2D-Fourier transform of rough apertures to complement scatterometric modelling

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Abstract. The characterisation of nanostructured surfaces by scatterometry is an established method in wafer metrology. From measured light diffraction patterns, critical dimensions (CDs) of periodic surface profiles are determined, i.e., line widths, heights and other profile properties in the sub-micrometer range. Along with the values for the reconstructed CDs, the estimation of their uncertainties is essential for evaluating the quality of the method. As structures become smaller and smaller, shorter wavelengths like extreme ultraviolet (EUV) at 13.5 nm ensure that the measured light diffraction pattern is sensitive with regard to the structure details. Obviously, the impact of structure roughness with amplitudes in the range of a few nanometers can no longer be neglected in the course of the profile reconstruction. In previous papers [1, 2] a rigorous finite element (FEM) approach with large computational domains were used to model line edge roughness, but in a simplified manner.

Here we present a 2D-Fourier transform method (FTM) to investigate the impact of line roughness on the light diffraction pattern for quite different roughness patterns. The key concept is to create samples of rough apertures composed of many slits and to calculate the irradiance of the illuminated apertures far away from the the aperture plane [3]. Applying the Fraunhofer approximation and interpreting the rough apertures as binary 2D-gratings, we compute their diffraction patterns very efficiently as the 2D-Fourier transform of the light distribution of the aperture plane. The roughness of the edges of the aperture slits is modelled by a power spectrum density (PSD) function, which is often used in metrology of rough geometries. Using the formula for this PSD, the roughness depends on three parameters, namely on the standard deviation, the correlation length and the roughness exponent. Compared to diffraction pattern of the unperturbed aperture, the rough samples are revealing the same systematic decrease of the mean efficiencies as those of the rigorous FEM simulations gained with a relatively crude and simple model of roughness. Thus the former results for the impact of line roughness on measured efficiencies are confirmed by a much more realistic model of line roughness and different types of roughness pattern.

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[2] M-A.Henn, S. Heidenreich, H. Gross, A. Rathsfeld, F. Scholze, and M. Bär, "Improved grating reconstruction by determination of line roughness in extreme ultraviolet scatterometry", Optics Letters, **37** (24), 5229 (2012).

[3] H. Gross, S. Heidenreich, M.-A. Henn, G. Dai, F. Scholze, and M. Bär, "Modelling line edge roughness in periodic line-space structures by Fourier optics to improve scatterometry", J. Europ. Opt. Soc. Rap. Public., **9**:14003 (2014).