Effectiveness of Pulsed Cu ECD in Void Reduction in Feature Fills

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Electrochemical deposition (ECD) of copper is the preferred process for copper metallization in ULSI circuits. One of the process challenges is to obtain void-free deposits in sub-micron trenches and vias. Bath additives and pulsed plating are used to form void-free deposits. In this paper, we present results of our simulation studies aimed at investigating the ability of pulsed deposition to form conformal films. We present feature scale, transient simulations of ECD of copper that use a simulation domain within the diffusion boundary layer. Migration effects on ion transfer are neglected, and a diffusion mass-transfer based model is developed for the charged species. Copper deposition occurs by a charge transfer reaction described by Butler-Volmer kinetics.

We consider pulse trains that can consist of pulse cycles: 1. An on interval during which deposition takes place and the concentration of copper ion is quickly depleted within the feature. 2. An off interval during which the concentration fields relax and become more uniform. 3. A de-plating interval during which copper is dissolved from the deposited film, resulting in a high concentration of ions near the electrode surface. This sequence raises the average concentration at which plating takes place, in the entire feature, and also lowers concentration gradients within the feature, leading to more uniform deposition rates and enhancing film conformality. Certain combinations of the voltages and duration of the pulsing sequence result in void free fills and significant void size reduction in high aspect ratio features. We present results of a study of ECD into sub-micron trenches of moderate to high aspect ratios under different pulsing sequences and demonstrate the gains obtained over ECD at a constant voltage.

We also present results of the effect of pulsed ECD on film evolution in the presence of additives and demonstrate how pulsing affects additive requirements for void-free filling. The additives are modeled as a two-component system consisting of a leveler and accelerator respectively. The leveler is modeled as reacting on the electrode to form surface species, which suppresses the copper deposition rate[1]. The accelerator is modeled as having a curvature dependant reaction rate and catalyzing the copper deposition reaction[2].

The simulations are done with the ECD module of EVOLVE[3], which has 2-D, transient and steady state solvers for the governing diffusion-reaction equations, and allows inclusion of chemistry based models for the component reactions[1].

1. EVOLVE is an extensible topography simulation framework. EVOLVE 5.0i was released in June 1999. Copyright 1990-2000, Timothy S. Cale.
2. S. Soukane, S. Sen, and T. S. Cale, “Modeling of Feature Superfilling in Copper Electrochemical Deposition”, submitted.
3. T. P. Moffat, D. Wheeler, W. H. Huber and D. Josell, *Electrochemical and Solid-State Letters*, **4(4)**, pp. C26-C29, (2001).