Influence of EUV mask structure on electron trajectories

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Electron beam (EB) is widely used for EUV mask-related technologies such as defect inspection[1], CD metrology[2] and EB lithography[3]. EB irradiation energy varies depending on the purpose [1-3]. Understanding of electron trajectories in the mask is very important for optimization of the beam energy. In this paper, we describe the influence of the EUV mask structures, especially for EUV reflective multi-layers (MLs) on electron trajectories using Monte Carlo simulation.

Figure 1 shows two types of sample structures used by the simulations. Type I (a) has MLs capped with 2.5 nm thick Ru. The MLs contain 2 pairs of 3 nm thick Mo and 4 nm thick Si. Type II (b) has 100 nm thick Ru layer. In order to investigate the secondary electron distribution in the vicinity of Ru surface, a 400 nm x 400 nm image detector was placed 1 nm from the Ru surface. The accuracy of the detector is at pixel size of 4 nm x 4 nm. In order to improve the reliability of the simulation result, secondary electron yield curve of the utilized materials were applied for the calibration of the experimental data. Potential barriers between adjacent layers were taken into account throughout the calculation in this paper.

Figure 2 shows electron trajectories injected into the MLs with irradiation energy of (a) 50 eV, (b) 500 eV and (c) 5000 eV, respectively. Secondary electrons are generated only inside Ru layer in the case of 50 eV and 500 eV. As the irradiation energy increase, injected electrons reach the Si layer. These electrons spread laterally along the Si layer as shown in Fig. 2 (c) because penetration depth in Si is larger due to its lower density than that in Ru and Mo. Moreover, electrons are confined by potential barriers between Si and adjacent metal materials. This confinement effect can enhance electrons to spread laterally. Figure 3 shows secondary electron distribution at the height of 1 nm above the sample with ML. When the irradiation energy is 50 eV and 500 eV, the area is almost same between type I and type II. However, the area drastically increases in the case of 5000 eV. This clearly indicates that the existence of Si layer affects the spreading of the area generating secondary electrons. This result suggests that nature of EUV mask structure such as MLs can leads to the degradation of the image resolutions in electron microscopy technique.

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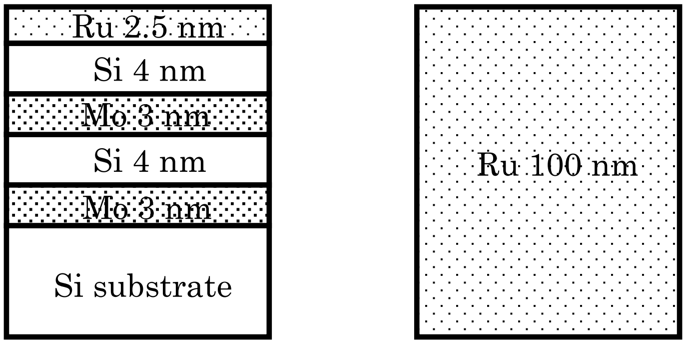
[3] G. P. Patsis, et al., J. Phys.: Conf. Ser. 10 385 (2005).



(a) (b)

Figure 1: Two types of sample structures are used by simulation. (a) Type I and (b) Type II.

(a) (b) (c)

Figure 2: Electron trajectory injected into the ML with irradiation energy of (a) 50 eV, (b) 500 eV and (c) 5000 eV, respectively.

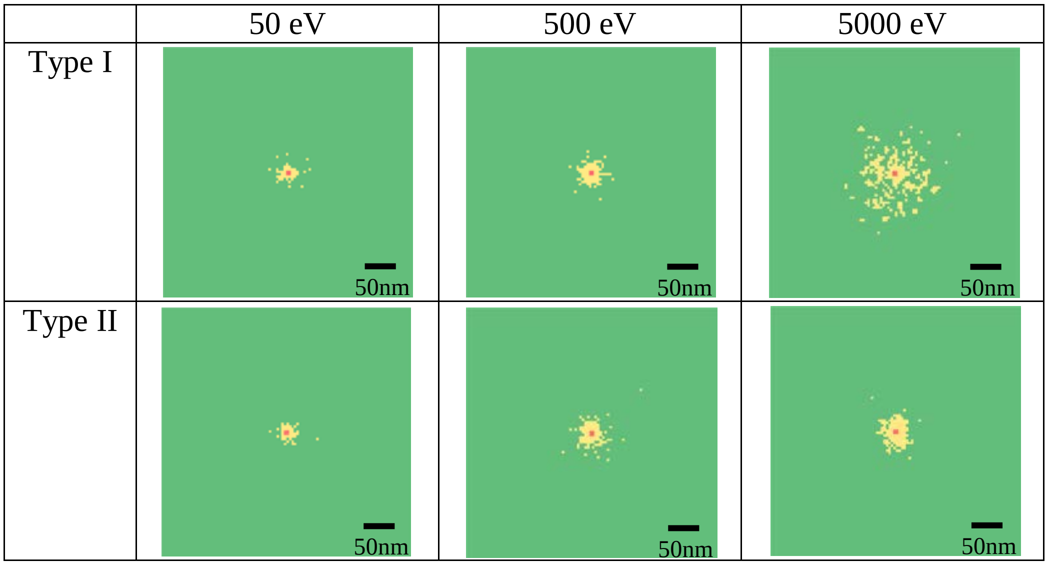


Figure 3: Secondary electron distribution with an image detector at the height of 1 nm above the sample.