IDENTIFICATION OF OPTIMAL DOSES FOR DEVICE QUALITY THIN-FILM AND STANDARD SIMOX STRUCTURES FORMED BY LOW (50keV, 70keV or 90keV) OR HIGH (200keV) ENERGY OXYGEN IMPLANTATION

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The potential of SIMOX technology to tailor the Si layer thickness for particular device applications is of great interest [1-5]. Thin-film SIMOX is of particular interest because of the potential for fabricating high speed, fully depleted CMOS devices [3-5]. Tayloring the Si layer thickness by direct formation has the advantages, over the alternative technique of high energy implantation and sacrificial oxidation [3-5], of fewer process steps and significantly lower cost. This paper reports the microstructure of SIMOX structures with thin (from 40nm) or thick (up to 400nm) surface silicon layers, formed by implanting high doses of oxygen ions at energies of 50keV, 70keV, 90keV or 200keV. The optimum experimental conditions, inparticular dose, for forming device quality (defect density $<10^5/cm^2$, buried oxide continuous, low density of Si islands in the buried oxide) thin-film and standard SIMOX structures have been identified.

Wafers were implanted using pre-heating and background heating provided by halogen lamps. The implantation temperature was either 680°C or 550°C. The doses ranged from 0.2×10^{18} O^+/cm^2 to 1.8×10^{18} O^+/cm^2. The samples were then capped with 500nm of Si oxide and annealed for 6hrs at 1300°C in argon + ½ % oxygen or at 1320°C in nitrogen. The material was analysed before and after annealing by cross sectional and planar TEM, SIMS, RBS, electrical measurements and chemical etch pit techniques.

<u>Thin-film (50keV, 70keV & 90keV) SIMOX</u>

SIMS and/or TEM results from annealed samples implanted with doses of 0.2, 0.5 and 0.7×10^{18} O^+/cm^2, at 50keV and doses of 0.3, 0.33, 0.4, 0.5 and 0.7×10^{18} O^+/cm^2, at 70keV show that a continuous oxide layer can be formed for all the doses except the lowest dose in each series. For the thinnest continuous oxide layer produced at both energies, the threading dislocation density was $<10^5/cm^2$. For the higher doses the threading dislocation density was of the order 10^6-$10^9/cm^2$, increasing with increasing dose, hence at both energies there is a dose "window" in which the oxide is continuous and the threading dislocation density is low, $<10^5/cm^2$ (fig 1). Preliminary results from cross section TEM and etch pit studies of material implanted at 90keV (dose range $0.3 \times 10^{18} O^+/cm^2$ to $1.8 \times 10^{18} O^+/cm^2$) suggest a low threading dislocation density in structures with a continuous oxide and hence a good quality structure can also be formed at 90keV. The device quality of these thin-film structures is further substantiated by C-V and I-V measurments which show that the Si/oxide interfaces are of good electrical quality and the oxide has a beakdown field of 6×10^6 V/cm, with Fowler-Nordheim type conduction observed prior to breakdown.

<u>Standard (200keV) SIMOX</u>

Samples have been implanted with doses in the range $0.45 \times 10^{18} O^+/cm^2$ to $1.8 \times 10^{18} O^+/cm^2$ to investigate the existence of a dose "window" at 200keV. Structures with Si layer thicknesses from 250nm to 430nm, buried oxide layers from 100nm to 420nm have been formed. The microstructure and defect

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densities, which vary from $<10^5/cm^2$ to $10^8/cm^2$, at such doses are found to depend strongly on dose. TEM results suggest that for doses close to $0.6 \times 10^{18} O^+/cm^2$ a dose "window" also exists at 200keV.

The TEM results demonstrate that, for all energies, the as-implanted structures within the dose windows, are free from implantation damage near the wafer surface (fig 2). A semi-imperical model has been developed to predict critical doses and Si and oxide layer thicknesses [6]. Comparing our experimental results with the predictions from this model demonstrates that the dose window occurs for doses less than the critical dose required to form a continuous layer during implantation. These results demonstrate the importance of the as-implanted structure and hence the implantation conditions in determining the presence of the dose window.

