Influence of high energy ion beam irradiation on nanocrystalline hafnium dioxide high-gate dielectric thin films grown by atomic layer deposition

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Abstract

Hafnium dioxide (HfO_2) is a promising candidate for gate dielectrics material with a relatively high refractive index and broad band gap. For this reason, HfO_2 is used in protective coatings because of its thermal stability, optical coatings, excellent interfacial properties, hardness and advanced metal-oxide-semiconductor devices. Effect of SHI beam irradiations on hafnium dioxide high-k thin films were grown by atomic layer deposition systematic data has not been reported in literature to the best of our knowledge. SHI beam irradiation has been used an effective tool for material modifications and generates controlled and systematic defects that can cause changes in structural, surface morphological, optical and chemical properties, which is difficult to achieve by other technique/method. Ion passes through the target material cause the nuclear energy losses (S_n) and electronic energy losses (S_e). S_e dominates over S_n in SHI. In the present work we report effect of ion beam irradiation (120 MeV Au^{9+}, with ion fluence $1x10^{11}$, $5x10^{11}$, $1x10^{12}$, $5x^{12}$ and$1x10^{13}$ ions/cm^2 using Tandem Accelerator at Inter University Accelerator Center (IUAC), New Delhi, India) on a systematic investigation on nanocrystline HfO_2 high-gate dielectric 100 nm thin films grown on silicon and glass substrates by atomic layer deposition technique. The pristine and irradiated representative HfO_2 thin films were characterized by XRD, AFM, UV-Vis., Raman, FTIR, PL, XPS and RBS. The X-ray diffraction technique which reveal the variation in crystallite size, stress, strain and dislocation density as a function of different fluence. The substantial root mean square (RMS) surface roughness and variation in grain size as a function of Au^{9+} ions irradiation were determined using atomic force microscope (AFM).The optical properties of HfO_2 thin films were analyzed by measuring absorbance and transmission spectra in 200–800 nm wavelength range followed by calculation of optical band gap (Eg) and Urbach energy (Eu). The obtained peaks in Rutherford backscattering spectrometry (RBS) affirm the existence of Hf and O elements and width of the peaks determine the sample thickness. X-ray photoelectron spectroscopy (XPS) was used to estimate the chemical states and variation in binding energy for pristine and irradiated HfO2 thin films. Detailed results will be discussed during the presentation.

Keywords: HfO_2 thin films, ALD, Au ion beam, XRD, AFM, UV-vis., Raman, XPS and RBS