1690
DOI: 10.1017/S1431927605504379

Microsc Microanal 11(Suppl 2), 2005

Time Dependent Charging of Insulators by Electron Beam Irradiation

M. Kotera and Y. Matsumoto

Department of Electronics, Information and Communication Engineering
Osaka Institute of Technology, 5-16-1, Omiya, Asahi-ku, Osaka, 535-8585, Japan

If an insulating material is exposed by an electron beam (EB), it will be charged negatively or positively, depending on the condition. This specimen charging is a critical issue for the electron microscopy and microanalysis. By using a Monte Carlo simulation of electron trajectories in insulators, the mechanisms of a specimen charging have been simulated [1-4]. In these simulations a treatment of electron beam induced conduction (EBIC) determines the final result, and how it is considered is quite important.

In order to take into account the influence of the electric field on the charge accumulation, here, EBIC is regarded using a method, which Tanaka et al. have proposed [5]. We assume that EB is incident at a point on a surface of polymethylmethacrylate (PMMA) plate of 20μm-thick. Both surfaces are grounded. It is divided virtually in 200nm cells. The charge distribution deposited by EB of 15keV is obtained by a Monte Carlo simulation of electron trajectories in non-charged PMMA in advance. Figure 1 shows the one-dimensional distribution as a function of depth, and it shows a sharp negative peak at the surface and a broad positive peak in the intermediate depth. The peak at the surface is obtained by secondary electron emission, and it is found at only the first cell of the surface. Figure 2 shows the one-dimensional energy deposition distribution by the EB irradiation.

The continuity equation of the charge accumulation, the Poisson equation and the Ohm's law are solved simultaneously, and the electric potential, the field, and the charge distribution in PMMA can be obtained as a function of irradiation time [4]. The EBIC is determined by:

$$\sigma(r,z,t) = \sigma_0 + k \cdot D(r,z,t)^{\Delta}$$

where D is a deposited energy density, σ_0 is the intrinsic conductivity, Δ=0.89, and k =7.7x10^{-18} s$^{\Delta}$/(Ω cm rad$^{\Delta}$). Based on the drift current flow based on the Ohm's law, numbers of electrons move from one cell to the neighboring cell along with the electric field. The EB current varies from 0.1 to 10μA. Figures 3 and 4 show the saturated electron charge variation and the electric field in PMMA, respectively after a long time EB exposure. If the higher EB current is used, the higher electric field is obtained after their saturation, but it is found that although the EB current varies 100 times, the final charge density and the electric field does not change so much.

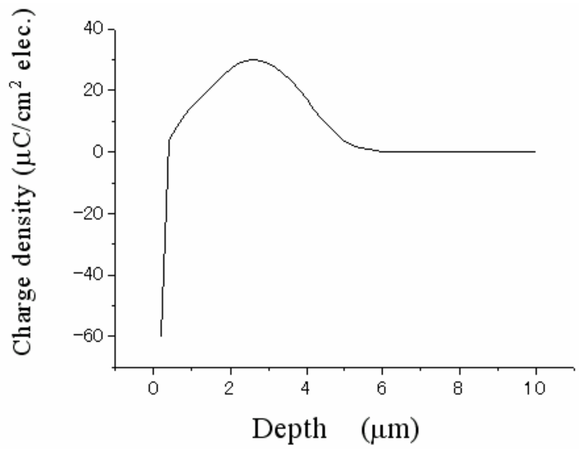

Fig.1 Charge distribution in no-charged PMMA.

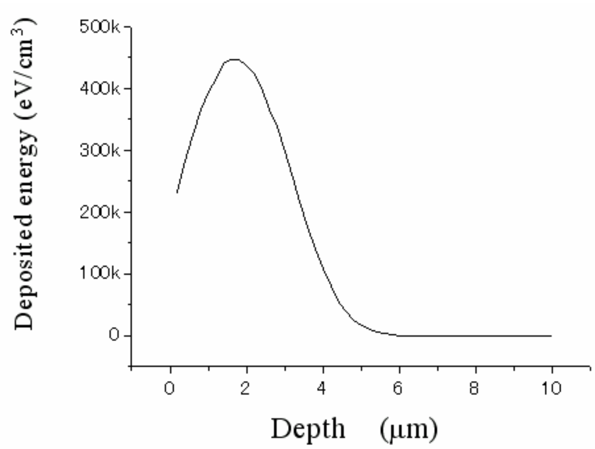

Fig.2 Energy deposition in no-charged PMMA.

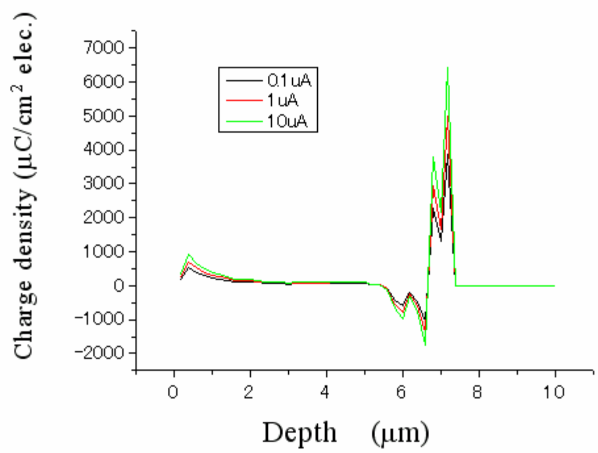

Fig.3 Saturated charge distribution for different current.

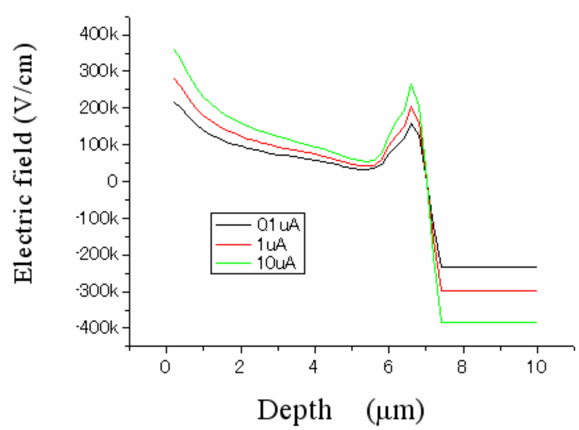

Fig.4 Saturated electric field in PMMA.

Because the energy deposition by incident electrons shows its peak at the middle of the electron range, the EBIC brings electrons toward the inverse direction of the electric field. Although the electron deposition is very low at the end of the electron range, since the energy deposition is low, electrons are almost impossible to move farther from the deposited position, and the electrons are accumulated at the end of the electron range.

References

[1] M. Kotera and H. Suga, J. Appl. Phys., 63 (1988) 261.
[2] Y.U. Ko et al., Scanning 20 (1998) 447.
[3] M. Bai et al., J. Vac. Sci Technol. B17 (1999) 2893.
[4] M. Kotera et al., Jpn. J. Appl. Phys. 38 (1999) 7176.
[5] R. Tanaka et al., IEEE Trans. NS-26, 4670 (1979).

https://doi.org/10.1017/S1431927605504379 Published online by Cambridge University Press