Software based optimization of gray scale laser lithography

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Gray scale lithography is a key technology for creating micro-optical elements such as micro-lens arrays, Fresnel lenses, blazed gratings, or DOE (diffractive optical elements). The advantage of gray scale lithography compared to other technologies is its geometric flexibility, high speed, and the possibility to scale it up to large exposure areas (e.g. 1.4 x 1.4 m^2). Major challenges for the fabrication are the non-linear resist response to the illumination light in conjunction with geometry-dependent effects related to the laser beam shape, and the isotropic movement of the development front (lateral development) which cause deviations in the topography.

The complexities of the process result in a very steep learning curve for anyone who starts with gray scale lithography. In fact, even experienced users need to perform a highly time-consuming optimization process that involves dozens of exposure iterations before achieving the precise geometry of a new structure. This experimental optimization is not a practical option.

The authors present a new model-based approach for creating highly accurate gray scale topographies with Gaussian beam laser illumination. The goal of this approach is to reduce the number of iterations needed in the optimization process, to make it easier for users to carry out gray scale lithography, and consequently lower the barrier to enter this field.

A micro-optical Fresnel lens design and other application-based test structures are exposed on a direct write lithography system using a focused Gaussian diode laser beam. Prior to the exposure, the design data is optimized by a new gray scale correction algorithm which takes into account the light-resist interaction and the resist development process after exposure. This is including the beam geometry, absorption and bleaching effects of the resist, as well as the translation of the exposure to resist dissolution rates and the following 3D development process, considering also the development in lateral direction.

The quality of the software optimization is quantified by comparing the remaining topography errors to the results of a non-data-optimized exposure.