Measurement of fogging electron current in scanning electron microscope

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In recent development of nano-technologies, electron beam (EB) is indispensable in processes, analyses, microscopy, evaluation, observation and measurement, etc. However, if a specimen is an insulator, electrons may be accumulated in the specimen and it is charged negatively or positively depending on materials or irradiation conditions. It has been understood that this charging mainly occurred locally in the specimen around the EB incident point, but in reality, backscattered electrons (BSEs) from the specimen hit plate of the objective lens (POL), which is located in front of the specimen surface, and re-backscattered electrons expose the specimen in a large area. In the present study electrons, produced by multiple scattering events between POL and the specimen, are called the fogging electrons (FGEs). Although the energy of FGEs is low in general, but if they stay on the specimen surface, the charge produces a surface potential distribution. This potential may influence the performance of specific EB applications. We have studied the charging mechanisms of the specimen, and we found that the contribution of FGEs is not negligible. In order to understand the influence of the FGEs, first, it is necessary to find the spatial distribution of the FGEs. In the present study, we measured the distribution in a specimen chamber of an ordinary scanning electron microscope (SEM) (JSM-6490LA).

Figure 1 shows a concept of measuring the FGE current in the specimen chamber of an SEM. The EB current is measured using the Faraday cup set on the central electrode. Five concentric annular electrodes (5-8, 10-13, 15-18, 20-23, 25-28 mm from the EB irradiation point) are made at a commercially available printed circuit board (PCB) to measure the radial FGE current distribution. The current at every electrode is measured by an electrometer. By changing the working distance of the electrode from the POL, the radial distribution is verified. On the other hand, electron trajectory simulation in and out the specimen surface considering the existence of the POL is performed.

Figure 2 shows an example of electron trajectories in the PCB and in the POL. The working distance is 1 μm in this case to see the configuration, and the acceleration voltage of the beam is 20 kV. The trajectories in vacuum are also calculated, but here, the influence of the leakage magnetic field around the objective lens is not considered. As we frequently experience, the image rotation of the SEM image as a function of the WD, the influence of the field is important,

and the results will be given at the conference.

Figure 3 shows the FGE current distribution at the PCB surface, where the accelerating voltage of EB is 30 kV, the EB current is 10 nA, and WD is 10 mm. Since the number of FGEs detected is small, the points are scattered considerably, but we succeeded to measure the FGE current distribution. Figure 4 shows the FGE current for one annular electrode for different WD's. The simulation result agrees well with the experimental results. Based on this agreement, we can proceed to the quantification of the global charging mechanism in EB applications.

This work was supported by KAKENHI (C) 22560026.
[1] M. Kotera, Jpn. J. Appl. Phys. 48 (2009) 06FB05.

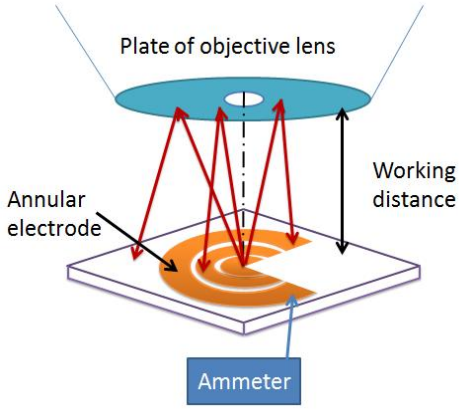

Figure 1: Schematic of the present measurement system of the FGE current on the specimen.

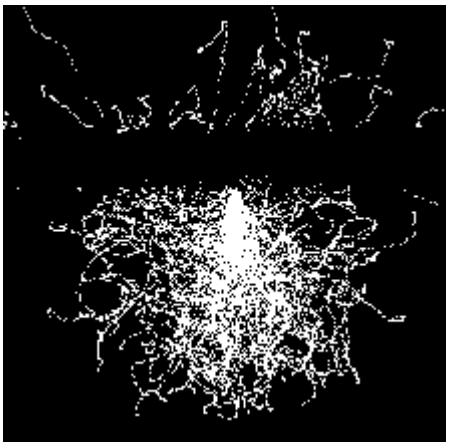

Figure 2: Example of electron trajectories in the specimen and the POL, which is above the specimen surface.

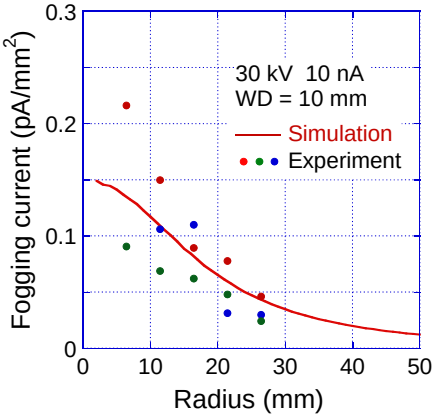

Figure 3: Radial FGE current distribution, as the EB current is 10 nA.

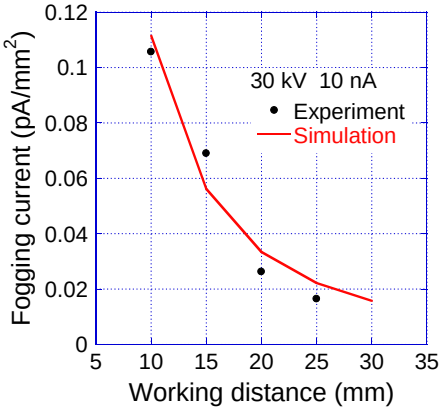

Figure 4: FGE current distribution for one annular electrode for different WD's.