Barrier capability of Hf-N films with various nitrogen concentrations against copper diffusion in Cu/Hf-N/n+-p junction diodes

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Abstract

Hafnium-based (Hf-N) films were prepared by reactive radio frequency (rf)-magnetron sputtering on blank silicon wafers. Nitrogen incorporation and phase transformation of hafnium-based thin film were analyzed by cross-sectional transmission electron microscopy, X-ray diffraction, and X-ray photoelectron spectroscopy. The as-deposited Hf film has a hexagonal close-packed structure and a low resistivity of 48.29 μΩ cm. With increasing nitrogen concentration of Hf-N film, phase transformations are identified as α-Hf → HfN0.4 → ε-Hf3N2 → fcc-HfN. The thermal stability of the Cu/Hf-N/Si contact system is evaluated by thermal stressing at various annealing temperatures. For the Cu/Hf/Si contact system, the interfacial reaction between the Hf barrier layer and the Cu layer is observed after annealing at 550°C for 30 min, and copper-hafnium compounds form. Highly resistive copper silicide forms after annealing at 600°C for 30 min. 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. However, no copper-hafnium and copper silicide compounds are found for the Cu/HfN0.47 /Si contact system even after annealing at 650°C for 30 min. A hafnium diffusion barrier incorporated with nitrogen can suppress the formation of copper-hafnium compounds and copper penetration, and thus enhance the thermal stability of the barrier layer.