Formation of a MnSixOy barrier with Cu–Mn alloy film deposited using PEALD

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With the scaling down of ultra large integrated circuits (ULSI) to the sub-50 nm technology node, the need for an ultra-thin, continuous and conformal diffusion barrier and Cu seed layer is increasing. However, diffusion barrier and Cu seed layer formation with a physical vapor deposition (PVD) method has become difficult as the technology node is reduced to 30 nm and beyond. Recent work on self-forming barrier processes using PVD Cu alloys have attracted great attention due to the capability of conformal ultra-thin barrier formation using a simple technique. However, as in the case of the conventional barrier and Cu seed layer, PVD of the Cu alloy seed layer will eventually encounter the difficulty in conformal deposition in narrow line trenches and via holes. Atomic layer deposition (ALD) has been known for its good step coverage and precise thickness control, and is a candidate technique for the formation of a thin conformal barrier layer and Cu seed layer. Conformal Cu-Mn seed layers were deposited by plasma enhanced atomic layer deposition (PEALD) at low temperature (120 °C), and the Mn content in the Cu-Mn alloys were controlled from 0 to approximately 10 atomic percent with various Mn precursor feeding times. Resistivity of the Cu-Mn alloy films decreased by annealing due to out-diffusion of Mn atoms. Out-diffused Mn atoms were segregated to the surface of the film and interface between a Cu-Mn alloy and SiO₂, resulting in self-formed MnOₓ and MnSixOy, respectively. No inter-diffusion was observed between Cu and SiO₂ after annealing at 500°C for 12 h, indicating an excellent diffusion barrier property of the MnSixOy. The adhesion between Cu and SiO₂ was enhanced by the formation of MnSixOy. Continuous and conductive Cu-Mn seed layers were deposited with PEALD into 32 nm SiO₂ trench, enabling a low temperature process, and the trench was perfectly filled using electrochemical plating (ECD) under conventional conditions. Thus, it is the resultant self-forming barrier process with PEALD Cu-Mn alloy film as a seed layer for plating Cu that has further potential to meet the requirement of the smaller than 30 nm node.