THERMAL AND ELECTRICAL STABILITY OF METAL/POROUS LOW-*K* DIELECTRIC INTERFACES

by

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ABSTRACT

This research work is to study the thermal and electrical stability of metal/porous low-*k* dielectric interfaces, which is key to understanding the reliability of the multilevel interconnect structures in gigascale integrated circuits. Under thermal or bias-temperature stress, there could be metal species penetrating into dielectrics from their interfaces, seriously degrading the dielectric insulating property. The present research is to explore the mechanisms of interface failures that can contribute to the generation of different metal species, including metal atoms and ions. Metal transport behaviors inside dielectrics are investigated as well. The learning from this research will be beneficial for a better understanding of metal-induced dielectric breakdown, and can further be applied to the study of the reliability of metal-oxide-semiconductor field-effect transistor and memristor devices.

Interfaces of Ta/porous low-*k* dielectrics and Cu/porous low-*k* dielectrics are the primary focus because they are major structures in the current Cu dual-damascene structure. Many controversial issues have been raised about their interface stability. Ta was widely proposed to be a diffusion barrier on dielectric surfaces and perceived to have stable interfaces with dielectrics. However, in this thesis work, using both electrical methods including Capacitance-Voltage and leakage current measurements and chemical measurement techniques such as Secondary Ion Mass Spectrometry, Ta ions are detected inside porous low-*k* dielectrics after thermal and electrical stress. In contrast, Cu contamination inside low-*k* dielectrics is identified to be mainly neutral atoms, instead of Cu ions that were generally assumed to penetrate into dielectrics under stressing. In addition, Cu atom diffusion is found to occur even during Cu deposition process. The mechanisms of metal atom release and ion generation from interfaces are proposed to associate with the metallic bonding within metal matrices and the quality of interface oxides, respectively. At the end, a new kinetics model of ion transport inside dielectrics, based upon an analytical calculation and assumptions justified by chemical measurements, is presented and verified by experimental measurements. Ta ion diffusivities in different low-*k* dielectric materials and in similar low-*k* dielectrics but with different porosities are compared for the first time.