THE EFFECT OF TRICHLOROETHYLENE ON ELECTRONIC PROPERTIES OF $Si\text{-}SiO_2$ STRUCTURES

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DEPARTMENT OF PHYSICS
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CERTIFICATE

This is to certify that the dissertation entitled, "The effect of trichloroethylene on electronic properties of Si-SiO_2 structures", which is being submitted by Ms. Lalita Manchanda to the Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy is a record of bonafide research work carried out by her under our guidance and supervision.

In our opinion this dissertation has reached the standard fulfilling the requirements of the regulations relating to the degree. The results contained in it have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

This dissertation investigates the influence of trichloroethylene (TCE) used in the oxidation ambient on electronic properties of Si-SiO_2 structures. The electronic properties of Si-SiO_2 structures are affected by various types of process induced defects near the Si-SiO_2 interface. A comparative study of dry thermal oxides and TCE oxides has been done to understand the nature of these defects near the Si-SiO_2 interface and to see the effect of trichloroethylene on these defects. Three main aspects of Si-SiO_2, namely bulk minority carrier lifetime near the interface, hole traps in SiO_2 and effects of avalanche injection (including charging of electron traps), have been studied.

The TCE process has been optimized for maximum storage time. The effect of high-temperature annealing in nitrogen at 1100°C on the minority carrier lifetime in the bulk of the silicon close to the Si-SiO_2 interface has been investigated for dry thermal oxides and TCE oxides. This annealing results in substantial reduction of lifetime for dry thermal oxides and the same annealing process enhances the lifetime for TCE oxides. The role of stacking faults and metallic impurities has been investigated to understand the mechanism of lifetime improvement in TCE oxides subjected to high-temperature anneal. Zerbst plots from transient capacitance versus time curves have been analysed. The variation in the slope of the

Zerbst plot for small values of depletion width has been ascribed to lifetime variation in the depletion region. The Zerbst technique has been modified for the determination of lifetime variation. This technique is used to scan the annealing-affected region in silicon near the interface and also the region affected by high molar concentration of TCE.

A detailed study of the spatial and energetic location of hole traps has been performed for dry thermal oxides and TCE oxides. These traps in dry thermal oxides are distributed in the energy range 1.0 to 1.5 eV with respect to the valence band edge of SiO_2. Their spatial location is within 200 Å of the $Si-SiO_2$ interface. The effect of nitrogen annealing and oxygen annealing for various durations and temperatures has been observed on the hole trap density. The annealing results support the trivalent-silicon model for hole traps. The validity of the hole trap model was checked by electron trap measurements. The change of intrinsic electron trap density due to oxygen annealing supports the model that trivalent silicon acts as an intrinsic hole trap and also indicates that non-bridging oxygen acts as an electron trap. The oxygen-annealing results also support Raider and Berman's model for fixed charge Q_f. Hole traps have also been investigated in TCE oxides. The addition of TCE during oxidation results in shallow hole traps which have energetic location less than 1.0 eV with respect to the valence band edge of silicon dioxide. The trap density and centroid are functions of the amount of trichloroethylene added during the growth.

The incorporation of chlorine atoms in the SiO_2 network seems to be giving rise to these shallow hole traps. A charge transfer mechanism via these traps is proposed for sodium passivation in chlorine-incorporated oxides.

Some investigations have been performed to determine the energetic and spatial location of electron traps in TCE oxides. Avalanche injection has been used to study the electron traps in TCE oxides and the accompanying effect of avalanche injection on interface states at the Si-SiO_2 interface of TCE oxides has also been studied. It was observed that the addition of TCE introduces shallow electron traps which have energetic location less than or equal to 1.1 eV with respect to the conduction band edge of silicon dioxide, but it reduces the density of deep traps which have an energetic location of approximately 2.4 eV with respect to the conduction band of SiO_2. An oxygen dangling bond seems to be a possible defect which gives rise to these shallow electron traps. The deep traps are probably due to sodium. Some investigations have also been made to understand the nature of interface states created by the avalanche injection. Some weak bands, possibly Si-Cl bonds, in TCE oxides break due to the avalanche injection and a large number of dangling bonds are generated resulting in larger number of interface states.

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