

Two-photon grayscale lithography

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In this presentation we introduce two-photon grayscale lithography (2GL®). In contrast to one-photon grayscale lithography, for 2GL®, the exposed volume pixel is strongly confined to the vicinity of the laser focus allowing for a truly 3-dimensional dose control with very high spatial resolution (see Figure 1). Discrete and accurate steps as well as essentially continuous topographies can be printed with increased throughput, on any substrate, and without the need for additional lithography steps or mask fabrication.

As demonstrators, we design, fabricate, and characterize diffractive optical elements (DOE) as continuous topographies (see Figure 2). The DOE topography is printed by modulating the exposure dose and associated voxel height, thus not limited anymore to a few levels that required a printed layer each, and strongly decreasing the print time while required high lateral and axial resolutions are still met. Such DOEs can be used either directly as prototypes or as masters for tooling production.

The 2GL® process is also applied to smooth surfaces of refractive micro-optical elements, by eliminating the stair casing effect when adding layers on top of each other (see Figure 1). This allows higher distances between layers and proportionally decreases print times, an important factor in industrial environment. The resulting structures are characterized by confocal and electron-beam microscopy. They show surface roughness below 10nm with high shape accuracy, without requiring any post-processing steps. This printing approach is compatible with micro-lens arrays with 100% fill factor, free form shapes and high aspect ratios.

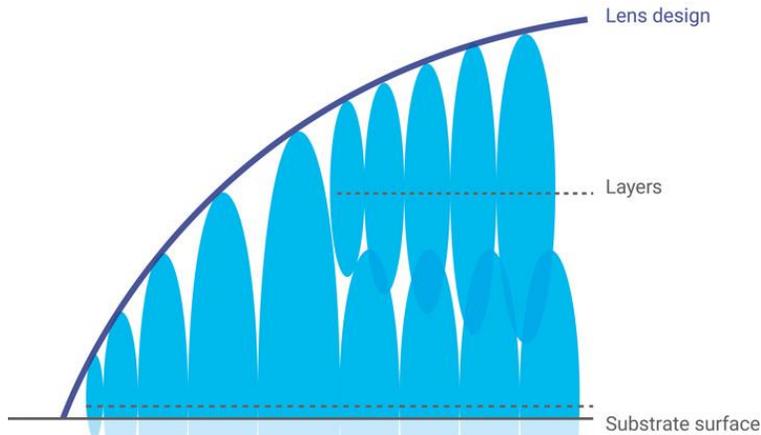


Figure 1: The principle of two-photon grayscale lithography: For the fabrication of micro lenses the layer spacing can be increased and by accurate tuning of the exposure dose along the layers the surface will remain smooth.

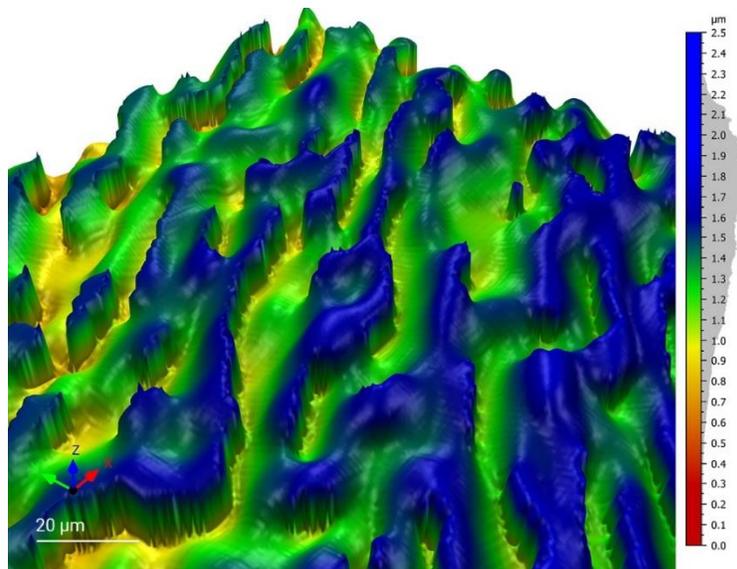


Figure 2: A quasi-continuous DOE: With the use of two-photon grayscale lithography, one can directly fabricate multi-level diffractive optical elements (DOEs) in a single layer. Up to 4,096-level designs can be processed into discrete or quasi-continuous topographies.