Effects of Electrical, Thermal and Thermal Gradient Stress on Reliability of Metal Interconnects

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Abstract:

Electromigration in integrated circuit metallization is of considerable importance in today's microelectronics industry. This decades-old problem which passes from technology node to technology node is a major contributor to the limited lifetime of integrated circuits and the associated reduction in reliability. It can be attributed to pressure on semiconductor manufacturers to set maximum current density limits at a level that allows designers to minimize the area and parasitic capacitances in metal interconnects. The resultant high current density creates drift in metal atoms that ultimately causes the interconnects to fail. This mass transport is due to momentum transfer between conducting electrons and metal atoms. In extreme situations, electromigration causes open circuits by creating voids in interconnects or creates short circuits due to hillocks bridging two conductors operating at different voltage levels though an interconnect effectively fails before the extreme open-circuit or short-circuit conditions occur .
Large currents also cause non uniform joule heating in interconnects which produce thermal gradients on the semiconductor die. These thermal gradients induce thermomigration (TM) which enhance electromigration (EM).

A reliability model for electromigration-induced failure in metal interconnects under time-dependent stress is introduced. In contrast to existing reliability models that are based upon the assumption that stress is constant throughout the useful life of a system, this model includes provisions for the more realistic situation where both thermal stress and current stress are time-dependent. A single parameter which can be represented as a real number is used to incorporate the total effects of the stress history making this approach applicable for dynamic power/thermal management algorithms. A reliability model that incorporates the effects of thermal gradient stress in the presence of temperature and current stress is also introduced. With these models, temperature measurement accuracy requirements are developed that are necessary if power/thermal management circuits are to be successful in achieving 10% accuracy in the median time to failure (MTF) of a circuit.