A theoretical model for the scatterometric study of the line-edge roughness

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Developments in microelectronics are strongly associated with the reduction of the characteristic sizes of nanostructures. This gives rise to a large number of issues and challenges for nanometrology. Line edge roughness (LER), being one of the factors limiting the critical dimension of EUV lithography [1], is of particular interest for the characterization. Statistical parameters of LER can be studied using grazing-incidence small-angle X-ray scattering (GISAXS), as demonstrated experimentally [2]. Previous GISAXS experimental studies reported on an interesting effect: diffuse scattering of evanescent X-rays in nanoscale gratings generates the so-called Yoneda bands [3]. Yoneda bands originate from dynamic scattering at the critical angle of total external reflection modulated by subsequent interference by the lateral periodic structure. The configuration of these Yoneda bands depends on the structure of the surface and results in characteristic diffuse scattering patterns. These can be used for LER characterization of the nanostructures. However, for quantitative analysis of the measurements, it is crucial to develop a theoretical model to describe these higher-order effects. Typically, GISAXS patterns are simulated by using the distorted wave Born approximation (DWBA) framework considered for the plane wave solution of the wave equation. In this approach, the whole structure of the grating is considered as a perturbation of the planar multilayer structure. Inherently, this assumption neglects any dynamical effects of the propagation of the scattered wave in the grating, and thereby it is not capable of reproducing Yoneda bands in the calculations. We develop a mathematical model which takes into account both the dynamical effects and the diffuse scattering in gratings. For that, we subdivide our system onto an ideal grating structure, and perturbations of the line edges, as opposed to the previous approach. To solve the Helmholtz equation for an ideal grating we use many-beam dynamical diffraction theory. Further, we coupled these solutions for the incident and scattered waves using DWBA. Theoretical model and result of numerical simulations will be discussed in the presentation.

[1] Brunner, Timothy A., et al. "Line-edge roughness performance targets for EUV lithography." Extreme Ultraviolet (EUV) Lithography VIII. Vol. 10143. International Society for Optics and Photonics, 2017.

[2] Fernández Herrero, Analía, et al. "Characteristic diffuse scattering from distinct line roughnesses." Journal of Applied Crystallography 50.6 (2017): 1766-1772.

[3] Soltwisch, Victor, et al. "Correlated diffuse x-ray scattering from periodically nanostructured surfaces." Physical Review B 94.3 (2016): 035419.