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Application of Material Evaluation using High-end Analysis Electron Microscope HF-3300

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In recent years, with high integration and high density of semiconductor devices, the clarification of the failure analysis and the process reaction became increasingly difficult using the general TEM methods. Especially, it is difficult to state the atomic diffusion in the multilayer structure and the low-density distribution such as the dopant profile in semiconductor devices.

Recently, we developed a 300 kV Cold FE-TEM (HF-3300) equipped with the spatially resolved electorn energy loss spectroscopy (EELS) technology and the special electron biprism system for electron holography[1]. Here, we report the latest results of the spatially resolved EELS applied for evaluation of the malitlayer structure and the electron holography applied for the observation of the dopant profile of Si device, respectively.

1. Spatially resolved EELS[2]

Figure 1 schematically shows the principle of the spatially resolved EELS technology. A post-column energy filter (Gatan, GIF 863 Tridiem) is adopted. GIF was specially aligned to keep positional informaiton perpendicular to the energy loss axis. Figure 2 shows a TEM image of the multilayer structure. The SiO and the SiN layers can be clearly seen.

Figure 3 shows the results of the spatially resolved EELS on the sample. Figure 3(A) shows a two-dimensional spectrum image recorded on a CCD camera. The vertical axis corresponds to the position Y in the white rectangle area, as shown in Fig. 2. The horizontal axis corresponds to the energy loss, which is calibrated using Si-L edge. Figure 3(B) shows the energy loss spectra obtained in each layer. Since all spectra were acquired simultaneously, the accuracy of the measurement of the energy sifts across the multilayer materials can be distinguished at a spatial resolution (along Y-direction) of about 1 nm, as shown in extracted spectrum (e) of Fig. 3(B).

2. Electron holography[3]

To obtain a high contrast and high quality hologram, sample preparation technique is very important. We used a FB-2100 focused ion beam (FIB) system with the FIB micro-sampling mechanism and the three-dimensional sample holder to fabricate sample for electron holography[4].

Figure 4 shows the bright field STEM image from the sample prepared according to the development method in this study. The sample thickness was approximately 300 nm. The region enclosed with the black rectangular square marked in Fig. 4 indicates an observation region with electron holography.

A phase image of the N-MOS transistor is shown in Fig. 5. In the phase image, the change of the contrast in the Si substrate can be clearly seen and was attributed to the electrostatic potential at the p-n junction.

It was shown that the HF-3300 TEM could select the analytical techniques according to the purpose of the material evaluation. These methods associated with HF-3300 are useful for the various analyses on the physical science.

References

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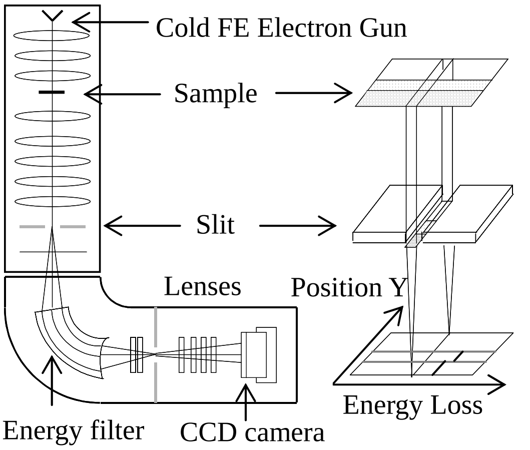

Fig.1 The scheme showing principle of spatially resolved EELS technology.

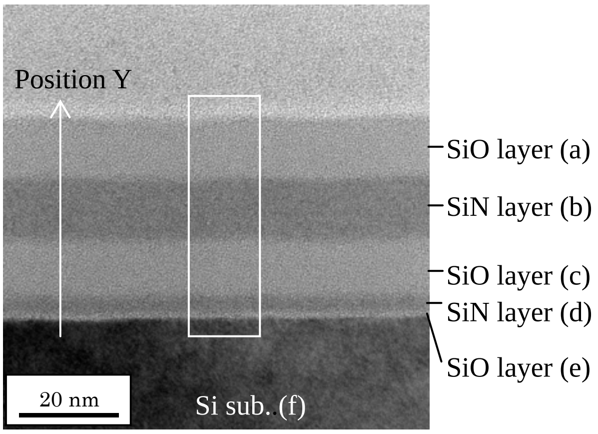

Fig.2 TEM image of a multilayer sample.

