Investigation of Non-Charging Exposure Conditions for Insulating Resist Films in Electron Beam Lithography

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The charging phenomenon of insulating resists in the electron beam (EB) lithography has a great influence on its patterning accuracy. The purpose of this study is to systematize the non-charging condition of the resists in EB irradiation.

The specimen is a photomask with an insulating resist (PRL009) on a 70 nm thick conductive Cr layer on bulk glass. In this study, the surface potential distribution was investigated when the electron beam acceleration voltage was 30 kV and the resist film thickness was 158.5 nm, 189.6 nm, and 245.1 nm. Fogging electrons (FGE), which are electrons reflected from the bottom surface of the objective lens, fall around the electron irradiation point on the specimen surface and affect a wide range of several millimeters from the beam irradiation point (global charging). According to our previous studies, FGE energy can have all energy spectra below the electron beam energy, but the most probable value is less than 5 eV. [1] Therefore, applying -5 V to the specimen stage prevents FGEs from re-entering the resist and reduces the specimen charging. [2] In this experiment, the area of 100 μm × 160 μm is irradiated with EB at various exposure doses, and then the surface potential is measured with an electrostatic force microscope (EFM). [2]

Fig.1 shows the dose dependence of the surface potential of the EB irradiation area for three different resist thicknesses. The surface potential of the EB irradiation area (local charging) is greatly affected by the exposure dose. It was found that the local charging becomes almost 0V when the dose is 11 $\mu C/cm^2$ and 205 $\mu C/cm^2$. However, detailed analysis revealed that the charging potential distribution at 11 $\mu C/cm^2$ was M-shaped, while the distribution at 205 $\mu C/cm^2$ was W-shaped. The reason why these shapes appear is thought to be that the charge accumulation density is microscopically large in the center of the irradiation area, and the phenomenon that occurs at a higher exposure dose has occurred in advance. Therefore, the potential obtained at a higher exposure dose appears as the potential at the center of the irradiation region. In addition, as shown in Fig. 2, it was found that the surface potential distribution changed with the elapsed time.

In the presentation, we will explain each charging mechanism based on the model we devised.

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[1] K. Morimoto et al., Jpn. J. App. Phys., 59, SIIB01-1 (2020).

[2] H. Mizuno et al., e-Journal of Surf. Sci. Nanotech. 18, 106 (2020).

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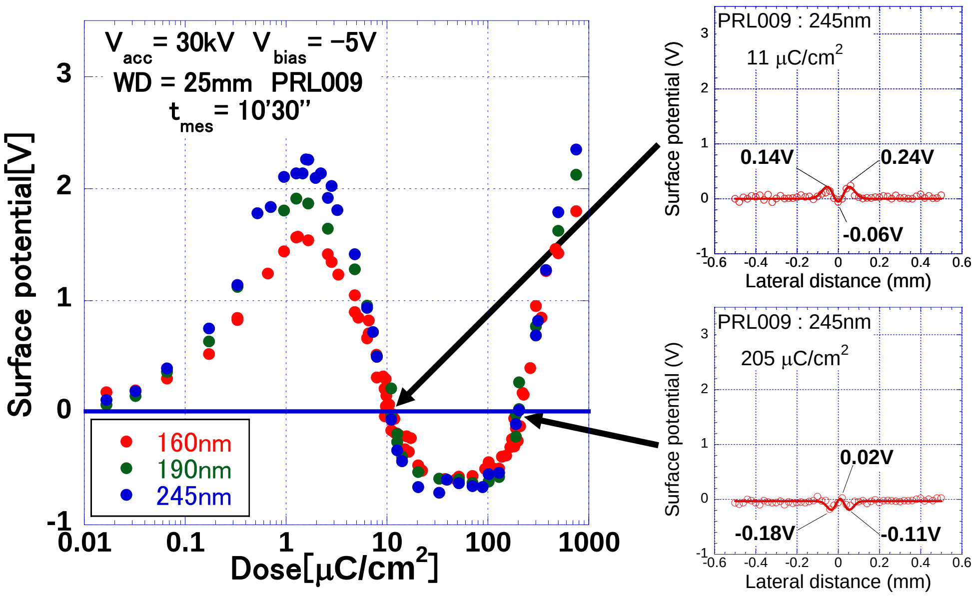

Figure 1: Surface potential variation with electron dose at the beam irradiated area for three different resist thicknesses: Comparing the three film thicknesses, it was found that the thicker the resist film thickness, the larger the absolute values of the positive and negative potentials.

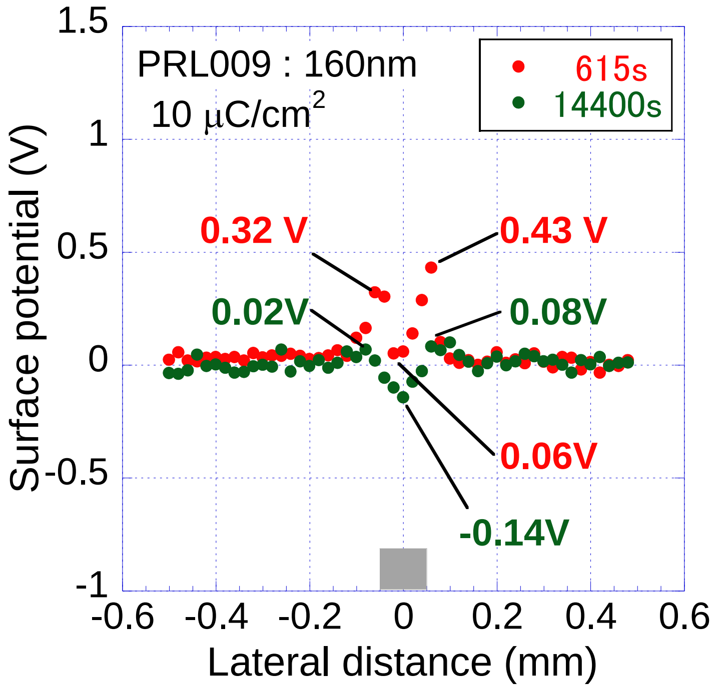

Figure 2: Changes in lateral potential distribution over time in these cases (Exposure dose: 10 μC/cm2): With the elapsed time, the negative charge accumulated in the resist is attracted by the positive charge on the surface and moves by drift, so that the surface potential of the irradiation area measured by EFM changes to a negative potential.