Integrity of Copper-Hafnium, Hafnium Nitride and Multilayered Amorphous-like Hafnium Nitride Metallization under Various Thickness

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Abstract

The barrier properties and failure mechanism of sputtered Hf, HfN and multilayered HfN/HfN thin films were studied for the application as a Cu diffusion barrier in metallization schemes. The barrier capability and thermal stability of Hf, HfN and HfN/HfN films were determined using X-ray diffraction (XRD), leakage current density, sheet resistance (Rs) and cross-sectional transmission electron microscopy (XTEM). The thin multi-amorphous-like HfN thin film (10 nm) possesses the best barrier capability than Hf (50 nm) and amorphous-like HfN (50 nm). Nitrogen incorporated Hf films possess better barrier performance than sputtered Hf films. The Cu/ Hf/n+-p junction diodes with the Hf barrier of 50 nm thickness were able to sustain a 30-min thermal annealing at temperature up to 500 °C. Copper silicide forms after annealing. The Hf barrier fails due to the reaction of Cu and the Hf barrier, in which Cu atoms penetrate into the Si substrate after annealing at high temperature. The thermal stabilities of Cu/Hf/n+-p junction diodes are enhanced by nitrogen incorporation. Nitrogen incorporated Hf (HfN, 50 nm) diffusion barriers retained the integrity of junction diodes up to 550 °C with lower leakage current densities. Multilayered amorphous-like HfN (10 nm) barriers also retained the integrity of junction diodes up to 550 °C even if the thickness is thin. No copper-hafnium and copper silicide compounds are found. Nitrogen incorporated hafnium diffusion barrier can suppress the formation of copper-hafnium compounds and copper penetration, and thus improve the thermal stability of barrier layer. Diffusion resistance of nitrogen-incorporated Hf barrier is more effective. In all characterization techniques, nitrogen in the film, inducing the microstructure variation appears to play an important role in thermal stability and resistance against Cu diffusion. Amorphousization effects of nitrogen variation are believed to be capable of lengthening grain structures to alleviate Cu diffusion effectively. In addition, a thin multilayered amorphous-like HfN film not only has lengthening grain structures to alleviate Cu diffusion, but block and discontinue fast diffusion paths as well. Hence, a thin multilayered amorphous-like HfN/HfN barrier shows the

excellent barrier property to suppress the formation of high resistance η'-(Cu,Si) compound phase to 700 °C.