Positive and negative charge accumulation mechanism generated by electron beam irradiation to insulating specimen

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Scanning electron microscope (SEM) is utilized in various fields as a means of observing nanoscale microstructure and composition. However, it is known that an insulator specimen is charged positively or negatively by electron beam (EB) irradiation depending on many conditions. In the SEM image, this voltage contrast appears in which the positive potential portion is dark and the negative potential portion is bright. This contrast may overlap the structural and compositional contrast, and confusion may arise in the interpretation of the image. Mechanisms to build positive charging and negative charging of a specimen can be listed as follows: (1) local electron accumulation, (2) electron emission from the surface and (3) local ionization, along with (4) electron beam induced conduction (EBIC) to release charges via the conduction path. EB is not only the source of electrons, but fogging electrons (FGEs), which are made by multiple backscattering events between the specimen surface and the pole-piece of the objective lens of SEM, can be the source of electrons to the specimen. Based on physics, positive charge cancels negative charge in a local volume, and accumulated charge can be released, if EBIC path is formed close to the charge. Furthermore, slow FGEs arrive so late and electron pileup may occur at the surface.

We have developed an electrostatic force microscope (EFM), and it was installed in SEM.[1] After EB is irradiated, the specimen surface potential is measured. Figure.1 shows results surface potential distribution after EB irradiation at an accelerating voltage of 0.3kV for various currents. The irradiation area is 100umX100um and irradiation time is 60 seconds at the working distance (WD), which is a distance between the bottom of objective lens and the surface of the specimen, is 5mm. The major reason of positive charging is the electron yields, which is a ratio of emitting electrons from the surface is larger than the number of incident electrons by EB. In the figure the positive potential decreases with increasing the current, and it can be because that electron storage besides the electron diffusion range increases with EB current.[2] This phenomenon can be understood by piling up of slow FGEs at the surface. Settling time of slow FGE with energy of 0.3keV is almost the same with the electron incident rate for 1nA at WD=25mm.[3]

If WD is increased to 25mm as shown in Figure.2, the surface potentials are decreased for all currents. The reason may be FGE density is decreased for longer WDs. If WD is short, fast FGEs generates secondary electrons at the surface in the vicinity of EB irradiation point, but since WD is large, possibility of making the specimen surface positive is low.

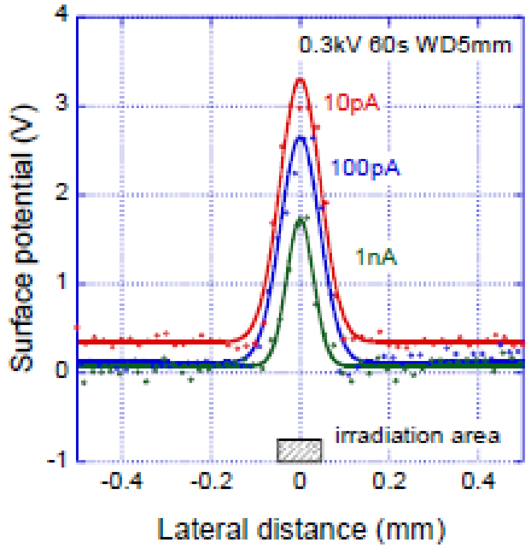

Figure.1 Surface potential distribution after EB irradiation at various EB current at WD=5mm.

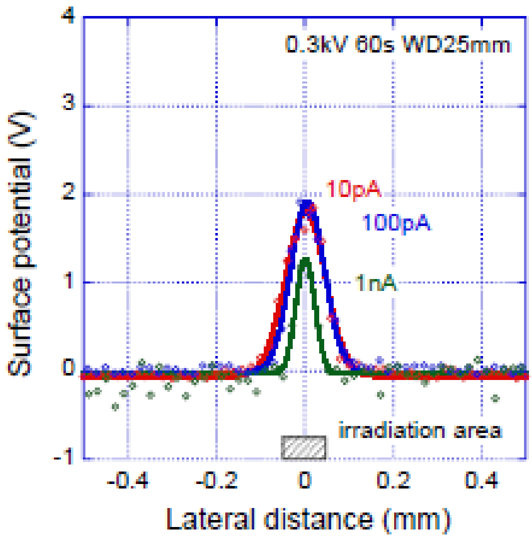

Figure.2 Surface potential distribution after EB irradiation at various EB current at WD=25mm

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