Nanoindentation for advanced microelectronic interconnects mechanical characterization

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There have been sudden changes in the materials used as microelectronic interconnects, as aluminum interconnects have been pushed to their dimensional limits due to reliability (electromigration and stress migration) problems. Copper, having higher conductivity and better electromigration properties is replacing aluminum in integrated circuits. It is also beneficial to use low dielectric constant (low-K) materials to fill the space between Cu interconnect lines in order to reduce the amount of cross talk between interconnects and place them closer to each other. Basically, the whole interconnect materials system has been changed with the introduction of Cu metallization. While most processing problems related to the new interconnect system have been overcome by Motorola and other Integrated Circuits (IC) manufacturers, interconnect reliability issues still remain. The device reliability depends on many factors including the ability of the material to withstand processing and intrinsic device stresses, the materials adhesion to its neighboring structures, requiring a thorough study to ensure the IC mechanical reliability. For the mechanical reliability four materials properties are important, namely thin film elastic modulus, yield stress, fracture toughness and adhesion. All these properties can be measured by means of nanoindentation techniques. This presentation describes nanoindentation techniques for measuring thin film mechanical properties, fracture toughness and adhesion as applied to microelectronic interconnects reliability. It is shown that Cu adhesion increases with the film thickness and the grain size due to enhanced plasticity at the crack tip, which allows preventing Chemical Mechanical Planarization (CMP) failures. In addition, mechanical failure mechanisms in porous low-K dielectrics are identified and recommendations for prevention are given.

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