High Quality Diffractive Optical Elements (DOEs) Using Nanoimprint Lithography

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Augmented reality (AR) enhancing the existing natural environment by overlaying a virtual world is an emerging and growing market and attracts huge commercial interest into optical devices which can be implemented into head-mounted AR equipment. Diffractive optical elements (DOEs) are considered as the most promising candidate to meet the market's requirements such as compactness, low-cost, and reliability [1] as they replace large display headsets for virtual reality (VR) by light-weight glasses. Their structures can vary from simple optical gratings for diffractive wave guides [2] to binary elements or pyramid-like multilevel structures [3]. There are many techniques to fabricate DOEs based on, e.g. greyscale lithography, direct writing using laser or electron beams, and direct machining. However, these methods exhibit great weaknesses such as low process variability and surface precision, high equipment costs, and low volumes limiting their suitability for mass production [3]. In contrast, soft lithography replication offers a pathway to the fabrication of large area DOEs with high aspect ratios, multilevel features, and critical dimensions below the diffractive optical limit down to 50 nm. In combination with UV-curable materials, the fabrication time can be drastically reduced in comparison to, e.g. hot embossing replication methods, making it very appealing to industrial applications [3].
Here, we present a very flexible approach to fabricate high quality DOEs using nanoimprint lithography based on porous soft stamp materials (see SEM image in Figure 1). Uniformly spin-coated substrates approach a flexible working stamp in a radial imprint wave from the center to the edge of the imprint substrate. As a result, any enclosure of air is avoided and a full-field imprint can be obtained. High DOE efficiency requires low total thickness variation (TTV) of both the structure height and the residual layer thickness (RLT). To this end, accurate control of the normal force over the complete substrate area on a uniformly spin-coated imprint resist is implemented before UV curing (see Figure 2). The in-plane rigidity of the stamp carrier and the repeated alignment during the imprint process yield excellent precision of the DOE structures on the stamp to the imprint substrate. In-machine separation of the substrate from the stamp enables high production rates and promotes the suitability of this technique for mass production. Furthermore, as this technique can also be applied for curved imprint substrates, it can be a boost in the production of high quality DOEs at low cost.

References:

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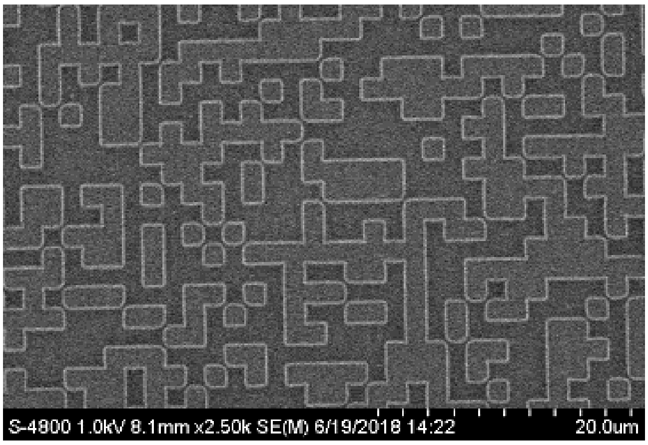

Figure 1. Top view SEM image of a binary diffractive optical element using nanoimprint lithography.

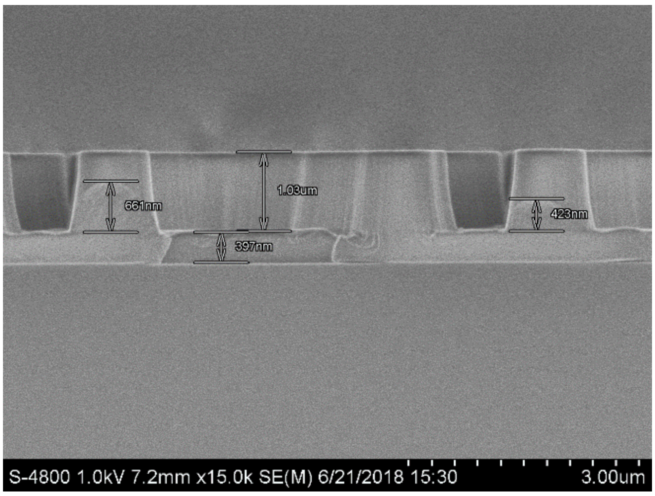

Figure 2: SEM side view image of a diffractive optical element on a silicon substrate.