Investigation of dopant concentration measurement by FE-SEM/EDS.

Konyuba, Y.[1], Sakuda, Y.[1], Asayama, K.[1], Fukunaga, K.[1], Suga, M.[1] and Nishioka, H.[1]

[1] JEOL Ltd., Japan

To improve the reliability and performance of semiconductor devices, dopant concentration measurement is essential. Currently, secondary ion mass spectrometry (SIMS) is widely used for one-dimensional dopant concentration measurement. On the other hand, the two-dimensional dopant concentration measurement is performed by various methods (i.e., scanning capacitance microscopy (SCM), scanning spreading resistance microscopy (SSRM), scanning tunneling microscopy (STM), electron beam holography, scanning transmission electron microscopy (STEM) and energy dispersive X-ray spectrometry (EDS), secondary electron contrast by scanning electron microscopy (SEM)). Among them, in recent years, the STEM/EDS method has been widely used since its detection sensitivity and throughput were improved by using plural EDS detectors having a large sensor area. However, since the thin film sample is indispensable for the STEM measurement, it is laborious to prepare the sample.

We examined measuring the dopant concentration using FE-SEM/EDS since it requires no special sample preparation of thin lamella: cross-sectional bulk specimen can be easily prepared by cleavage [1]. In the sample for the measurement, Arsenic (As) or Boron (B) ions were implanted into a silicon wafer, a silicon oxide film was plated on the wafer, and finally annealed.After preparing the cross sectional sample by cleavage, it was introduced into a FE-SEM (JSM-7800FPRIME, JEOL Ltd.) equipped with two silicon drift detectors (X-Max Extreme and X-Max^N 150, Oxford Instruments).

In the secondary electron images of the cross-section of the As and B doped silicon specimens (Figs. 1 and 2), the brightness of the doped region was different from the undoped region, reflecting the conductivity type where N type (As) is dark and P type (B) is bright, as reported before [2]. The profiles of As concentration along depth direction measured by FE-SEM/EDS (As-Lα) and SIMS are shown in Fig. 3. In FE-SEM/EDS, information of 768 pixels is integrated and shown to reduce statistical fluctuation. Both profiles of As concentration by As-Lα and SIMS were similar in the region deeper than 20 nm from the SiO_2/Si interface. On the other hand, both results were different in the region shallower than the depth of 20 nm from the SiO_2/Si interface. This is thought to be due to spreading of the X-ray generation region by incident electrons (2.5 kV). Furthermore, the detection limit of As in this measurement condition was calculated using the spectrum obtained from the region of As concentration 5.00×10^{20} /cm^3 [3]. As a result, the detection limit of As was approximately 6.64×10^{19} /cm^3. We also tried to improve the detection limit using a method of multivariate curve resolution. By the multivariate curve resolution, it was confirmed that As exists in the region of 150.6 nm from the SiO_2/Si interface and the detection limit is 4.50×10^{19} /cm^3 which is calibrated by the result of SIMS.

The estimated detection limit by FE-SEM/EDS is low enough to measure the concentration in a high concentration diffusion layer of a MOS transistor. Thus, we conclude that FE-SEM/EDS can be used for significant case of failure in dopant concentration such as deficiency of ion implantation.

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[3] J.Goldstein, et al. Scanning Electron Microscopy and X-ray Microanalysis, 2003.

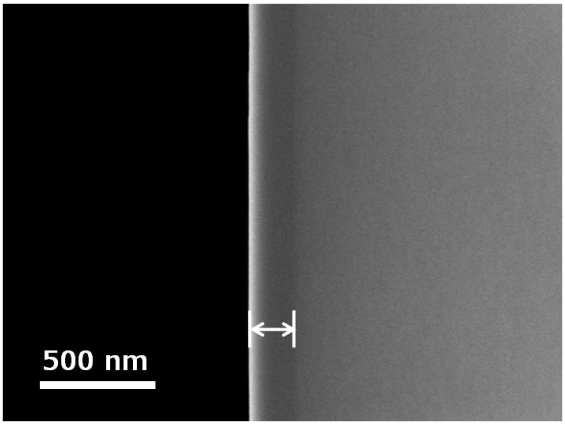

Figure 1. Cross sectional secondary electron image of silicon wafer after As ion implantation and annealing.

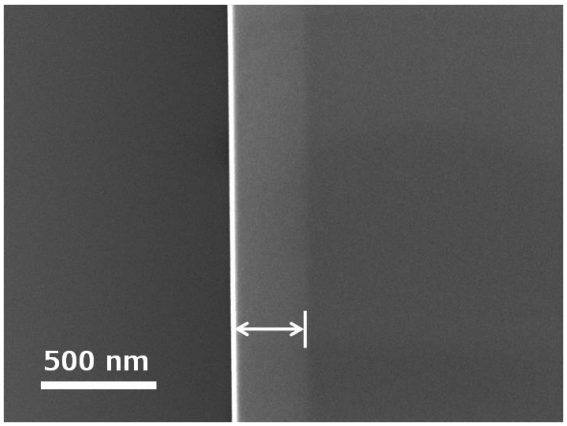

Figure 2. Cross sectional secondary electron image of silicon wafer after B ion implantation and annealing.

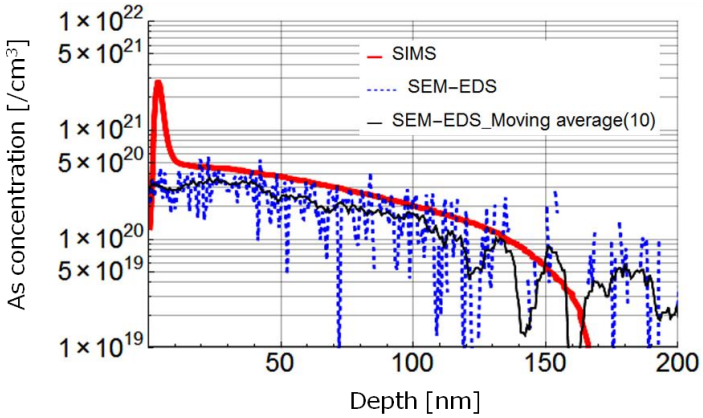

Figure 3. Depth profile of As concentration by FE-SEM/EDS and SIMS.