Measurement and modelling of arsenic and boron diffusion in oxygen implanted silicon-on-insulator (SOI) layers

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The diffusion of arsenic and boron in oxygen implanted SOI layers has been studied using Secondary Ion Mass Spectrometry (SIMS), Rutherford Backscattering Spectroscopy (RBS), Spreading Resistance Profiling (SRP) and Transmission Electron Microscopy (TEM). The SIMOX material was implanted by Eaton Nova using an energy of 150 keV to a dose of $1.7 \times 10^{15} \text{ cm}^{-2}$ through a 75 nm screen oxide. The implantation temperature was nominally 570°C and subsequent annealing was performed at 1300°C for 2 hrs with an undoped oxide cap. From cross-sectional TEM measurements, it was found that the final SOI structure had a 0.14 μm silicon overlayer with a buried oxide thickness of 0.33 μm . The implant/anneal schedule used results in material with a well-defined back interface and some dislocations threading the layer, but none of the oxygen precipitates seen near the back of the silicon layer when annealing is at a lower temperature.

After the SIMOX structure had been produced, a 27 nm oxide layer was grown prior to implantation of either arsenic (80 keV, $5 \times 10^{15} \text{ cm}^{-2}$) or boron (15 keV, $2 \times 10^{15} \text{ cm}^{-2}$). The samples were annealed at 900 C for 10 min, 30 min and 120 min in an inert ambient and analysed using the range of techniques previously mentioned. The resultant experimental information has been compared with process modelling simulations where diffusion behaviour appropriate to bulk silicon has been incorporated (1). In contrast to previous work performed on 0.3 μm thick silicon-on-sapphire substrates (2), it has been found that the major features of the experimental data can be understood without considering mechanisms which may be affected by the particular properties of the SIMOX structure, such as residual defects or high oxygen concentrations. For example, SRP measurements on boron samples diffused for 120 min indicate activation up to the solid solubility limit to a silicon depth of 0.11 μm with a reduced level of carriers in the remaining portion of the silicon overlayer. Similar measurements on SOS substrates showed substantial deactivation and mobility degradation in the 0.1 μm of silicon near the sapphire substrate. In addition, for arsenic diffused in SOS it was found that rapid diffusion associated with the crystalline defects in the silicon resulted in a peak in the non-substitutional arsenic at the silicon/sapphire interface. The importance of this diffusion mechanism is greatly reduced in the SIMOX samples studied in this work and evidence for a local peak in the arsenic distribution close to the silicon/silicon dioxide interface as measured by RBS could only be determined for the longest heat treatment times.

In conclusion, it has been found that by using appropriate implant and anneal schedules it is possible to produce SIMOX material where the quality of the silicon overlayer allows the majority of diffusion behaviour to be predicted using models developed for bulk silicon. The detailed experimental data obtained in this study together with the results of process modelling simulations will be presented. In addition, the mechanisms required to interpret the additional features present in diffusion in SIMOX material (e.g. point defect generation and recombination at interfaces) will be discussed.

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References

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