564c Effects of Elastic Stress on Electromigration-Driven Void Dynamics in Metallic Thin Films

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Relaxation of thermomechanical residual stresses and electromigration-induced stresses through nucleation and evolution of voids in metallic thin-film interconnects has been a problem of major interest. This is due to interconnect reliability concerns in the microelectronics industry, as well as the intriguing fundamental nature of the dynamical problem in the area of materials microstructural evolution. By employing both atomistic and continuum methods, recent theoretical work on this problem has demonstrated the growth, morphological evolution, and surface morphological instability of voids that may lead to failure of metallic thin films driven by electromigration, stress-induced surface diffusion, and elastoplastic deformation. In this presentation, we focus on the analysis of the effects of biaxially applied elastic stress on the migration of stable voids in metallic thin films.

Our theoretical analysis is based on self-consistent numerical simulations of current-induced and stress-induced migration and morphological evolution of void surfaces in metallic thin films. The simulations account rigorously for current crowding and stress concentration effects that become particularly important in narrow metallic films, as well as surface curvature effects that are particularly strong due to the strong anisotropy of adatom diffusion on void surfaces. The mass transport problem on the void surface is solved coupled with the electrostatic and mechanical deformation problems in the conducting film that contains the morphologically evolving void. A two-dimensional (2D) implementation is followed in the xy-plane of a metallic film of finite width that extends infinitely in the x-direction; this 2D representation is based on the assumption that the void extends throughout the film thickness (in z), which is consistent with experimental observations.

Contrary to the common belief that the effects of elastic stress are generally catastrophic on the stability of void surface morphology, we demonstrate that under certain surface diffusion anisotropy, plane-strain mechanical loading, and electromigration conditions, there is an applied stress range that stabilizes the void morphological response, which would be unstable without the application of stress. In addition, we demonstrate, again contrary to common belief, significant effects on the electromigration-induced stable void migration of mechanical stress application in a metallic thin film. Specifically, we find that under certain electromechanical conditions, elastic stress can cause substantial retardation of void motion, as measured by the constant speed of electromigration-induced translation of morphologically stable voids. More importantly, this effect suggests the possibility for complete inhibition of void motion under stress. Finally, we present results of linear stability analysis of void morphological evolution under the combined driving forces of capillarity, elastic stress, and electromigration and use them to discuss the findings of our numerical simulations.