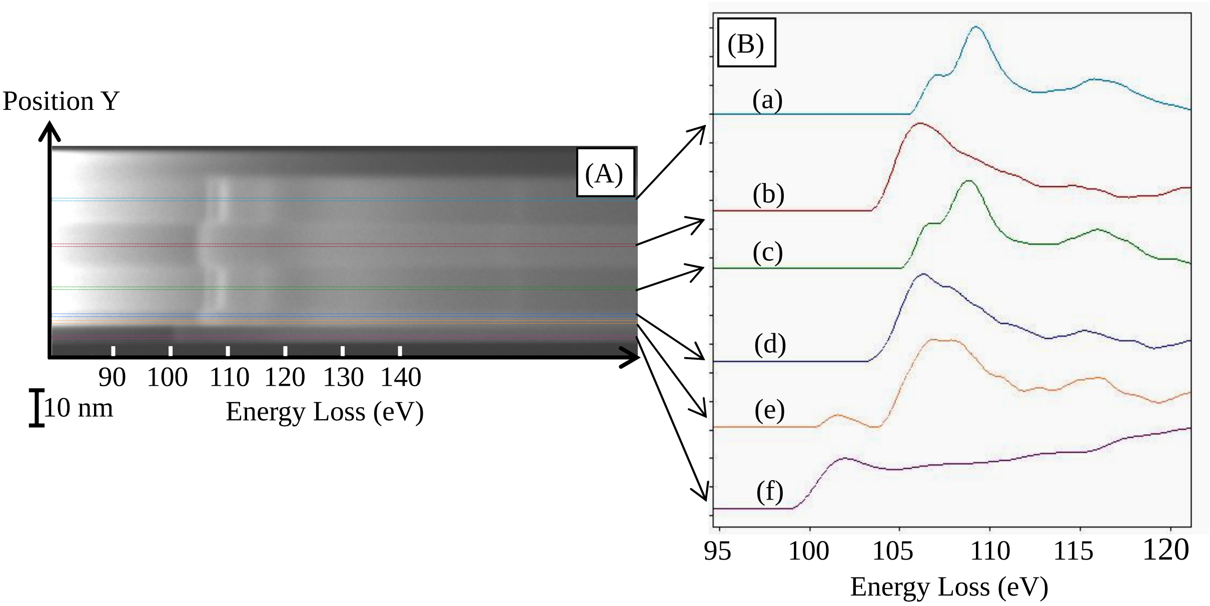

Fig.3 The result of the spatially resolved EELS of the multilayer sample. (A) is the spatially resolved EELS image of Si-L edge (99 eV). (B) is the extracted spectra from EELS image (A). Energy dispersion is 0.05 eV.

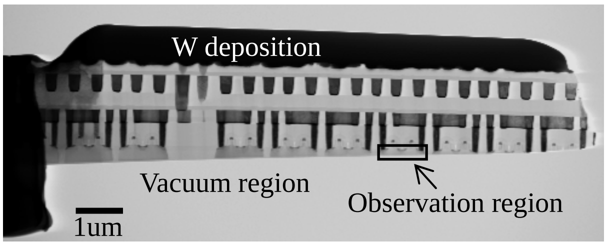

Fig.4 Bright field STEM image from a FIB-prepared sample.

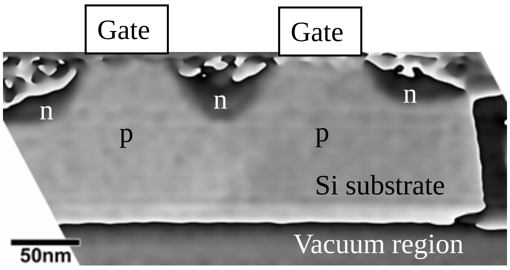

Fig.5 The phase image of the N-MOS doped with Arsenic.