Modeling of Local Dielectric Charging-up during SEM Observation

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It is known that during SEM observation, the electron irradiation on dielectrics results in charging-up at the dielectrics. The accumulated charge results in not only distortion, but also contrast of SEM images [2-3]. In this study, authors propose an analytical model and derive the intrinsic parameters that govern the collecting efficiency, which provides a convenient way to suppress the variation in image contrast within the field of view during SEM observation.

The experimental setup is based on a CD-SEM (S-9380, Hitachi High-Technologies Corporation) modified with variable scanning speed capability and corresponding image-acquisition system. The current of secondary electrons collected from sample surface of dielectrics during single-line scanning of the primary electron beam, varied in probe current I_p and scan speed v, was deduced from the corresponding SEM images. A concept named "scanning-line-density" λ_{in}, the number of incident electrons per unit scan distance during a single-line scanning, is proposed. Besides, the collecting efficiency Y_s quoted in the following is defined as the ratio of the current I_c of collected SEs and BSEs to I_p. Experiments showed that Y_s obtained from flat SiO_2 layer decreased sharply at the initial stage of a single-line scanning and leveled out at a distance of around 100 nm from the start position of the line scan. Y_s at steady state decreases monotonously with increment of λ_{in} and settled to 1 at λ_{in} greater than 5.7 electrons/nm, while it increases up to 5.3 at $\lambda_{\rm in}$ of 0.057 electrons/nm. Figure 1 indicates that during a single-line scanning, the intrinsic parameter that controls Y_s is λ_{in}. We propose a macroscopic model for the analytical simulation of evolution of potential V_s at an irradiated position on a sample surface, the potential barrier V_B over the position and I_c during single-line scanning. Change in Y_s, together with calculated V_s and V_B, during single-line scanning with λ_{in} of 3.4 electrons/nm is summarized in Fig. 2. Y_s decreased to 45% of its initial magnitude at steady state. Calculation reproduced the trend well. Our model indicated that it resulted from the building-up of charge and V_B, which pulled back more SEs to the sample surface at the subsequent irradiation positions. Variation in Y_s during single-line scanning can be suppressed by decreasing λ_{in}. The brightness profile obtained at a single-line scanning with λ_{in} of 0.17 electrons/nm is plotted in Fig. 3. Decrease in Y_s was suppressed to 6%.

In conclusion, λ_{in} is an effective parameter in controlling Y_s during SEM observation of dielectrics, which is very important for keeping uniformity in image contrast during SEM observation.

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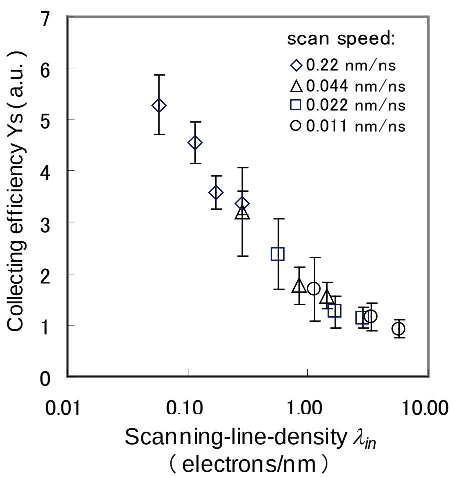

Fig.1 Dependence of collecting efficiency Y_s of SEs and BSEs on scanning line density (λ_{in}).

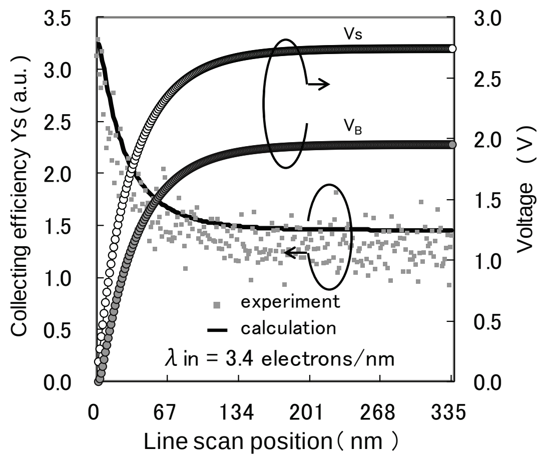

Fig.2 Decrease in Y_s during single-line scanning with λ_{in} of 3.4 electrons/nm. Charge building-up resulted to increment in V_B, which pulled more SEs back to sample surface.

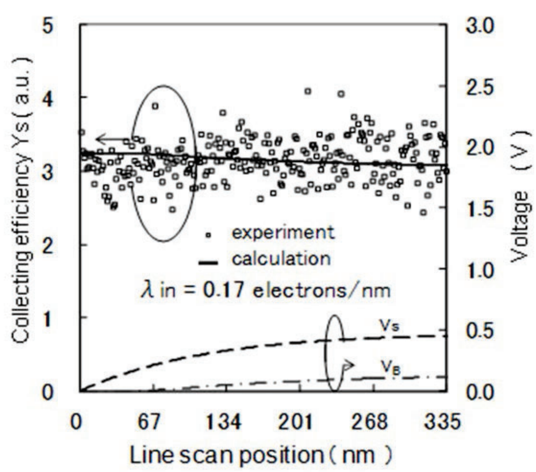

Fig.3 Change in Y_s during single-line scanning with λ_{in} of 0.17 electrons/nm. Weaker V_B at individual irradiation position contributes to higher Y_s and less variation in Y_s during the scanning.