Flare electrons that cause positive charging by scattering in scanning electron microscope

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Electron beam (EB) can be focused in nanometers, and it is an indispensable tool for nanoscale observation and processing, etc. However, when the electron scattering behavior is examined in detail, secondary electrons and backscattered electrons from the specimen back and forth between the objective lens and the specimen, so that electrons are found not only in the vicinity of the EB irradiation point but also in a wide range of several cm from the irradiation point. We call those electrons as Fogging electrons (FGEs). In order to measure the spatial distribution of FGEs, we use a photomask as a specimen, where 300nm-thick insulating electron beam resist is coated on it. By using our homemade electrostatic force microscope (EFM), the surface potential distribution of the resist is measured, and it is possible to know the distribution of electrons accumulated on the surface or inside. After the EB irradiation, the EFM probe is approached and the stress is monitored while the bias voltage applying to the specimen is swept, and then, the surface potential is determined by the null method.In order to investigate the contribution of FGEs to the charging, the following experiment was conducted: As shown in Fig. 1, surface potential is built because of EB irradiation of 0.3keV at 70pA in 60seconds on an area of 100um×100um. In this experiment the specimen is positively biased during EB exposure at 50V, and electrons above the specimen surface are attracted. FGEs with less than 50eV should be adsorbed by the specimen. That is why the potential shows a negative value around the EB irradiation point. However, if the distance is more than 6mm, the potential shows a positive value, and it increases with increasing the distance. It is hard to understand this mechanism based on the law of conservation of energy.We doubt that there is a kind of leakage of electrons from the bottom of the objective lens, and we tried to measure the leakage electrons by using the configuration shown in the left of Fig. 2. In this experiment positive bias toward the specimen is not applied. We found that even if EB is focused on the opening of a Faraday cup, the surface potential increases with the increase of the distance, and we confirm that there are leakage electrons. We call them flare electrons (FLEs). We assume that typical energy of FLEs is almost EB energy. The incident angle of FLEs at 40 mm at WD = 25 mm is as large as 58 degrees with respect to the normal line, and the angle is large, so the electron emission ratio is larger than unity. It is found that FLEs are the cause of large-scale positive charging in scanning electron microscope.

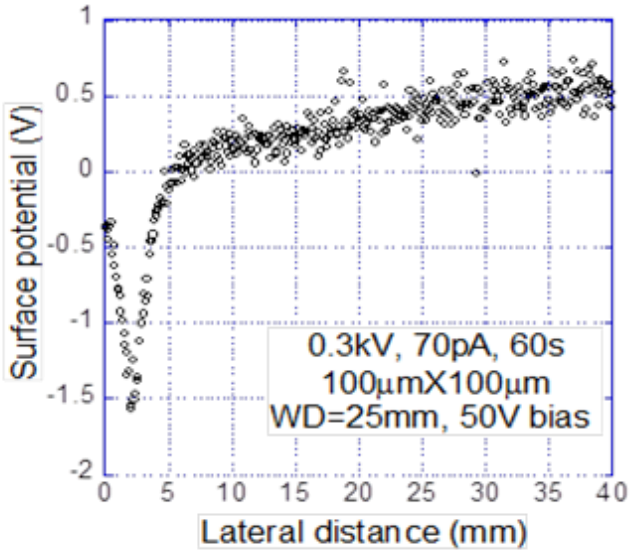

Figure1 Large-scale positive charging, while positive specimen bias is applied in scanning electron microscope.

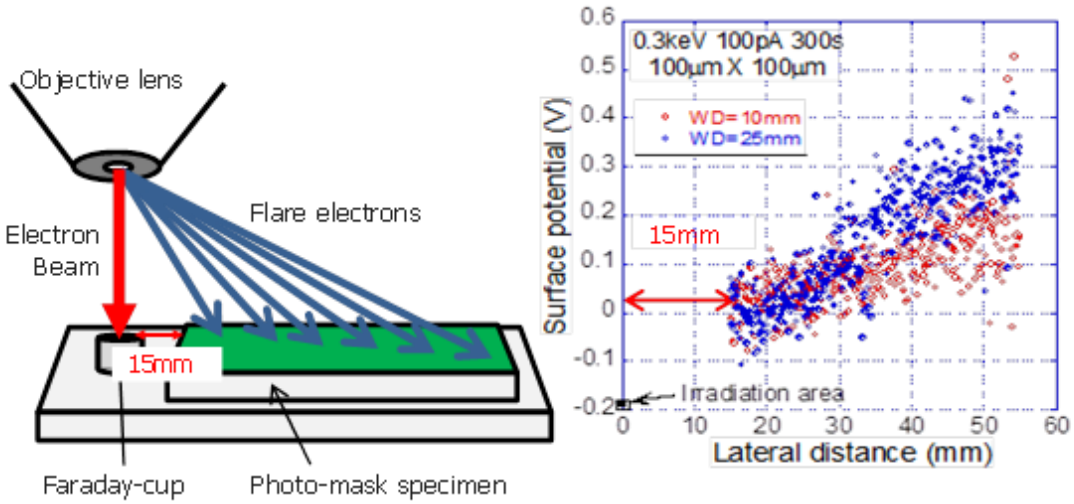

Figure2 Measurement configuration and the surface potential due to flare electrons.

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