STRUCURAL STABILITY STUDY FOR ULTRA-THIN HFO_2 FILMS BASED ON GIXRR AND GIXRD

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High-k materials, such as HfO_2, Al_2O_3, and many others, have been employed to replace SiO_2 insulator in gate dielectric device in order to offer significant gate leakage reduction. In this study, the structural stability of hafnium dioxide (HfO_2) thin films in the cases of 'as-deposited' and 'post-deposition annealing' (PDA) was analyzed and characterized. Ultra-thin hafnium dioxide films of thickness 2.5, 5 and 10 nm were deposited on Si (100) substrates using atomic layer deposition (ALD) at temperature of 300 ℃. After deposition, the films were annealed using furnace in Ar ambient for 10 minutes for selected temperatures at 450 ℃, 550 ℃, 650 ℃, 750 ℃, 850 ℃, and 1000 ℃. The thickness, density, roughness and the crystalline evolution of the HfO_2 films were investigated by Grazing Incidence X-Ray Reflectometry (GIXRR) and Grazing Incidence X-Ray Diffraction (GIXRD) for both as-deposited and post-annealing conditions. Transmission Electron Microscope (TEM) was used to provide image verification of the two-layer model applied in XRR fitting analysis. Furthermore, the grain sizes were evaluated by X-ray diffraction peak-broadening (full width at half maximum, FWHM) calculation according to the Scherrer method. The experimental results showed that the annealing temperatures had significant impact on the thickness, density and roughness of the HfO_2 and SiO_2 layers. In addition, the experimental results demonstrated the grain sizes depend on not only the thickness of the film, but also the annealing temperatures in the crystallization process.

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