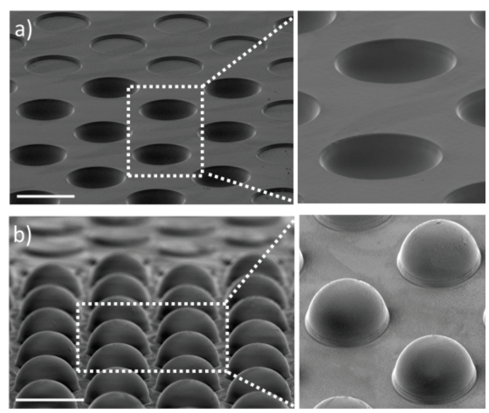

Figure 4: a) Step 5; Replicated MLA into a (negative) working stamp of OrmoStamp®. b) Step 6; Replication into final desired material; example with OrmoComp® shown here. The scale bar is 100 µm.