HYDROGEN/DEUTERIUM IMPLANTATION FOR SI-DIELECTRIC INTERFACE IN NANOSCALE DEVICES

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Recently deuterium has been used to passivate dangling bonds at the Si/SiO_2 interface and Si/HfO_2 interface after the hydrogen/deuterium (H/D) isotope effect was discovered.[1,2] Deuterium passivation brings significant improvement in hot-carrier lifetime in metal-oxide-semiconductor (MOS) transistors.[3] It is because hot carrier stimulated deuterium desorption and depassivation of the silicon dangling bonds that generates interface trap states, is substantially reduced as compared to hydrogen desorption. Deuterium is typically incorporated at the Si/SiO_2 interface by annealing. There are many disadvantages.

This work investigates the electrical active interface states to study the impact of hydrogen/deuterium implantation at the Si/SiO_2 interface when a thin oxide is grown on implanted silicon substrate. To optimize the passivation various implanted energies starting from 15keV to 35keV were used to implant hydrogen and deuterium into 5–inch *p*-type Si wafer with a resistivity 0.8-1.2 ohm-cm and with a 20nm-thick sacrificial oxide deposited by steam oxidation. The wafer without any implantation was used as a control wafer. Dry oxidation was used to grow 6nm gate oxide at 800°C for 30 min with a flow rate of 750 sccm N_2 and 500 sccm O_2. 3000Å of Al was deposited to form MOS capacitors. The thickness was measured using ellipsometer on 13 sites. This was also compared to the thickness estimated from the electrical measurements (CV measurements), which yielded similar results. Interface state density was estimated using HP 4284 using the HF-LF technique across the band gap.

Implantation energy and implantation dose significantly influence the interface state density. Fig. 1 shows the variation of interface states for different deuterium implantation energies and doses. At constant implantation energy and at lower implantation dose $1x\ 10^{13}$-atoms/cm^2 (dose-1) and $1x\ 10^{14}$-atoms/cm^2 (dose-2) deuterium passivates the dangling bonds at the interface but at a higher dose $1x\ 10^{15}$ atoms/cm^2 (dose-3) passivation by hydrogen is dominant. Transient enhanced diffusion of implanted hydrogen and deuterium is believed to be affected by the vacancies created due to implantation damage. Observed interface states at the Si/SiO_2 interface further suggests an isotope effect where deuterium implanted devices yielded better interface results compared to that of hydrogen implanted devices. Deuterium implanted at 20keV with a dose of $1x\ 10^{14}$ atoms/cm^2 seems to be most effectively passivating the interface.

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References

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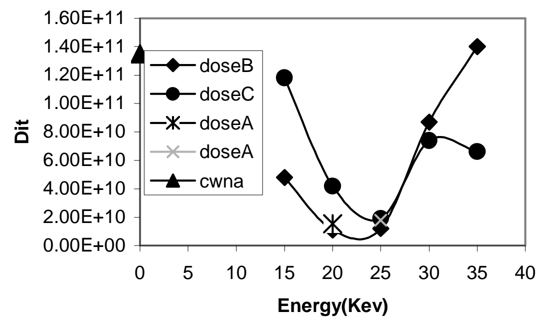

Figure 1

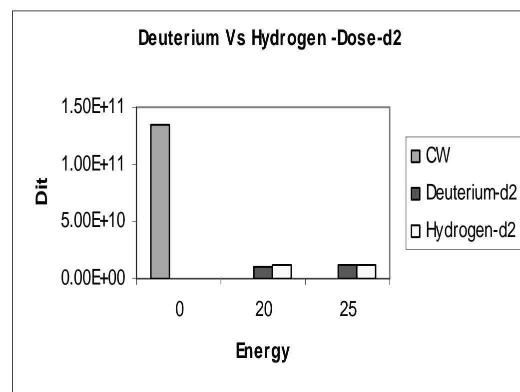

Figure 2 (a)

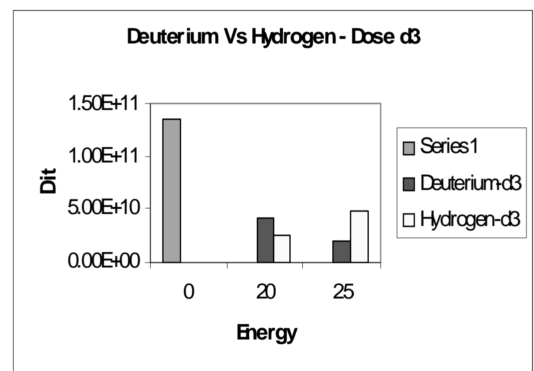

Figure (2b)