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Passivation of Radiation Damage in MOS Structures by Hydrogen Ion Implantation

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To generate the radiation-induced defects in the metal-oxide-silicon [MOS] structures, oxidized silicon wafers were exposed to a beam of 16 keV silicon ions. The oxide thickness was either 115 or 350 Å. The ion dosage varied between 10^{12} and 10^{15} per cm^2. To passivate the ion-beam-induced defects, half the samples underwent ion beam hydrogenation, using a Kaufman gun, at room temperature. The hydrogen ion energy was 400 eV. All the samples were metallized to obtain the MOS structures. I-V, C-V [static, quasi-static, and sinusoidal], G-V, and G-f measurements were made on hydrogenated, unhydrogenated, and control samples. The admittance characteristics were analyzed to obtain the electronic trap parameters [trap energy in the Si bandgap, trap density, and the trap cross-section]. The room-temperature hydrogenation was found to bring about profound changes in the trap parameters as well as in the admittance characteristics. Figure 1 illustrates the degree of change brought about by ion-beam hydrogenation, in a sample, that had received a prior silicon ion dosage of $10^{15}/cm^2$. Before hydrogenation, the capacitance-voltage characteristics were absolutely flat, as indicated by the broken lines in Fig. 1. Upon hydrogenation, the admittance-voltage characteristics reverted to the standard MOS form, as indicated by the solid lines.

Upon hydrogenation, the trap density significantly decreased for the Si-ion-exposed samples, however, for the control [unexposed to Si-ion-beam] sample, there was an increase in the state density, cf. Fig. 2A. This result indicates that the implanted hydrogen ions play a dual role, i.e. they neutralize electronic defects, generated by the Si-ion-induced damage, perhaps, by saturating the dangling bonds, while, at the same time, generating new defects, perhaps, by forming defect complexes. The profile of the residual trap density vs energy of each hydrogenated sample exhibited a peak about, 0.3 eV below E_c. This peak represents the defect induced by hydrogenation. Si-ion-beam-exposed samples exhibited very low capture cross-sections before hydrogenation, but this was not observed in the hydrogenated samples, cf. Fig. 2B. This result suggests that the oxide traps are effectively removed by hydrogen ion implantation.

Ion beam hydrogenation was effective in reducing the oxide leakage current, although about 15 % of the oxide was etched during hydrogenation. The room temperature hydrogenation was also very effective in removing other manifestations of radiation damage such as oxide space charge effects and low frequency dispersion of the accumulation capacitance.

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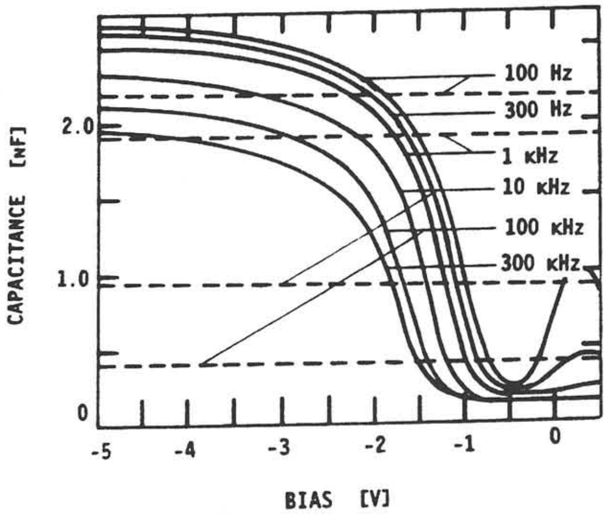

FIG. 1: Capacitance-voltage characteristics of sample A15, with an original oxide thickness of 115 Å, and exposed to a Si ion dosage of $10^{15}/cm^2$, measured at different frequencies, before [broken lines], and after [solid lines], room-temperature ion-beam hydrogenation.

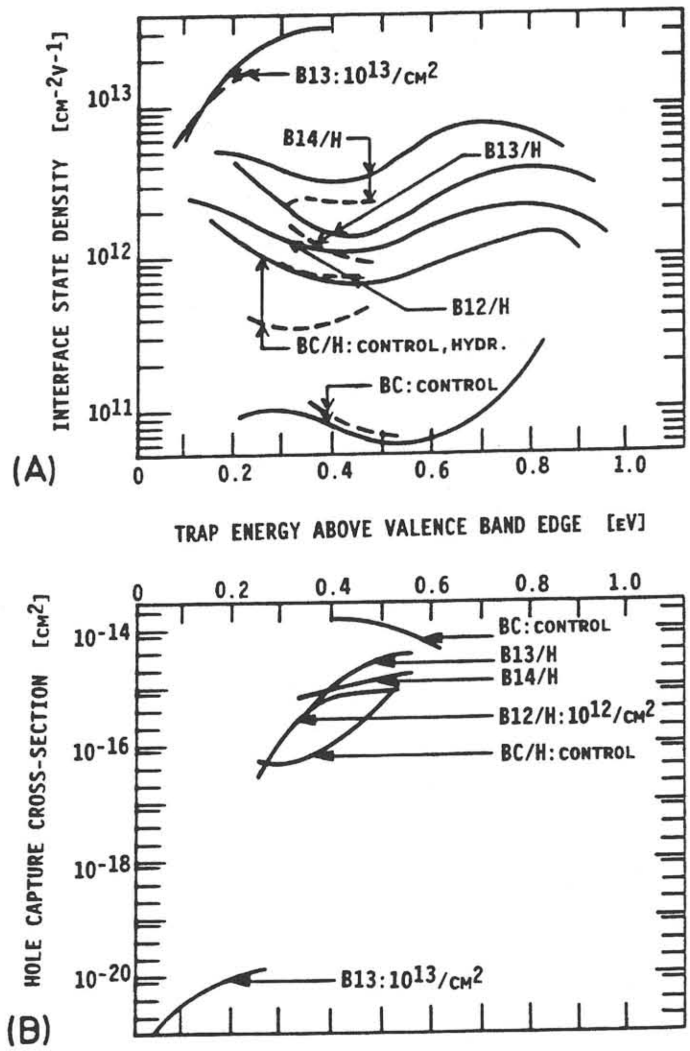

FIG.2: [A] Interface trap density, obtained experimentally from the static C-V characteristics [solid lines], as well as from the G-f characteristics [broken lines], as a function of the bandgap energy for the hydrogenated samples B14/H, B13/H, B12/H, BC/H, and unpassivated samples BC and B13. The Si ion dosages for samples B14/H, B13/H and B13, B12/H, BC/H and BC, were, 10^{14}, 10^{13}, 10^{12}, nil per cm^2, respectively. [B] Hole capture cross-section, obtained experimentally from the G-f characteristics, as a function of the bandgap energy, for the same samples as in [A].