Low reflection Fresnel lenses via double imprint combined with vacuum-UV surface hardening

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Polymer-based Fresnel lenses are low-cost alternatives for conventional glass optics, in particular when large area light management is required. Such Fresnel lenses can be prepared at high throughput e.g. by roll-to-roll processes like extrusion coating[1] on a variety of substrates. These Fresnel structures are well-suited for light concentration (non-imaging), or, the other way around, for artificial direct lightning (imaging). The optical performance of such lenses (optical components in general[2]) can be optimized by reducing the light reflection via introducing antireflective structures (AR) on top of the Fresnel structures. The effect of combining lenses with nanostructures has been confirmed experimentally; however, so far a nanostructured film was attached on top of the filled-up lens structures. A disadvantage of this preparation is the discontinuity of the refractive index at the layer interface as well as the absorption loss in the relatively thick additional layer.

Our approach is different. We explore the potential of a double imprint combined with vacuum-UV (VUV) surface hardening to apply the nanostructures directly onto the micro-structured lens. First the nanostructures are imprinted in a negative tone photoresist; then these structures are exposed surface-near by a short wavelength excimer radiation (172 nm). During the second imprint at elevated temperature, which defines the microstructures, the nanostructures cross-link, thus providing a thin hardened top layer to the microstructures. This double imprint technique allows a combination of nano- and microstructures within one material[3].

To achieve a successful combination the imprint pressure and the VUV treatment time have to be adjusted. If the VUV time is too short (< 5 s), the nanostructured top layer may rupture during the imprinting of the micro-prisms under the pressure applied. On the other hand, if the VUV time is too long (>20 s) the micro-prisms cannot be replicated. We demonstrate that adequate adjustment of VUV time and pressure allows the preparation of the AR-structures on the micro-prisms without rupture of the pre-cured nanostructured layer. Templates prepared in this way may serve as a master for e.g. roll-to-roll processing.

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[1] S. Murphy et al., Adv. Eng. Mater. **18**, 484 (2016)
[2] J.-J. Kim et al., Nano Lett. **16**, 2994 (2016)
[3] C. Steinberg et al., Microelectron. Eng. **155**, 14 (2016)

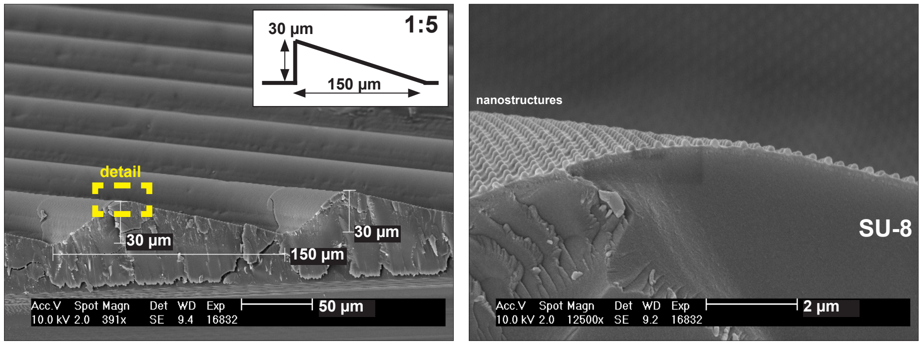

Figure 1: Fresnel prisms (height ratio 1:5) in combination with anti-reflective nanostructures. (Left) Overview of the imprinted micro-prisms in SU-8, (right) detail of the top. The nanostrcutres cover the complete lens surface.

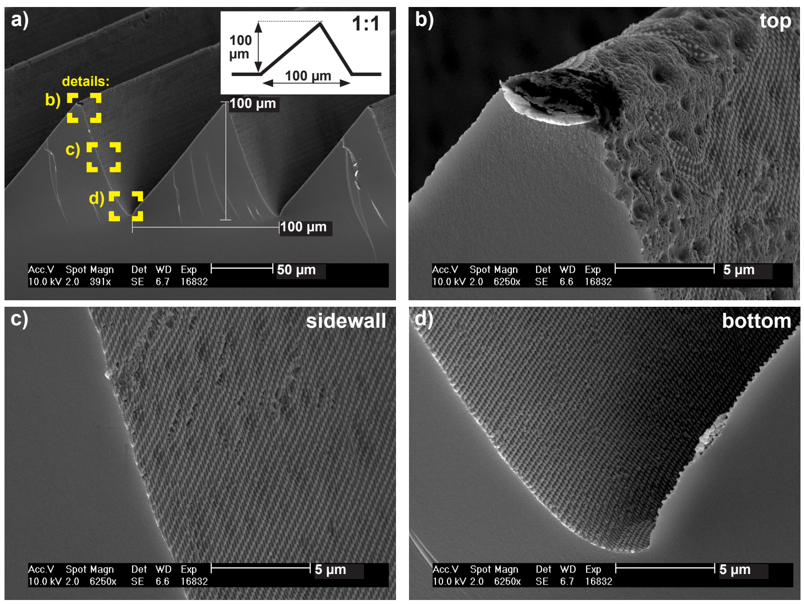

Figure 2: Fresnel prisms (height ratio ≈ 1:1) in combination with anti-reflective nanostructures. (a) Overview of the imprinted micro-prisms in SU-8, (b-d) details corresponding to the marked positions.

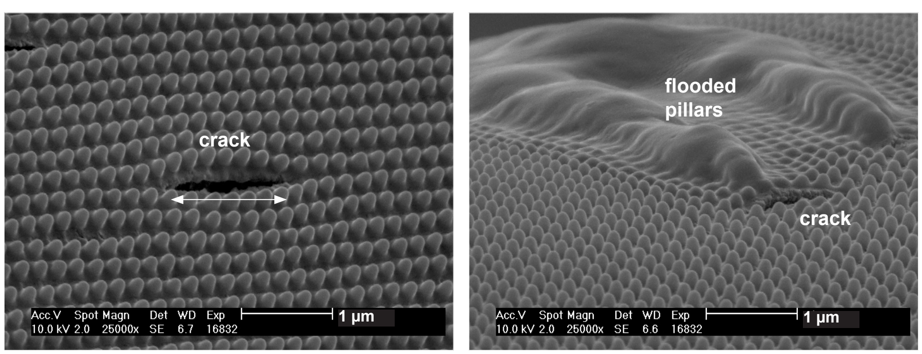

Figure 3: Process issue with a too thin cross-linked layer. (Left) Onset of crack formation, (right) liquid SU-8 from the core starts to flood the nanostructures during the second imprint for definition of the micro-prisms.