Modeling of Charging Effect on Ion Induced Secondary Electron Emission from Nano-Structured Materials

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Because of the shrinking device dimensions and growing integration schemes in complexity, scanning ion microscope (SIM) using helium (He) and gallium (Ga) beam has been increasingly used for inspection, metrology and failure analysis in device fabrication, in addition to conventional scanning electron microscope (SEM). For insulating materials, the charging caused by secondary electron (SE) emission brings about unwilling deformations of SE images in both SIM and SEM. However, charging effects are rather less clear for SIM than for SEM. We developed a Monte Carlo based model for SE emission from SiO_2, in which the charging induced by ion beam (IB) irradiation is taken into account.[1] Self-consistent calculation was performed to model the transport of the ions and SEs, the charge accumulation in SiO_2 and the electric fields in it and in vacuum.

For basic structures of IC device, such as an insulator/metal bilayer and insulating step/trench formed on a base, the charging is sensitive to layer thickness, step height and trench depth changes of several tens of nanometers.[2] Therefore, we investigate charging effects on the structured materials at 10–100 nm scale. The SiO_2 layer and step/trench formed on a Si base was exposed to 30-keV He and Ga IB irradiation. Dynamic changes in position-dependent SE yield and surface voltage were calculated, along with the trajectories of SEs emitted from the surface and charge distributions accumulated in SiO_2. The calculation was compared with the case of 1-keV electron beam (EB) irradiation.

The insulating material is charged positively or negatively during EB irradiation, depending on the beam energy. By IB irradiation, it can be charged positively because of the incoming positive ions and outgoing SEs. When the SiO_2 layer is thick, the SE yield is decreased during IB irradiation and finally it vanishes. Even if there is no emission of SEs, the positive charging of the surface progressively increases due to successive injection of positive ions. However, it is strongly suppressed as the thickness decreases and position of the irradiation approaches the edge of the step. When the bottom of the step is irradiated, the negative charging of the edge localizes an edge effect caused by absorption of emitted SEs into the edge. Furthermore, the negative charging can produce a bright SE image of the bottom surface of a trench. In conclusion, charging effects will be one of key tool for the analysis of nanoscale materials using SIM.

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[1] K. Ohya, T. Yamanaka, D. Takami, K. Inai, Proc. SPIE **7729** (2010) 7729-24.

[2] K. Ohya, K. Inai, R. Kawasaki, et al., J. Electron Microsc. **59** (2010) S189.