A Novel Scanning Electron Microscopy with Charging Control

N. Tsuno, Y. Ominami[a)], H. Ohta, H. Shinada, H. Makino and Y. Kimura
Hitachi Ltd., Central Research Laboratory, 1-280 Higashi-Koigakubo Kokubunji-shi, Tokyo, 185-8601 Japan
[a)]Hitachi High-Technologies Corporation Nanotechnology Products Business Group, 882 Ichige, Hitachinaka-shi, Ibaraki-ken, 312-8504 Japan
email: natsuki.tsuno.mz@hitachi.com

Voltage contrast imaging by conventional scanning electron microscopy can reveal the local electric field of a specimen, and makes it possible to detect electrical defects in processed materials such as nano-composite materials and semiconductor devices. However, it is difficult to obtain a clear voltage contrast image between adjacent dielectrics with different composition because of similar charging of dielectrics under electron irradiation. In this study, we investigated the charging abilities and its transient properties of high-impedance poly-Si and SiO_2 films under pulsed electron irradiation. Moreover, we attempted to obtain a distinct voltage contrast image by using scanning electron microscopy to control the charging dynamics.

Fig. 1(a) plots substrate current (I_s) values of 500-nm-thick poly-Si and SiO_2 films on a silicon substrate exposed under a pulsed electron beam (E=300 eV, Ip=1 μA, Δt=1 s). The amount of charge absorbed (i.e., absorption charge, Q_a) corresponding to the surface charge can be obtained from the time integration of displacement-current (I_a) component of I_s as shown in Fig.1 (b).

In the case of both the poly-Si film and the SiO_2 film, Q_a increases up to 35 nC/cm^2 with irradiation charge (Q_i), and saturates (Fig.2). There is a significant difference between the charging of the poly-Si film and the SiO_2 film when Q_i is less than 1 μC/cm^2. As shown in Fig.3, Q_a in the poly-Si film is almost completely released in about 1 ms, while that in the SiO_2 film is not released much. Thus, under conventional SEM conditions (namely, slow scanning with short repetition time), difference of charging and discharging between poly-Si and SiO_2 are little. Considering these results, we conclude that a smaller irradiation charge (< 1 μC/cm^2) and longer relaxation time (> 1 ms) are effective for voltage contrast enhancement. As a result, we developed a scanning electron microscopy that can control charging dynamics. As shown in Fig. 4, the voltage contrast signal at poly-Si plugs processed into a SiO_2 film increases tenfold compared the signal in conventional SEM.

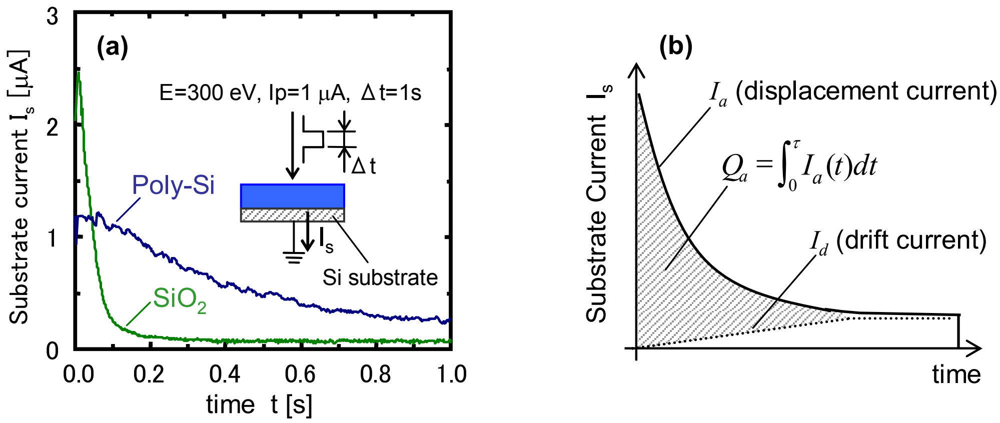

Fig. 1: (a) Transient properties of substrate current (b) Method for derivation of absorption charge

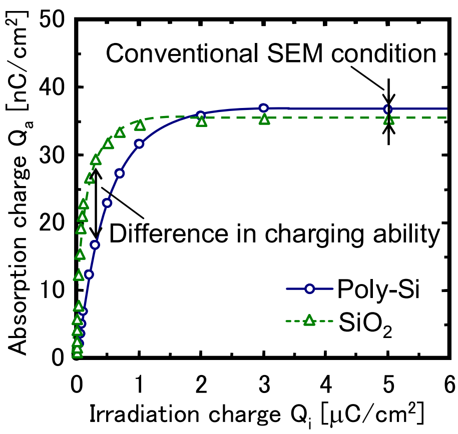

Fig. 2: Absorption charge as a function of irradiation charge

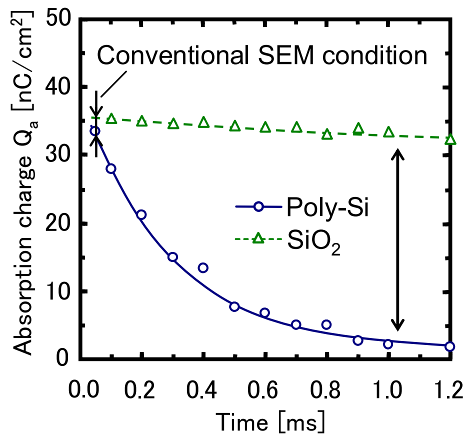

Fig. 3: Transient properties of absorption charge

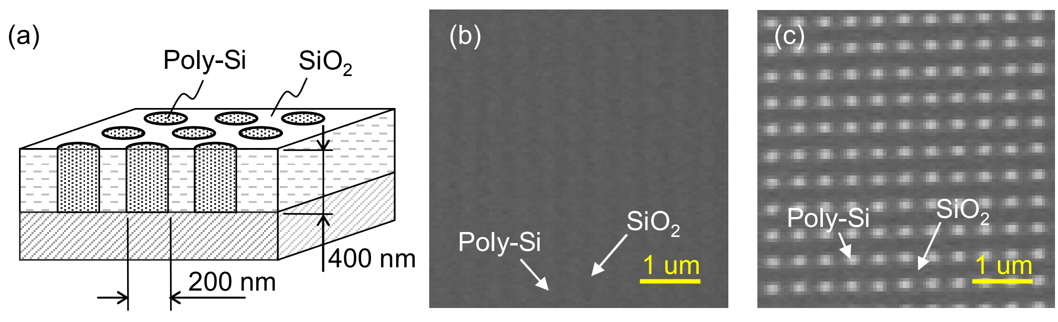

Fig. 4: (a) Schematic of high-impedance poly-Si plugs processed into a SiO_2 film
(b) Voltage contrast image with conventional SEM (c) Voltage contrast image with charging controlling (in this study)