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Comparative Study of Dopant Profiling by Electron Holography, Scanning Capacitance Microscopy, and Secondary-Ion Mass Spectrometry

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Secondary-ion mass spectrometry (SIMS) is a widely accepted technique for analyzing one-dimensional doping profiles, while scanning capacitance microscopy (SCM) is mainly used for two-dimensional (2D) junction profiles [1]. As an alternative, off-axis election holography (EH), based on transmission electron microscopy (TEM), is utilized to map 2D junctions [2]. The dopant distribution detection is based on completely different principles in these techniques. Therefore, it is important to examine and compare the results from these techniques and see how well they correlate to each other.

To make such a comparison, two shallow n+/p junction samples were made in Si (100) wafers at the same implanting and annealing conditions. One wafer was coated by a 180nm polysilicon layer to prevent surface damage during sample preparations for SCM and EH.

Both samples were examined by SIMS. Two profiles were taken on each sample to verify repeatability. Figs. 1(a) and (b) show the depth-distribution of implanted As and substrate B. The depth at which As concentration equaled that of B ($C_{As} = C_B$) was determined to be about 40nm. The SCM experiment was performed using a Digital Instruments Dimension 5000 scanning probe microscope with SCM attachment, and images were acquired with a 1.0V AC bias applied to the sample. Figs. 2(a) and (b) show a SCM image and the corresponding topographic image. In the SCM image, dark-color regions represent negative signals coming from n-doped regions, while bright colors are positive signals from p-doped areas. Cross-section analysis of the images indicates that the p/n junction depth is about 71nm. The cross-sectional TEM samples for EH were prepared by focus ion beam (FIB), and the EH experiments were performed on a JEOL 2010F TEM equipped with an electron biprism. Figs. 3(a) and (b) show a hologram and the corresponding reconstructed phase image. In the phase image, the implanted n-region is clearly distinguished from p-region by brighter contrast. The measured p/n junction depth is about 68nm.

Comparison of experimental results from SIMS, SCM and EH indicates: (1) the junction depth measured by EH agrees with that from SCM, but is far from the one given by SIMS analysis; and (2) the spatial resolution of SCM is limited significantly by probe size, and thus EH has higher spatial resolution for 2D junction profiling. The reason why the junction depth measured by SIMS differs from those measured by SCM and EH is because SIMS result represents the concentration of total doping atoms, while SCM and EH results are associated with activated doping atoms only.

References

[1] N. Duhayon et al., J. Vac. Sci. Technol. B 22 (2004) 385.

[2] W.D. Rau et al., Phys. Rev. Letts. **82** (1999) 2614.

