Novel UV-curable Hybrid Polymers with Elevated Refractive Index and Improved PDMS-compatibility

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The availability of polymers as optical materials plays a crucial role for the easy, cost-efficient and reliable manufacture of micro- and nano-optical components by standard and advanced production techniques. The increased market expectation of processability as well as the rising diversity of applications such as camera lenses, LED's, waveguides etc. are constantly challenging the technical compatibility as well as optical performance of polymer materials. In this context, UV-curable inorganic-organic hybrid polymers based on ORMOCER®-technology[1] have been evolved and are widely used for various applications[2] due to their excellent optical properties. Amongst them OrmoComp® and OrmoClear® are established candidates for the manufacture of micro optical components and devices.[3] In this contribution, we report on the development of innovative OrmoClear®-based polymers which not only meet the anticipated material's optical performance, but also exhibit an improved adaptability to patterning technologies and advanced micro- and nano-optical applications. In this regard, the prototype OrmoClear®HI01 with elevated refractive index (RI) was evolved by the employment of surface-modified ZrO_2-nanoparticles (see dispersion curve in Figure 1). It exhibits an RI of approximately 1.60 (at 589 nm). Despite addition of nanoparticles the excellent transparency (see transmittance curve in Figure 1) as well as micro- and nano-replication capability (i.e. UV molding) of the base material OrmoClear® remained unaffected (Figure 2). Furthermore, a second prototype OrmoClear® FX with enhanced curing behavior was developed to efficiently suppress the formation of an oxygen-induced inhibition layer during UV curing. This improves the compatibility to PDMS, a vastly used mold material, since it allows an UV-induced crosslinking under ambient atmosphere, which further extends the technical compatibility to micro- and nano-molding techniques. Hence, OrmoClear®FX can be considered as a cost-efficient alternative to OrmoComp® bearing comparable optical properties and processing behavior and therefore fulfilling the high technical requirements of nanoimprint and UV molding technologies for potential industrial large-scale productions such as surface conformal NIL (SCIL), see Figure 3.

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[1] UV-curable hybrid polymers (ORMOCER®s) for micro optics based on a license granted by the Fraunhofergesellschaft zur Förderung der Angewandten Forschung in Deutschland e.V.
[2] C. Sanchez, P. Belleville, M. Popall, and L. Nicole, Chem. Soc. Rev. 40 (2011) 696-753.
[3] G. Gruetzner, J. Klein, M. Vogler, A. Schleunitz, Proc. SPIE 8974, Advanced Fabrication Technologies for Micro/Nano Optics and Photonics VII, 897406 (2014).

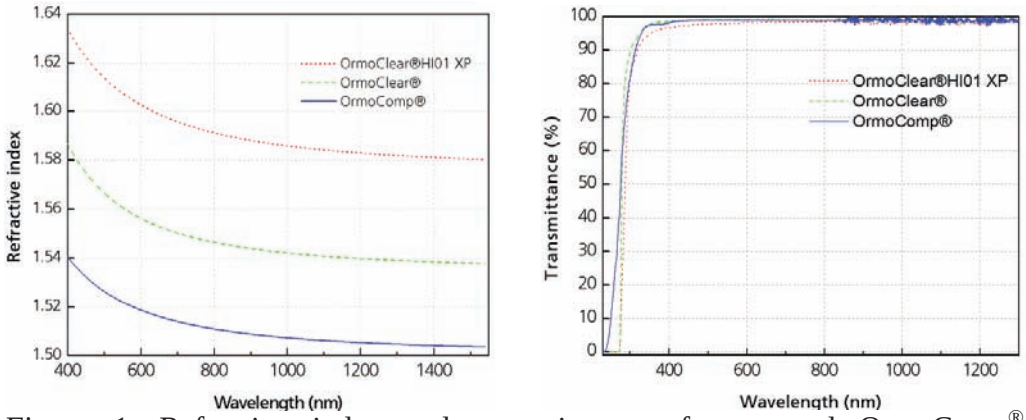

Figure 1: Refractive index and transmittance of processed OrmoComp®, OrmoClear® and newly developed OrmoClear®HI01 prototype revealing the elevated refractive index of the prototype.

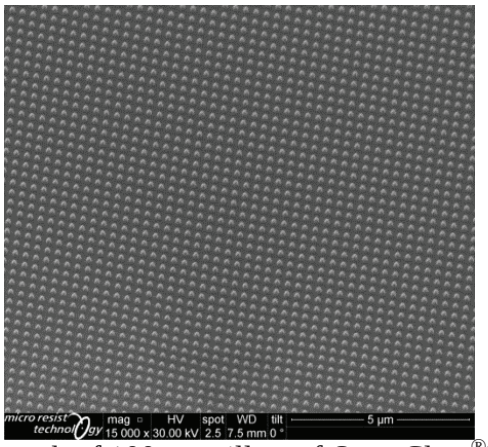

Figure 2: SEM micrograph of 100 nm pillars of OrmoClear®HI01 on a Si substrate proving the nanoreplication capabilities despite the addition of ZrO_2-nanoparticles.

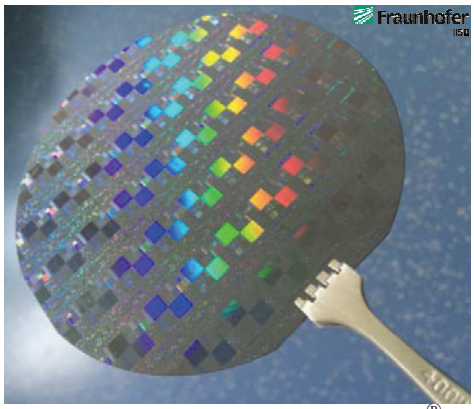

Figure 3: Waferscale replication (4 inch) of OrmoClear®FX showing micro- and nanostructures obtained by SCIL technology using a PDMS mold verifying the achieved oxygen insensitivity of the prototype (courtesy of FhG IISB, Germany).