Bend the curve: the benefit of optical proximity correction in direct writing lithography – simulation and experiment

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For grayscale lithography using direct writing lithography (DWL), the intensity of the focused laser is modulated during the lateral scan and after exposure, and during wet development, the topography is revealed. Typical structures are multilevel structures with precise steps or continuous surface topographies for which the shape has to match a desired optical function, e.g., in microlenses [1,2]. If dissolution of the positive photoresist in vertical direction is fast enough, the effect of lateral development can be limited, and the assigned dose is equivalent to a desired depth. However, the nonlinear contrast curve in photosensitive resists requires the assignment of corrected dose values to every specific pixel of a design. Typically, an iterative approach is chosen to approach the desired linear behavior. This becomes impractical if proximity effects have to be taken into account. Then doses are not only corrected depending on the contrast curve, but also on the design. For this, software such as BEAMER from GenISys GmbH has been developed. The model-based approach enables the correction in one step, avoiding the iterative approach with many experiments. Even if the model is sufficient for most scenarios, for some cases it may require additional components. In particular, the use in DWL requires different parameters such as substrate reflection, refractive index and vertical focus location that are often not available. Here, we show the importance of such parameters that enable the fast approximation of a desired shape without tedious iterations.

An adjustment of the so-called gray-value distribution has to be performed in order to achieve a resist topography that matches with the target. We have used this for exposure of staircase structures and lens like shapes using a Heidelberg Instruments DWL 66+ with the write mode III (min. resolutions 1 µm, focus length 4, depth of focus range of 5 µm) using a 405 nm laser. As resist we chose AZ 4562 from MicroChemicals GmbH with thickness of 15 µm, a novolak based positive resists optimized for grayscale lithography. The experiments show good agreement between simulations and exposures, with the expected improvement of the resist topography. The use of GenISys LAB allowed us to investigate intensity distribution inside the resist as well as the concentration of activated PAC. A next step would be to optimize the sidewall verticality of the structures by adjusting the focus.

[1] A. Grushina, Adv. Opt. Techn. 8(3–4) (2019) 163–169.
[2] V.J. Cadarso et al., J. Micromech. Microeng. 21 (2010) 017003.

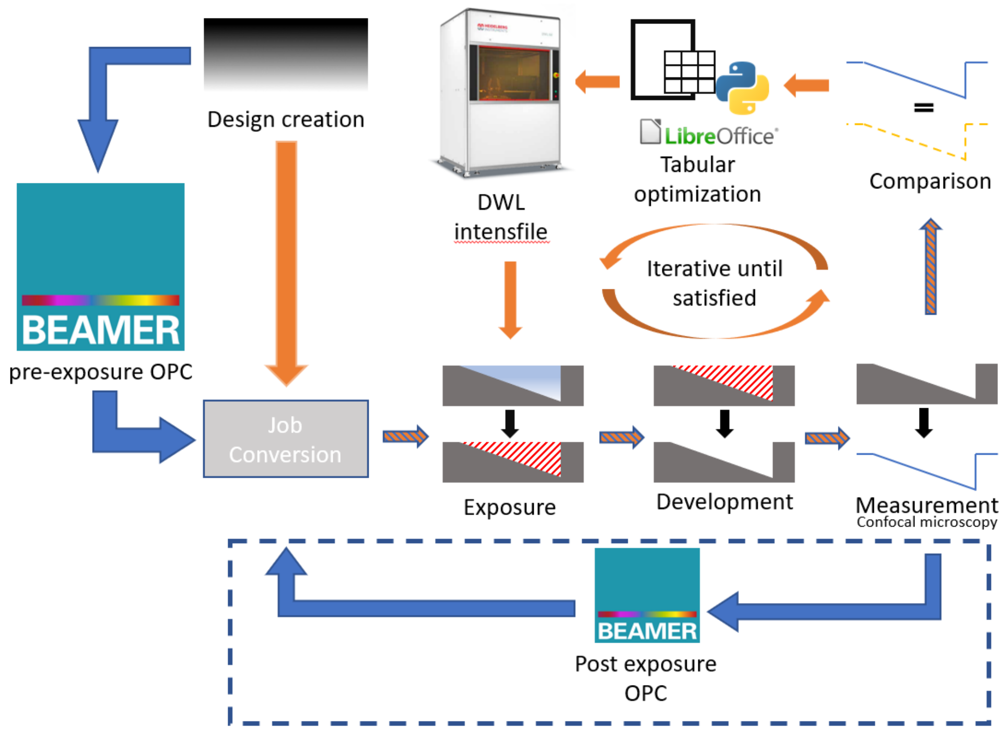

Figure 1: Process flows of both optimization methods used. The arrows indicate of the approaches, orange (iterative) and blue (optical proximity correction).

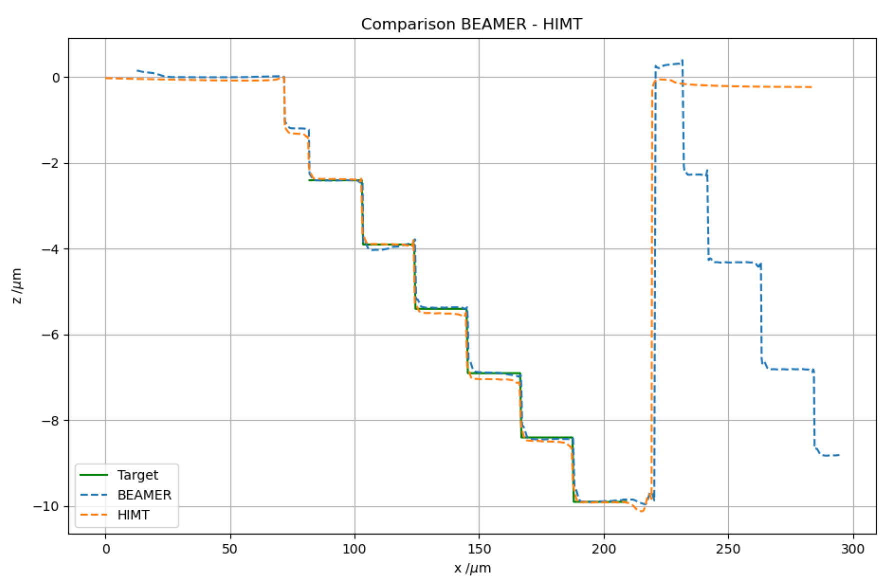

Figure 2: Comparison between target profile and both optimization results. Notice how both have similar verticality while the difference in depth of the steps is lower for GenISys' BEAMER for optical proximity correction.