Dependence of Image Characteristics on Incident Electron Beam Energy for EUV Mask inspection using Monte Carlo simulation

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The electron beam technique is a candidate for 1X nm EUV mask inspection. Especially the projection electron inspection technique has a potential to take the clearer images of small patterns than those by DUV and a potential to inspect masks with the higher throughput than that of SEM inspection system. In this paper, we describe the dependence of the image characteristics on incident beam energy using Monte Carlo simulation.

The mask used by simulation has 66-nm-thick Ta-based absorber layer and three types of residual bridge defects 1) in 88-nm half pitch line and space patterns on ruthenium capped EUV reflective multi-layer. The thicknesses of the defects are 3 nm, 33 nm and 66 nm. Figure 1 shows the secondary electron images of residual bridge defects using projection electron with landing energy of (a) 5 eV, (b) 250 eV and (c) 1000 eV. Charging effect was not taken into account in this case. All types of defects were identified throughout the range of calculated landing energy, although the defect signal intensities decreased along with height decrease of those.

We also simulated the trajectories of electrons with 0 eV landing energy. The incident electron did not touch the sample by applying appropriate electric field. The incident electrons arrived between the lines were slowed down and reversed in the vicinity of the ruthenium surface without touching it. This type of electron is defined as the mirror electron 2). The height of the reverse point can be determined by controlling the incident beam energies. The mirror electron images with various reverse points of residual bridge defects are shown in Figure 2. The bright parts in the figures correspond to the area where the mirror electrons are detected, whereas the dark parts without detection correspond to lines and defects, because electrons touched the area and did not reverse as the mirror electron. We can distinguish the height of the defects by controlling the incident beam energy as shown in Figure 2. This result suggests that this technique has a potential to selectively detect the only printable defects by controlling the incident electron beam energy.

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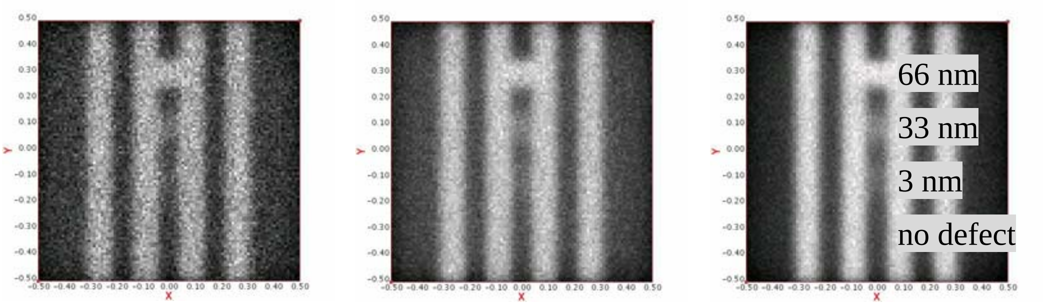
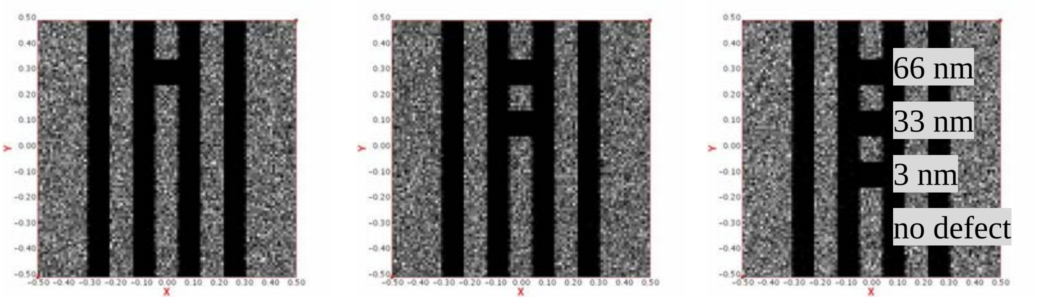
[1] H. Aoyama, et al., in Proceedings of the SPIE, 2007, vol. 6730, 67305L, Repair specification study for half pitch 32-nm patterns for EUVL

[2] A. J. Hermans, et al., J. Engineering Math., vol. 4 (1970) 141-154



(a) (b) (c)

Figure 1: Secondary electron images of residual bridge defects using projection electron with landing energy of (a) 5 eV, (b) 250 eV and (c) 1000 eV, respectively. Charging effect was not taken into account.



(a) (b) (c)

Figure 2: Mirror electron images of residual bridge defects using projection electron with landing energy of 0 eV. Reverse points are (a) between 66 nm and 33 nm, (b) between 33 nm and 3 nm and (c) between 3 nm and 0 nm above the ruthenium surface, respectively.