The characterisation of As plasma doping and processing using medium energy ion scattering

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Plasma doping (PLAD) is capable of implanting micro-electronic devices with high fluences of low energy As with high throughput. In a PLAD process considered here, a wafer was immersed in a mixed AsH_3/H_2 plasma and biased with -7 kV to effect deposition and (recoil) implantation of As from the plasma boundary into the wafer. A total ion fluence of $1x10^{16}$ cm^{-2} was measured during the implant.

MEIS analysis, using 100 keV He ions scattered through 90° in conjunction with energy spectrum simulation, was used to understand the details of this PLAD process together with the changes resulting from a subsequently applied chemical wet clean and a 1000 °C spike anneal. Although information on layer thicknesses and concentrations was sought, MEIS strictly measured areal atomic densities and information on the layer thickness was based on knowledge, or reasonable assumptions, regarding the layer density or on additional XTEM measurements.

In agreement with XTEM energy dispersive spectrometry measurements, MEIS showed that the PLAD implant process produced an intermixed As/Si layer whose As concentration decayed from a surface concentration of ~$2x10^{22}$ cm^{-3} to close to zero at a depth of ~20 nm, commensurate the maximum range of As ions implanted into the changing matrix. The deposited layer was capped by a 1-2 nm thin silicon oxide layer. Over a timescale of several months, As was lost by sublimation and the silicon oxide cap thickness increased.

Deposited As was removed by a wet chemical clean which, due to the presence of an oxidising agent, oxidised the Si left behind, producing a ~15nm thick Si oxide. MEIS depth profiling showed that the post clean As distribution matched the tail end of the original (recoil) implanted profile. A second sample that had undergone a similar PLAD implant but different clean showed an altered oxide thickness, and the MEIS measurements indicated where the processes differed. A detailed comparison of aligned and random MEIS spectra after annealing enabled the interstitial and substitutional As profiles to be determined. They showed that during solid phase epitaxial regrowth

of the disordered Si upon annealing, As partly moved into substitutional sites (with a concentration that correlated closely with sheet resistance measurements) whilst ~$5x10^{14}$ cm^{-2} of segregated As was trapped under the surface oxide.