Measurement of Surface Potential Distribution at an Insulating Film Produced by Fogging Electrons in a Scanning Electron Microscope

M. Otani[1], A. Osada[2], Y. Ohara[1], M. Kotera[1,2]

[1]*Dept. of Electronics, Information and Communication Engineering*
Osaka Institute of Technology, Japan, 535-8585
[2]*Nanomaterials Microdevices Research Center*
Osaka Institute of Technology, Japan, 535-8585
kotera@elc.oit.ac.jp

In recent development of nano-technologies, electron beam (EB) is indispensable in various analyses and fabrications. However, the resistivity of the specimen is low in most cases, then, electrons may be accumulated in the specimen and it is electrically charged. Depending on the conditions, the polarity of the charging varies, and even it is distributed in the specimen.

In the scanning electron microscopy (SEM), it is known that secondary electrons (SEs) are produced not only by the EB at the irradiation point, but also by backscattered electrons (BSEs) at the emission point. It is known that there is another contribution to produce SEs, that is, fogging electrons(FGEs), which are produced by multiple scattering of BSEs between specimen and pole-piece-plate of objective lens(POL). In the matter of energies, the contribution of FGEs is negligible, but in the matter of the accumulated charge, it cannot be negligible and they produce appreciable voltages on the surface of specimen. In the present study we measured the potential distribution at an insulating film on a conductive substrate, produced by pure FGEs in an SEM specimen chamber, by using our recently developed electrostatic force microscope.[1]

The schematic diagram of the present system of charging and measuring the surface potential produced by fogging electrons is illustrated in Fig. 1. Here, the insulating specimen is 300 nm-thick FEP171 resist film on Cr film on glass substrate with 30 mm on a side, and the working distance to the POL is 20 mm. Sequence of the charging and measuring is as follows: (1)as illustrated in Fig.2, EB is irradiated on the center of Au-wire of 25 $\mu m\phi$ and the FGEs irradiate the surface of the resist. (2)after the EB irradiation, the lateral potential distribution of the resist surface is measured by scanning the SEM stage. The height of Au-wire from the resist surface is 2mm, and the height of the probe to measure the surface potential is 20μm. The EB irradiation is done by the current of 1 nA in one minute. The accelerated voltage (Vacc) of EB varies from 0.3 to 30 kV. Fig.3 shows an example of electron trajectory of FGEs simulated in (POL)-(Au wire)-(specimen) system in an SEM specimen chamber. Figure 4 shows the lateral distribution of the surface potential obtained below the Au wire for various EB accelerating voltages. The value of potential is as large as several volts. The polarity of charging is the same with that shown before for direct EB irradiation of the resist, [1] and if Vacc is lower than 1.0 kV, or higher than 3 kV, the surface potential shows a positive value, and if Vacc is between 1.1 and 2.6 kV, the surface potential is negative. In this figure it is found that all of the negative distributions are limited in the range of +/- 300μm. On the other hand, the distribution of 0.3 kV is very wide. Since FGEs are generated in a randum scattering events, the dispersion of the distribution is mainly determined by the solid angle and the distance between POL and the specimen. As a matter of fact in the previous simulation of FGEs,[2] no such limitation has been observed in the distribution. The limitation should be made by leakage magnetic field from the objective lens, and we consider the influence of the field in the FGE trajectory simulation.

[1] M. Kotera et al., J. Vac. Sci. Tech., B 29(6) (2011) 06F316-1.
[2] M. Kotera et al., Jpn. J. Appl. Phys., 48 (2009) 06FB05.

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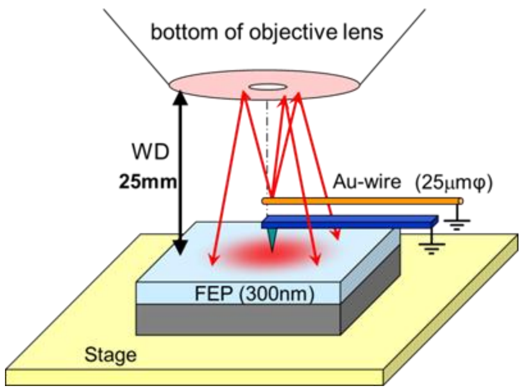

Figure 1: Schematic of charging and measuring the surface potential produced by fogging electrons.

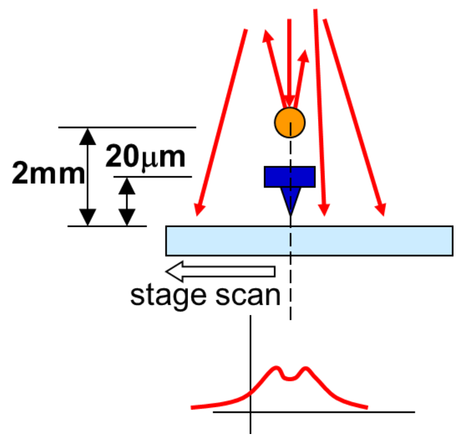

Figure 2: Illustration of the sequence of measurement and the distances of Au wire and the probe from the specimen surface.

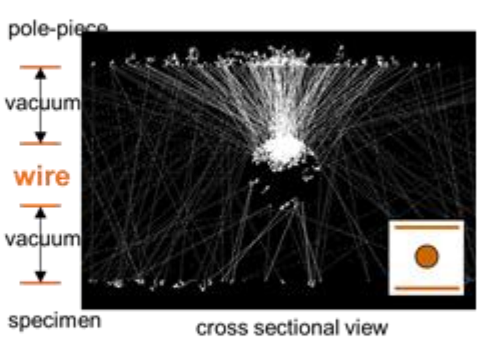

Figure 3:Trajectory of fogging electrons simulated in (POL)-(Au wire)-(specimen) system in an SEM specimen chamber.

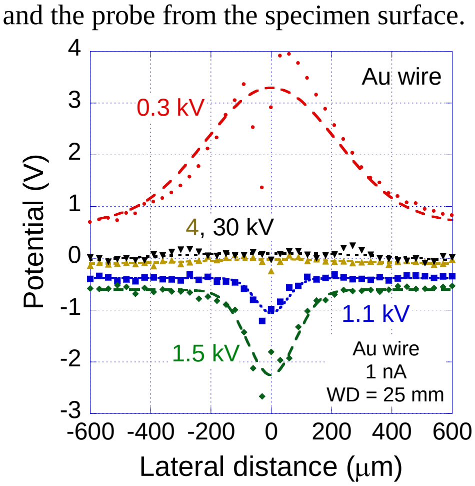

Figure 4: Lateral distribution of the surface potential below the Au wire for various EB accelerated voltages.