Effect of Nitrogen Plasma Treatments on Tantalum Diffusion Barriers in Copper Metallization

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Abstract

In this study, the harrier properties of ultrathin Ta, TaN, and nitrogen plasma-treated Ta films were investigated by Cu/Ta(N)/Si structure. The barrier properties were evaluated by sheet resistance, film stress. X-ray diffraction, transmission electron microscopy, scanning electron microscopy, atomic force microscopy, and X-ray photoelectron spectroscopy. Nitrogen plasma-treated Ta films possess better barrier performance than sputtered Ta and TaN films. The sheet resistance of Cu/Ta/Si and Cu/TaN/Si increases, apparently, after annealing at 600 and 625°C, respectively. The Cu/30 min plasma-treated Ta/Si is fairly stable up to annealing at 700°C for I h. Diffusion resistance of the plasma-treated Ta barrier is more effective. It is believed that a new amorphous layer forms on the surface of Ta film after plasma treatment. The new amorphous layer possesses some nanocrystalline Ta2N phases with lattice constant 0.305 nm. It is believed that the amorphous layer containing some nanocrystals can alleviate Cu diffusion into the Si substrate and, hence, improve barrier performance.