Electrical Stability Study of Metal/Dielectric Systems

by

Ya Ou

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Examining Committee:

Toh-Ming Lu, Thesis Adviser

Hassaram Bakhru, Thesis Co-adviser

Ishwara Bhat, Member

Kim Lewis, Member

Saroj Nayak, Member

Rensselaer Polytechnic Institute
Troy, New York

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ABSTRACT

The primary focus of this research work is to study the fundamental electrical properties of the metal/dielectric system subjected to thermal and electrical stresses. Metal ions tend to drift into the dielectric under a sufficiently strong electric field at elevated temperatures. The existence of metal ions can modify the dielectric properties of the surrounding insulator. In this thesis, the metal ion penetration process, including the mechanisms of the generation of metal ions and the kinetics of the diffusion/drift process of ions into the dielectric are presented. A diffusion/drift model has been adopted to provide insight into the movement of metal ions in the dielectric matrix. The effect of trapped metal ions on the electrical properties of the dielectric is also explored.

Bias temperature stressing method combined with capacitance-voltage measurement is utilized to study the metal ion penetration process. Metals with higher oxidation tendency drift more readily into porous dielectrics, such as porous methyl silsesquioxane and porous SiCOH. Interfacial oxides, especially sub-oxides are not thermodynamically robust and therefore may break down under electric field and consequently release free metal ions to drift into the underneath dielectric materials. However, the formation of a robust and continuous thin layer of metal oxide such as stoichiometric aluminum oxide at the Al/dense SiO_2 interface has shown its ability to dramatically reduce the penetration of metal ions.

The effects of trapped metal ions on the electrical property of the dielectric are investigated by using a current-voltage ramping method. High temperature conduction mechanisms of Ta/porous SiCOH/Si structure have been found to transit from the Schottky emission regime to the Poole-Frenkel emission regime as more metal ions drift into the dielectrics. Metal ions in the dielectric act as electron traps that consequently enhance the transport of electrons through the dielectric under external electric field.