Three-dimensional trajectory simulation of scattered electrons in scanning electron microscope specimen chamber

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Electron beam (EB) can be focused in nanometer scale, and it is an essential tool in nano-scale processing, observation, etc. It is found recently that in a vacuum specimen chamber of scanning electron microscope (SEM), fogging electrons (FGEs) are generated by multiple backscattering events of electrons between the specimen surface and the pole piece of objective lens plate as illustrated in the left of Fig. 1, and they can give a considerable influence on the spatial resolution of the SEM. FGEs spread up to more than 10 mm from the beam irradiation point. They may be responsible for a global charging phenomenon on a specimen, if it is made of insulators.

In order to estimate the quantitative contribution of FGEs, in a present paper, electron trajectories are simulated not only in the specimen and objective lens, but also in a vacuum specimen chamber. Electron scattering events in the material are simulated by the Monte Carlo method. Since both backscattered electron (BSE) and secondary electron (SE) yields are adjusted to each experimental data, the number of FGEs we obtain here should be reasonable. The volume of the three dimensional space of the specimen chamber is 300 mm × 300 mm × 300 mm, and the realistic arrangement of optical devices are taken into account, including the Everhart-Thornley type SE detector. As shown in the right of Fig. 1, the SEs emitted at around the beam irradiation point on the specimen surface and directly collected by the SE detector is defined as "SE1+SE2", and the SE produced by FGEs are defined as "SE3".

Figures 2 and 3 show the accelerating voltage dependence of SE intensities for SE1+SE2 and SE3 obtained by the simulation. The parameter is the working distance (WD), which is a distance between the bottom of the objective lens and the surface of the specimen. The value indicated in Fig.2 is the "SE detection probability", which is ratio of the number of detected SEs versus the number of incident electrons in the EB, and the probability of SE1+SE2 detected is less than 10%, and the probability of SE3 is almost 70%, when the EB energy is almost 1 keV and the WD is 30 mm. If we look at the "SE detection ratio" in Fig. 3, which is the ratio of detection of SE1+SE2 and SE3 versus all detected SEs, it is found that almost 90% of SEs are SE3, as EB energy is about 1 keV and WD is larger than 20 mm. The reason why SE detection probability for WD = 10 mm is much lower than others is that because WD is so small that electric field from the detector is difficult to intrude the space of the WD, where both electrodes are electrically grounded.

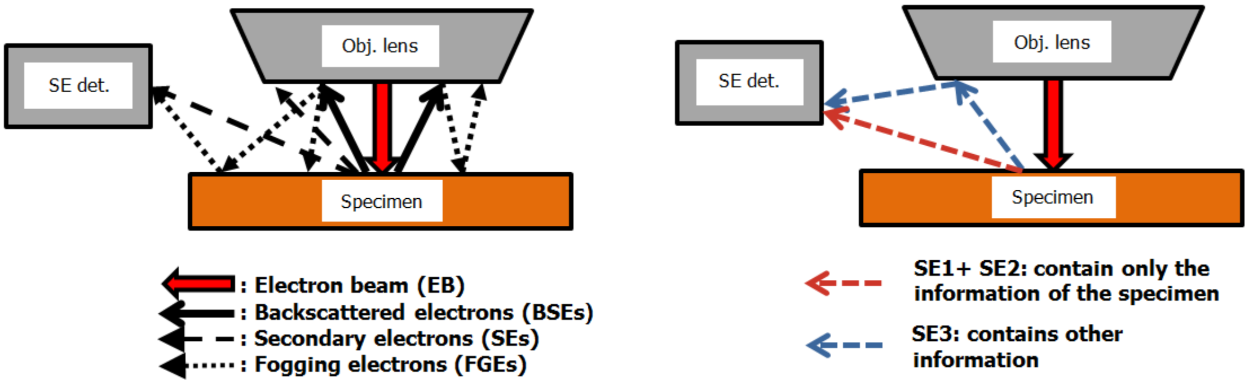

Fig. 1 The Schematic diagram of FGEs and detected electrons by the SE detector.

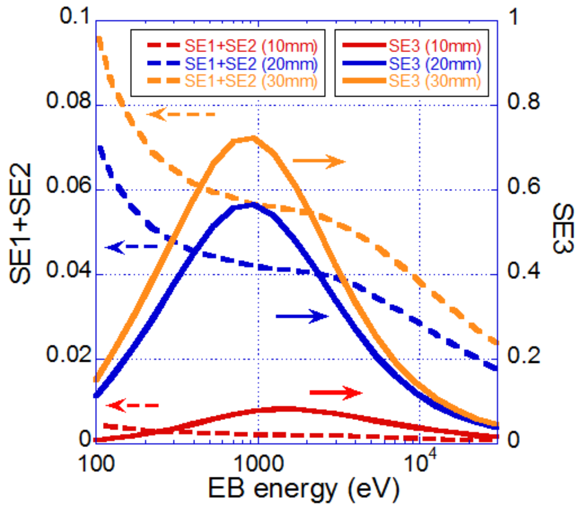

Fig. 2 SE detection probability.

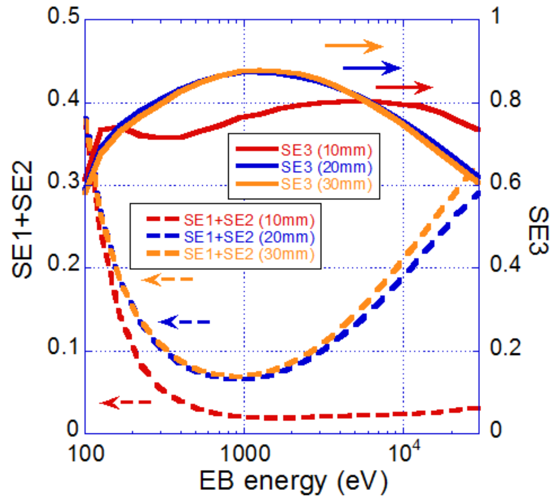

Fig. 3 SE detection ratio.

[1] M. Kotera, A. Osada, M. Otani, Y. Ohara, Journal of Vacuum Science and Technology, B 29 (6) 06F316-1-06F316-6 (2011).

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