I2-4 Dopant Profiling on Ultra Shallow Junctions in Si with ADF-STEM.

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The utmost scaling of the electronic devices nowadays attained, requires both ultra shallow junctions and high levels of dopant concentration and activation. In these conditions, the presence of surfaces or interfaces assumes a very important role in the determination of the dopant distribution during post-implantation annealing. In this work, we show how the Z-contrast annular dark field scanning transmission electron microscopy (ADF-STEM) technique, pioneered by Pennycook and co-workers [1], can be optimised to give reliable dopant profiles at a sub-nanometer scale thus satisfying some of the new needs of the ultrashallow implants characterization.

(100) Czochralski grown silicon wafers were implanted with $2x10^{15}$ As^{+}/cm^{2} at 5 keV energy and subsequently annealed at 800 °C for 3 min with a rapid thermal system. A F.E.I. Tecnai F20 transmission electron microscope operating at 200 kV and equipped with a Schottky type electron emitter was used to perform ADF-STEM observations on cross sectional samples. Key parameters were found to be the electron probe convergence angle (8 mrad), the inner detector angle (62 mrad) and a slight tilt of the sample away from the (011) cross-section zone axis around the <100> surface normal. Incident probe size was kept in between 0.2 and 0.3 nm. Electron energy loss spectra obtained with a Gatan 666 parallel spectrometer were employed to calculate the specimen thickness. SIMS analyses were carried out using a 0.5 keV impact energy Cs^{+} beam (incidence angle 45°) and collecting $^{28}Si^{75}As^{-}$ and $^{28}Si_2^{-}$.

Figure 1 (a) reports the SIMS profiles obtained after implantation and annealing at 800 °C for 3 min. An As diffusion toward the surface and a consequent dopant pileup in the surface region is evidenced. However, it is known that SIMS measurements could be affected by some artifacts in proximity of the surface or of the interface with the surface oxide. To verify the presence of a surface dopant accumulation, ADF-STEM cross-sectional observations have been carried out as preliminarly reported in [2]. Fig. 1 (b) and (c), taken on the same region of the as-implanted sample, show how diffraction and channeling contrast can be effectively removed from ADF-

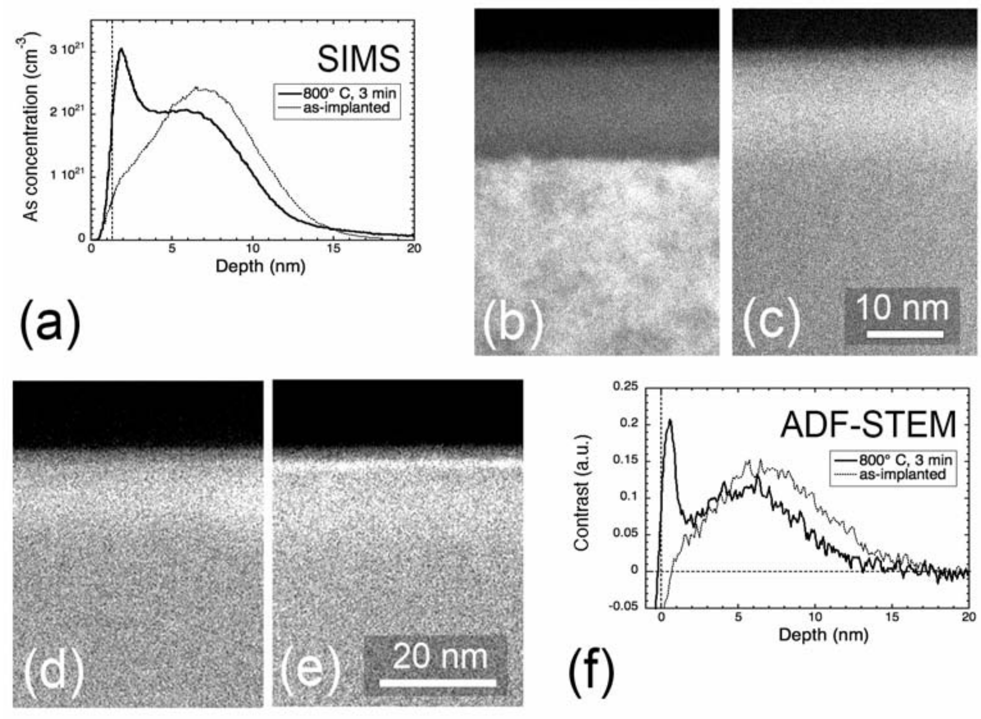

Fig. 1. Comparison of SIMS (a) and ADF-STEM contrast profiles (f) obtained on 5 keV $2x10^{15}$ As^{+}/cm^{2} implanted Si samples before (d) and after (e) annealing at 800 °C for 3 min. The effect of a sample tilt on the ADF-STEM contrast is shown in (b) and (c).

STEM micrographs by slightly tilting the sample. The contrast profiles reported in Fig 1 (f), obtained from the ADF-STEM micrographs shown in Figs. 1 (d) and (e), have been obtained from regions of equal thickness of the as-implanted and annealed samples, respectively. In Fig. 1 (f), the ADF-STEM profiles evidence that after annealing, a pronounced contrast peak close to the sample surface is present thus confirming that an uphill As diffusion phenomenon has taken place. The agreement of both the profiles with the corresponding SIMS profiles shown in Fig. 1 (a) is remarkable and seems to indicate that, in this case, the sensitivity of the technique is of the order of, or slightly better than 1 at. %, while the spatial resolution, defined by the probe size, is about 0.3nm.

References:

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