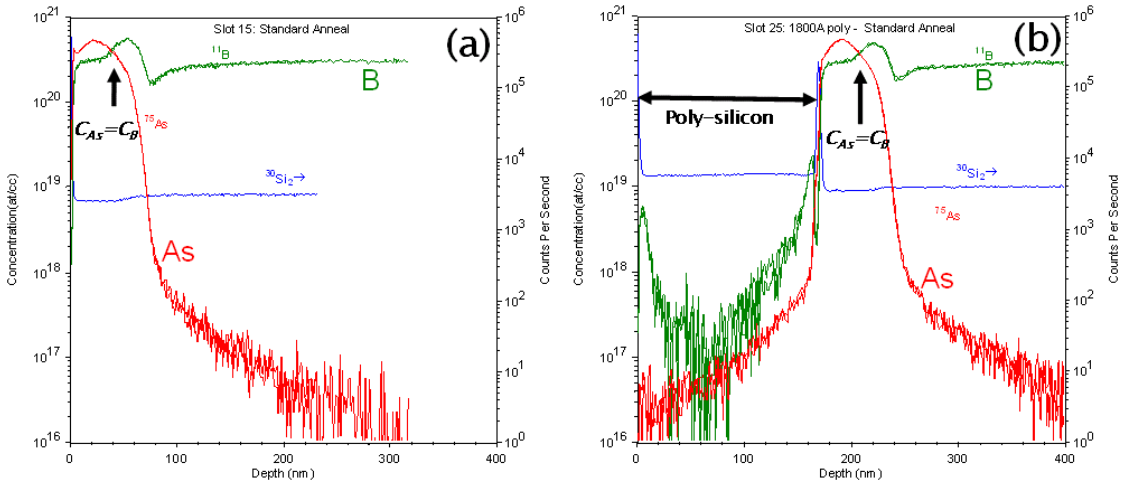

Fig. 1 SIMS measurements of dopant profiles for samples without (a) and with (b) poly-Si layer.

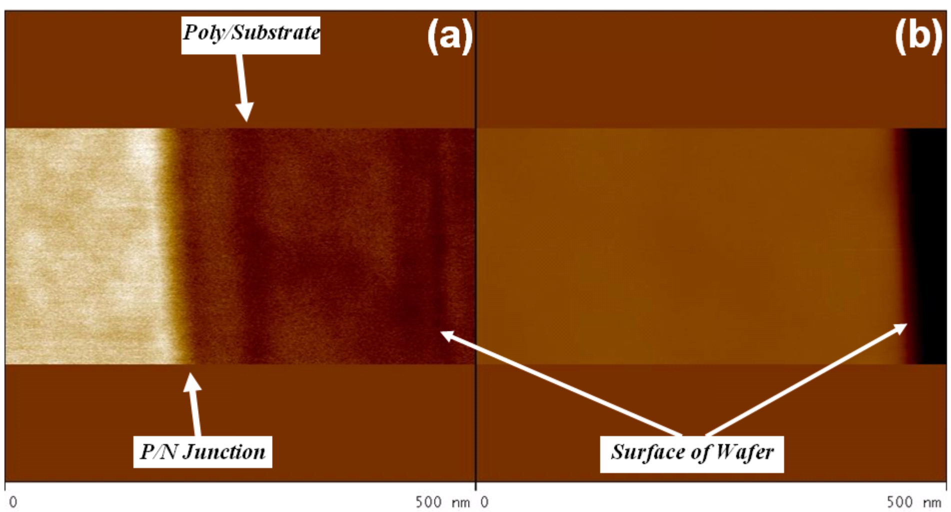

Fig. 2 SCM image (a) and the corresponding topographic image (b).

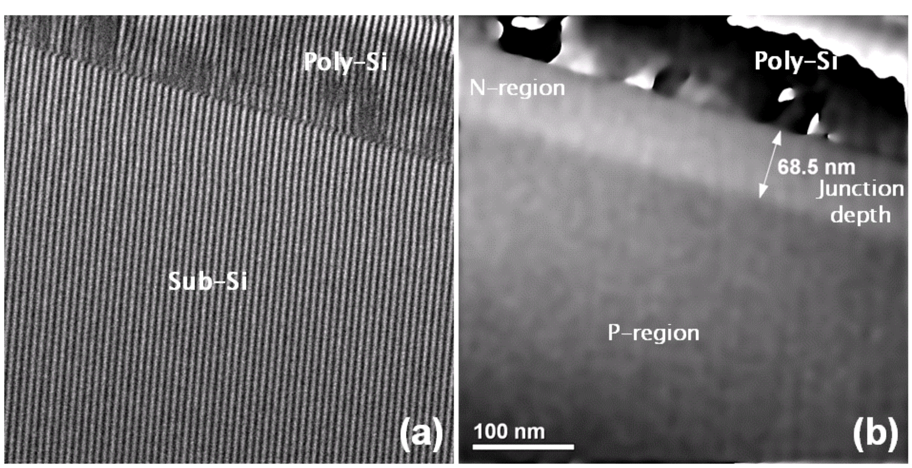

Fig. 3 Electron hologram (a) and the corresponding reconstructed phase image (b).

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