Scatterometry, the analysis of light diffracted from a periodic structure, is a versatile methodology for characterizing periodic structures, regarding critical dimension (CD) and other profile properties. When exposing an EUV mask with EUV radiation of 13.5 nm, the radiation is reflected by the multilayer stack which is about 300 nm thick. For EUV radiation, all layers in the stack contribute to the reflection. Therefore, only EUV scatterometry provides direct information on the mask performance comparable to an EUV lithography tool. With respect to the small feature dimensions on EUV masks, the short wavelength of EUV is also advantageous since it provides more diffraction orders as compared to UV. PTB’s EUV reflectometer II allows mask surface scanning in Cartesian coordinates at 10 μm positioning reproducibility. The probed area (photon beam size) is about 1 mm square. We present measurements on prototype EUV masks and we demonstrate the use of EUV scatterometry to determine the CD and side-wall geometry of lines using rigorous calculations of EUV diffraction.

Scheme of scatterometry (measurements above). The detector angle is scanned at fixed entrance angle of 6°.

The geometrical parameters, top CD, sidewall angle, and top corner radius, indicated right above, are varied for simulation.

At right, a typical measurement of diffraction intensity as function of detector angle is shown, λ=13.65 nm.

FEM simulation of EUV scatterometry

SEM pictures of EUV mask patterns and corresponding triangulated geometries for FEM computation.

The measured diffraction orders of EUV masks do not carry direct information about the absorber line profile. In order to deduce the geometrical parameters we perform finite element (FEM) simulations of EUV scatterometry.

The FEM method is especially suited for this application:
- Maxwell’s equations are solved rigorously without approximations
- The flexibility of triangulations allows modeling of almost arbitrary structures (see above)
- With appropriate localized ansatz functions physical properties of the electric field like discontinuities and singular behaviour can be modeled very accurately (see above)
- The convergence of the FEM method to the exact solution is proven mathematically

In our work we used the FEM solver JCMharmony which has been successfully applied to various electromagnetic field computations like waveguide structures, DUV phase masks, and other nano-structured materials.

FEM solution for the electric field propagating through a phase mask. The electric field has singular behavior at corners of the absorber and discontinuities at material interfaces.

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References