Our results show that a low threading dislocation density ($<10^5/cm^2$) and a continuous buried oxide are not mutually exclusive. The results suggest that for each energy there exists a dose window in which the defect density is low and the buried oxide is continuous. Hence at each energy a good quality SIMOX structure is formed. The implantation conditions are important in controling the existence of the window. The results demonstrate that, within the limits set by the dose window, the thickness of a device quality Si layer can be taylored to a particular application, by implanting at the appropriate energy. It is within the dose window that thin-film or standard SIMOX suitable for device fabrication can be formed.

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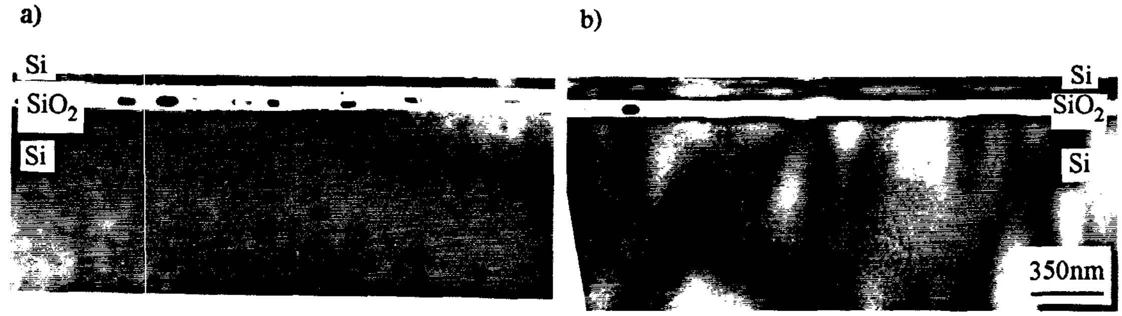

Fig 1 : Cross sectional TEM micrographs of annealed thin-film SIMOX structures with a threading dislocation density $<10^5/cm^2$ implanted at a) 50keV, Si thickness 55nm and b) 70keV, Si thickness 110nm. Fig b) shows that optimisation of the parameters greatly reduces the density of silicon islands remaining in the buried oxide.

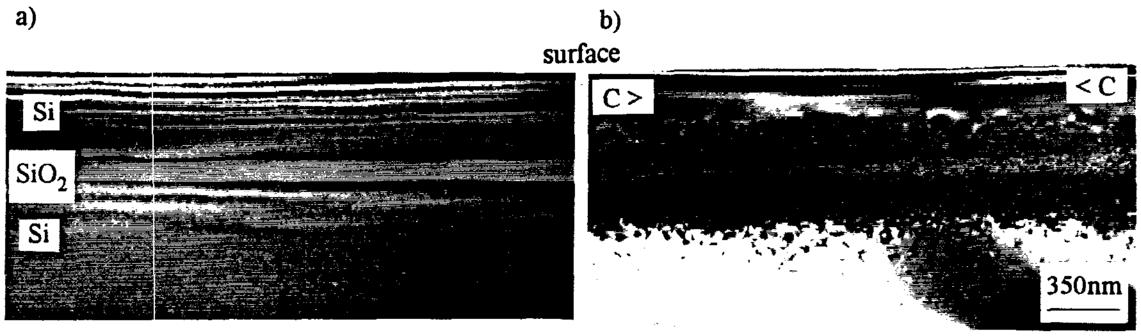

Fig 2 : Cross sectional TEM micrographs of a SIMOX structure implanted at 200keV, dose of $0.6 \times 10^{18} O^+/cm^2$, with a threading dislocation density after annealing $<10^5/cm^2$, a) annealed, Si thickness 400nm, and b) as-implanted, demonstrating the connection between the absence of damage near the silicon surface, (region c, fig b), after implantation and a low threading dislocation density after annealing (fig a).