4 - 23 Radiation Effects Study of High-k HfO_2 Gate Device

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The gate dielectric thickness decreases dramatically with the continuous scaling of MOS devices, which has serious consequences on the leakage current and the power consumption of the SiO_2-based MOS devices. Hafnium dioxide (HfO_2), as a kind of high-k material, are recognized as alternatives to SiO_2 for future advanced gate devices and space applications[1]. Radiation-induced effects on conventional SiO_2 dielectrics have been investigated. Now, an enormous amount of effort was required to adapt the new high-k systems for radiation hard application. In this work, modifications of heavy ions on the dielectric properties of HfO_2-metal oxide semiconductor (MOS) capacitors were investigated.

The typical sample structure is W (75 nm) /TiN_2 (5 nm) /HfO_2 (8 nm) /p-Si (substrate). The samples were irradiated by 4 MeV Xe ions at room temperature to ion fluences varied from 1×10^{11} to 1×10^{14} ions/cm^2. The current-voltage (I-V) and capacitance-voltage (C-V) characteristics of the devices before and after irradiation were performed using Keithley S530 integrated system analyzer and shielding probe station.

Fig. 1 shows an example of typical current-voltage characteristics of the HfO_2 MOS capacitor before and after 4 MeV Xe ion irradiation to the fluences of 1×10^{13} and 1×10^{14} ions/cm^2. It was found that leakage current increased by several orders of magnitude for the highest fluence. The obvious increase in the leakage current would imply that there is a degradation of the insulation properties in the HfO_2 dielectric. This would be expected that the swift heavy ions induced physical damage to the gate dielectric and generate traps from a roughened HfO_2/Si interface along the latent track[2].

Fig. 2 shows capacitance-voltage characteristics measured from accumulation to inversion for a non-irradiated HfO_2 capacitor and a HfO_2 capacitor irradiated to 1×10^{14} ions/cm^2 at 4 and 5 MHz. The values of the capacitance in the accumulation region increase with increasing in test frequency, which indicates the presence of frequency dependent interface states. C-V curves shift to the negative voltage after irradiation by heavy ions, which suggested that positive charge get trapped or a recombination occurs for negatively trapped charge. The “stretch out” of the C-V curves after irradiation was resulted by existence of the net negative charge. The large number of defects induced by irradiation in the HfO_2 thin films are responsible for the increase in oxide trapped charges and leakage current[3].

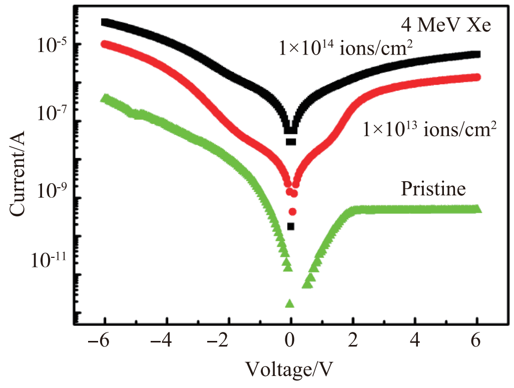

Fig. 1 (color online) I-V characteristics of the HfO_2 MOS capacitor before and after 4 MeV Xe ion irradiation.

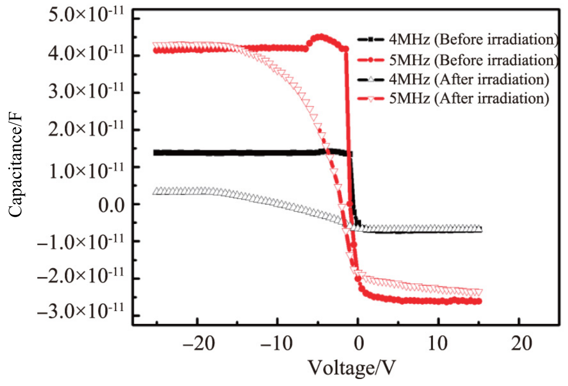

Fig. 2 (color online) C-V characteristics of the HfO_2 MOS capacitors before and after 4 MeV Xe ion irradiation measured at 4 and 5 MHz.

In the next step, the influence of radiation-induced defects and interface states on electrical characterization of the device will be explained via a investigation of the micro-structure of the HfO_2 gate dielectric.

References

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