

## NEW APPROACH TO OBTAIN ELEMENTAL MAPS BY USING ENERGY-FILTERED IMAGES

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The ability to obtain elemental maps processed by using inelastically scattered electrons in a transmission electron microscope (TEM) or a scanning transmission electron microscope (STEM) is extremely useful in the analysis of materials, and semiconductor devices such as ULSI's and GMR heads. Hitachi developed an elemental mapping system, consisting of a STEM (Hitachi, HD-2000) equipped with a two-window energy filter (Hitachi, ELV-2000), and performed real-time conventional jump-ratio images with nanometer resolution by in-situ calculation of energy-filtered signals [1]. Since images can be obtained by only one-scan of the electron beam on the specimen, no artifacts due to sample-drift appear. But it is problem that artifacts in jump-ratio images due to the difference of inclination in EEL (Electron Energy-Loss) spectra will give incorrect information when investigating elemental maps. For example, heavy elements such as tungsten (W) often show bright contrast as artifacts in light elemental jump-ratio images such as nitrogen and oxygen. On the other hand, it is possible to obtain the quantitative elemental maps by using 3-window method. In this paper, we propose new approach to obtain elemental maps without artifacts due to heavy elements.

It is assumed that the intensity of EEL spectra can be fitted by the function of  $A \cdot \exp(-r \cdot E)$ .  $E$  is energy-loss (eV), and  $A$  and  $r$  are coefficients dependent on specimen, respectively. Figure 1 shows a schematic figure of an EEL spectrum. Core-loss edge is observed in the energy-loss range from  $E_2$  to  $E_3$ , and another energy-loss ranges from  $E_0$  to  $E_1$  and from  $E_1$  to  $E_2$  are selected to integrate the electron intensities ( $I$ ), respectively, as follow as equation (1). Jump-ratio images are given by the equation (2).  $\Delta E$  in the equation (2) is  $E_3 - E_2 = E_2 - E_1 = E_1 - E_0$ . It is clear from the equation (2) that jump-ratio images depend on the coefficient of  $r$ . In general, since  $r$  is dependent on the specimen, jump-ratio images often show the artifacts due to difference in  $r$ .

$$I(A, r, E_2, E_3) = \int dE = A/r \{ \exp(-r \cdot E_2) - \exp(-r \cdot E_3) \} \quad \text{eq. (1)}$$

$$I(A, r, E_2, E_3) / I(A, r, E_1, E_2) = \exp(-r \cdot \Delta E) \quad \text{eq. (2)}$$

In this work, we propose the image derived by the ratio,  $\{I(A, r, E_2, E_3) / I(A, r, E_1, E_2)\} / \{I(A, r, E_1, E_2) / I(A, r, E_0, E_1)\}$ , in order to cancel the dependence of  $r$  in jump-ratio images. As shown in the equation (3), this ratio gives one when calculating background signals of EEL spectrum. However, if core-loss edge is observed in EEL spectra, the ratio is greater than one. Therefore, even if there are both light and heavy elements in observation area, it is expected that light elemental map derived from the ratio will give correct contrast without artifacts.

$$\{I(A, r, E_2, E_3) / I(A, r, E_1, E_2)\} / \{I(A, r, E_1, E_2) / I(A, r, E_0, E_1)\} = 1 \quad \text{eq. (3)}$$

Figure 2 shows the results of nitrogen maps of semiconductor device that were obtained by jump-ratio method by real-time mapping system (a), 3-window method (b) and this work (c). Nitrogen jump-ratio image as shown in figure 2 (a), not only nitrogen layer but also tungsten electrode show bright contrast. In figure 2 (b), although signal/noise ratio of this figure became weaker than one of figure (a), artifact of tungsten electrode vanished. On the other hand, figure (c) also showed that the nitrogen layer was bright contrast but tungsten electrode became dark. Therefore, it is clear that the proposed method is effective to observe elemental images without artifacts.

#### Reference

- [1] K. Kaji et al., Proc. Ann M&M Meeting 6 (2000) 179.

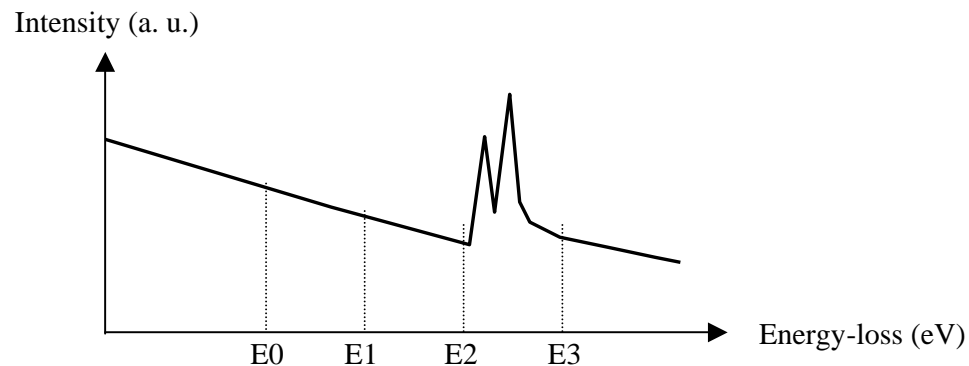


Figure 1 A schematic figure of EEL spectrum.

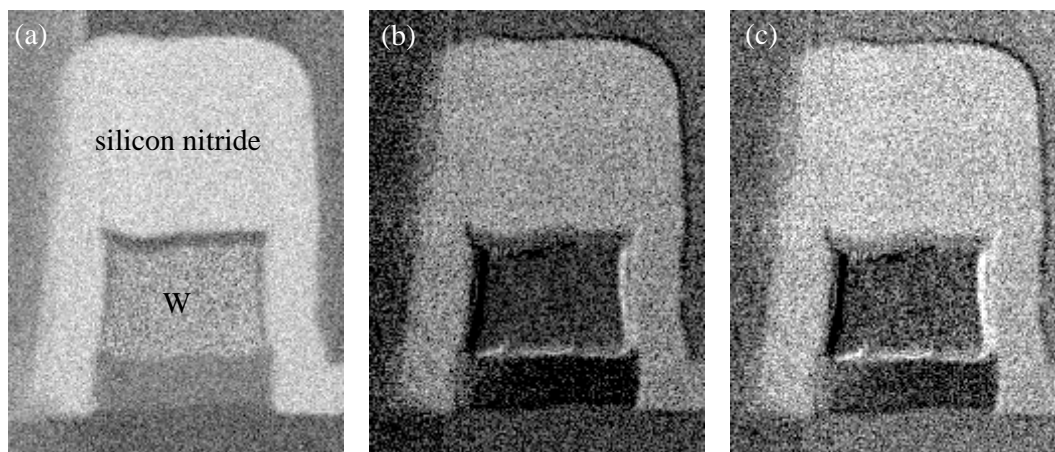


Figure 2 Nitrogen images of semiconductor device obtained by jump-ratio method (a), 3-window method (b) and this work (c).