Simulation technique for pattern inspection using projection electron microscope

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Predicting and understanding image formation in an electron microscope is a critical and doable task. In recent times, the accuracy of simulations using advanced Monte Carlo methods has improved significantly. We developed an upgraded CHARIOT Monte Carlo software[1] (Abeam Technologies, Inc.) for pattern inspection using projection electron microscope (PEM). PEM is one of the electron microscope techniques that is based upon the imaging electron optics (EO), and has an advantage of giving a considerably higher throughput than achievable in the case of conventional scanning electron microscope (SEM) type inspection system as shown in Fig.1.[2] That is because PEM probes a sample target with areal illumination, whereas SEM probes a sample with a spot beam. Therefore, we have been developing a PEM for EUV patterned mask inspection.[3] In order to accelerate this development program, we also develop the upgraded simulator that has the capabilities to take into account electron scattering in 3D patterns, charging and discharging effect, size of an aperture stop, and imaging EO.[4] Since most of the simulation time was spent during the calculation in the imaging EO, in order to speed up the calculation time in the field, CUDA (Compute Unified Device Architecture) technique was applied in this simulator. In this paper, we describe the simulation techniques to demonstrate the defect detection. As shown in Fig.2, secondary electrons emitted from the sample are focused on an image detector through the imaging EO, and a 22 nm sized dot defect on the line and space (L/S) pattern is successfully identified in the case of using aperture stop. The defect detection can be demonstrated by the difference between the simulated PEM image with defects and that without defects. Fig. 3 shows schematic illustration of a top view of EUV mask with various sized and shaped defects, the simulated difference image. By adjusting the inspection condition, 16 nm sized defects are detected more than 10 times the intensity of the standard deviation of the background intensity levels. Sensitivity of defect detection was affected by the image contrast and the pattern edge profile. We also analyzed the influence of sample material and geometry on the image contrast and pattern profile.

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[1] S. Babin et al., Physics Procedia 1, 305 (2008).
[2] M. Miyoshi et al., J. Vac. Sci. Technol. B 19, 2852 (2001).
[3] R. Hirano, et al., J. Micro/Nanolith. MEMS MOEMS 13, 013009 (2014).
[4] S. Iida et al., Jpn. J. appl. Phys. 53, 116602 (2014).

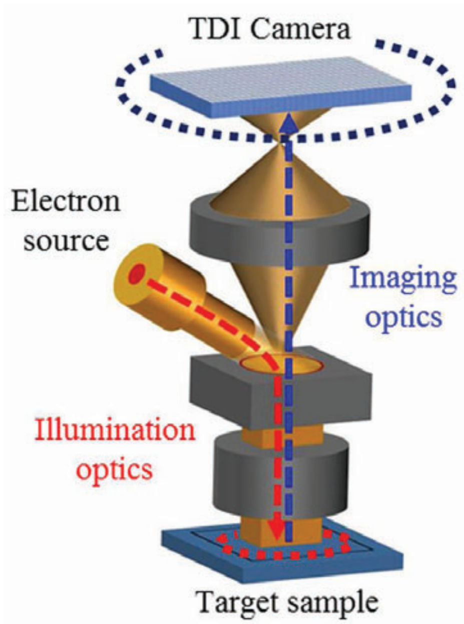

Figure 1: Schematic illustration of PEM.

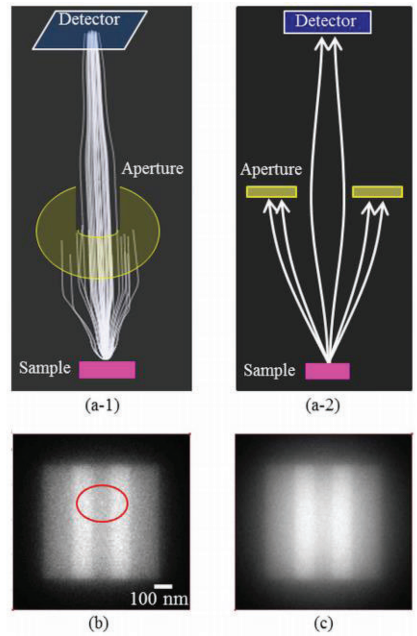

Figure 2: (a-1) The simulated electron trajectories and, (a-2) the schematic illustration with an aperture stop at the middle of imaging optics, and the PEM image of (b) with, and (c) without aperture stop.

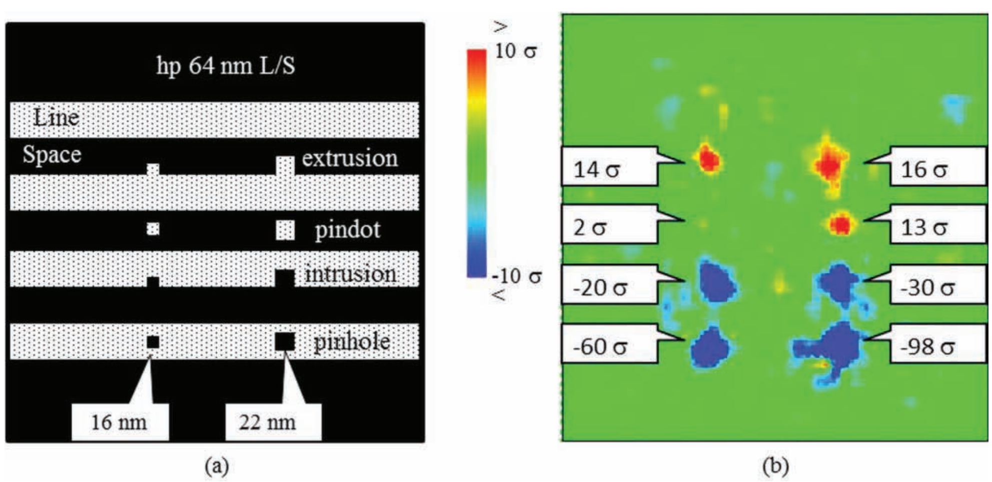

Figure 3: (a) Schematic illustration of a top view of EUV mask with various sized and shaped defects, (b) the difference image between simulated PEM image with defects and that without defects.