Modelling and experimental evaluation of near-field intensity distributions for high-resolution EUV transmission masks

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For high-resolution patterning of periodic structures with partially coherent EUV radiation the (achromatic) Talbot lithography is well suited, with a theoretical resolution limit in the sub-10 nm range. This approach can accept partially coherent radiation, but requires precise positioning of the resist-coated wafer in sub-100 µm distance to the transmission mask. In this distance all diffraction orders contribute to the intensity modulation making its calculation challenging. Especially for complex mask structures the resulting intensity modulation cannot be predicted easily anymore and precise calculation tools are needed.

The presented simulations are based on the finite-difference time-domain (FDTD) method and executed with the commercial simulation tool 'Dr. LiTHO' of the Fraunhofer IISB. It offers the possibility to calculate the intensity distributions behind the mask, while taking several interfering factors like the bandwidth and polarization of the radiation into account. It also allows for both the calculation of complex mask designs as well as the optimization of structure size in the realized lithographic pattern.

The simulation results are experimentally evaluated with the EUV laboratory exposure tool (EUV-LET), a compact nanostructuring setup developed and used at the Chair for Technology of Optical Systems (TOS) at the RWTH Aachen University. The setup utilizes partially coherent radiation of a compact discharge-produced plasma EUV-source at 13.5 nm with 4 % bandwidth (FWHM) and allows for the realization of structures with sub-30 nm resolution. Further improvement of the achievable resolution will be achieved by designing phase-shifting transmission masks with simulation-based mask designs and the utilization of alternative grating materials leading to lower aspect ratios and more relaxed fabrication requirements. The system is equipped with a precise positioning system for mask and wafer, so that the evaluation of the calculated intensity distribution can be performed at defined distances behind the mask.

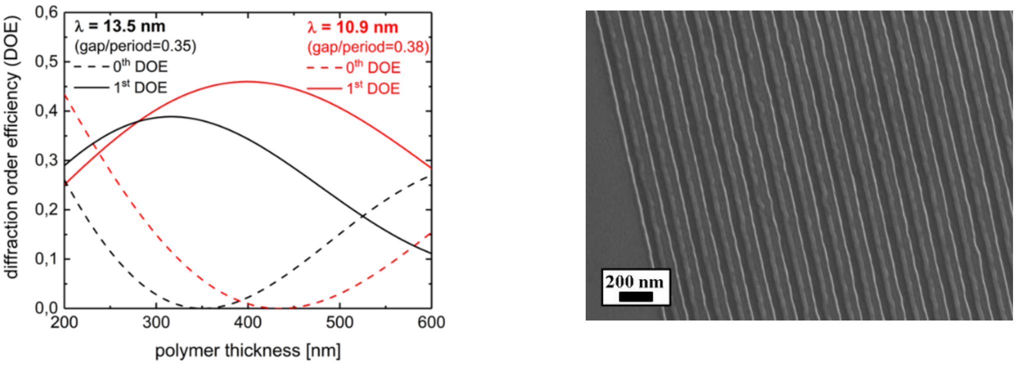

Fig. 1 *Left: Calculated 0th and 1st diffraction order efficiencies (DOE) for two different working wavelengths for optimal gap/period ratio as a function of gratings polymer thickness. Right: Exemplary transmission grating line structure with a period of 150 nm.*

In this paper we present the simulation of near-field intensity distributions for different phase-shifting transmission mask designs together with an experimental evaluation of their predicted lithographic performance. Addressed exemplary applications for different designed mask geometries will be presented and discussed.