Accurate dimensional monitoring of e-beam patterned grating structures by Mueller matrix polarimetry

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Process control in microelectronic manufacturing requires real-time monitoring techniques. Among these different techniques, optical scatterometry has gained widespread applications due to its advantages, such as low cost, noncontact, non-destruction and high throughput. Recently, the Mueller matrix polarimetry (MMP) has been successfully introduced for CD and overlay metrology. Compared with conventional ellipsometric scatterometry, which only obtains two ellipsometric angles, MMP-based scatterometry can provide up to 16 quantities of a 4×4 Mueller matrix in a single measurement. Consequently, MMP can acquire much more useful information about the sample and thereby can achieve better measurement sensitivity and accuracy [1].

In this paper, we use MMP to characterize e-beam patterned grating structures. The factors that affect the final measurement accuracy are fully investigated, including the geometric models applied in the fitting process and the depolarization effects. Figure 1(a) depicts the comparison of the reconstructed top *CD*s of one of the e-beam patterned grating structures when applying different geometric models and at different azimuthal angles. Figure 1(a) exhibits that the reconstructed top *CD*s associated with both Model1 and Model3 are consistent when the azimuthal angle is varied from 0° to 90°. Considering that Model1 is much simpler than Model3, Model1 is a better geometric model. Figure 1(a) depicts the corresponding fitting errors between the polarimeter-measured and calculated best-fit Mueller matrix spectra. As depicted in Fig. 1(b), all the three geometric models show a large jump at the azimuthal angle of 45°. We further demonstrated that the large jump in the fitting error curve shown in Fig. 1(b) was attributed to the depolarization effects induced by finite spectral bandwidth and numerical aperture of the instrument. After incorporating the depolarization effects, the corresponding fitting error at the azimuthal angle of 45° exhibited a decrease of ~85% for Model1. As an example, Fig. 2 gives the fitting results between the polarimeter-measured and calculated best-fit Mueller matrix spectra at the azimuthal angle of 45° when applying Model1.

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[1] X. G. Chen, C. W. Zhang, S. Y. Liu, Appl. Phys. Lett. **103**, 151605 (2013).

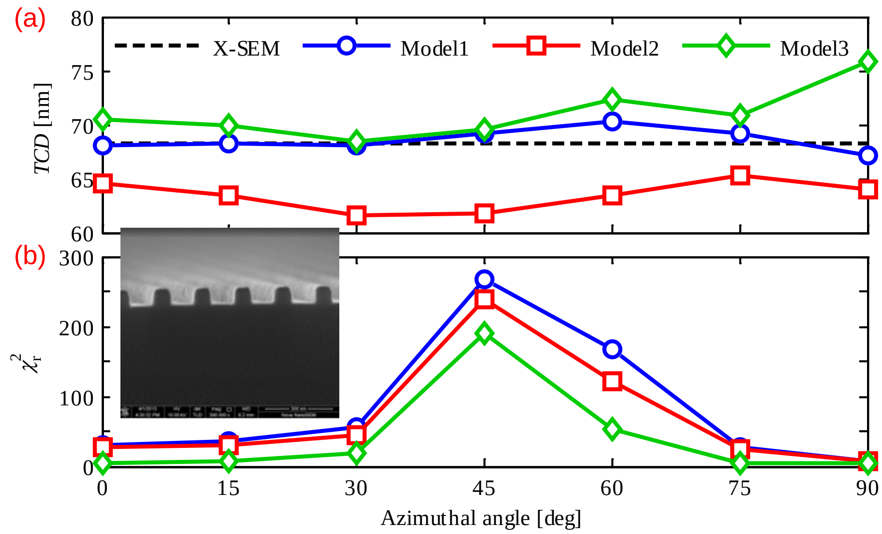

Figure 1: Comparison of the reconstructed top CDs (TCD) of one of the e-beam patterned grating structures and the associated fitting errors (χ_r^2) between the polarimeter-measured and calculated best-fit Mueller matrices when applying different geometric models and at different azimuthal angles. Model1 is a rectangular model, Model2 is an isosceles trapezoidal model, and Model3 is a two-layer isosceles trapezoidal model. The inset depicts the cross-sectional scanning electron microscopy (X-SEM) image of the investigated grating structure. The grating pitch is 180 nm.

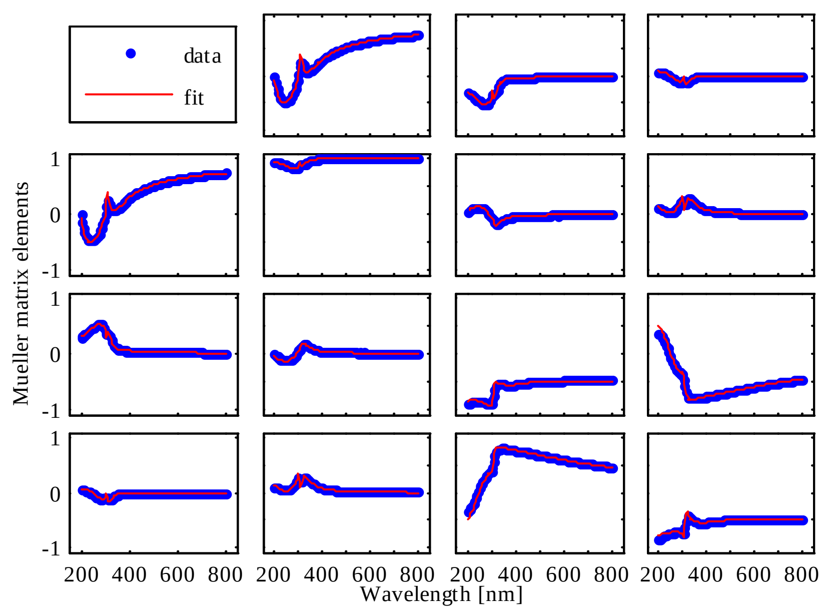

Figure 2: Fitting result of the polarimeter-measured and calculated best-fit Mueller matrix spectra at the azimuthal angle of 45° when applying Model1 and *taking the depolarization effects into account.* The Mueller matrix elements are normalized to m_{11}, which is not shown. The incidence angle is fixed at 65°, and the wavelength is varied from 200 to 800 nm with increments of 5 nm.