Electromigration in Nano-Interconnects

Lado Filipovic and Roberto Lacerda de Orio
Institute for Microelectronics, TU Wien, Austria
filipovic@iue.tuwien.ac.at

Continued device and interconnect scaling has shown to significantly contribute to the reduced lifetime of back-end-of-line copper metallization. The primary reason for this is the growing impact of grain boundaries and surface effects on the movement of electrons and atoms in the thin film. Modeling this phenomenon is very challenging since it requires a very fine definition of all boundaries and interfaces, which behave differently to bulk copper or the copper inside a single grain. To include the effects of granularity in electromigration (EM) simulations most studies apply an effective diffusivity (D_{eff}) parameter, which combines the known bulk diffusivity (D_B) with the grain boundary diffusivity (D_{GB}) using $D_{eff} = D_B + t_{GB}/D*D_{GB}$, where t_{GB} is the thickness of the grain boundary migration channel and D is the mean grain size [1][2]. An alternative to this approach is defining the grain boundaries and material interfaces as separate materials and meshing the full structure [3][4]. This requires very fine meshes, especially to properly define points where grain boundaries and material interfaces intersect, so-called triple points. Because of the mesh size and complexity, this approach allows for small sections of an interconnect to be modeled, with few grains defined.

We provide an alternative framework which allows for a full interconnect to be modeled while taking the microstructure into consideration. The framework includes three stages: (1) Tessellation, to generate the granular structure; (2) Grid-dependent parameter assignment, which ensures a differentiation between the parameters assigned to the copper grain and those assigned to the grain boundaries and material interfaces using spatial parameter assignment [5][6][7]; and (3) Electromigration simulation in a finite element environment, including vacancy diffusion and induced stress. The EM simulation takes as input the parameter assignments from the previous step in order to calculate the vacancy diffusion and the induced hydrostatic stress. Using this method, the stress accumulation at triple points can be reproduced even with very coarse meshes. Increasing the grid spacing from 0.25nm to 1nm results in an eight-times speedup of the simulation time with only a 7.6% error introduced in the simulation.

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