Analytical Mass Transfer Models for the Pulse Plating of Copper into High Aspect Ratio Sub-Micron Trenches

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Electrochemical deposition of copper for interconnect wiring has been receiving much attention of late. Copper is preferred over aluminum for interconnect applications because of its superior mechanical and electrical properties.

West *et al.*[1] analyzed pulse reverse copper electrodeposition in high aspect ratio trenches and vias. They assumed linear kinetics for the copper deposition. Varadarajan *et al.*[2] analyzed the pulse plating of copper assuming nonlinear kinetics. West *et al* and Varadarajan *et al* simulated both 1D and 2D models numerically. Both the models confirm that 1D model can be used to predict the plating behavior accurately.

Existing analytical models in the literature for electrodeposition of copper are limited to steady state diffusion. Takahashi and Gross[3] presented an analytical solution for the steady state diffusion with linear reaction. Varadarajan *et al.*[2] presented similar analytical solutions for linear kinetics as a special case. However, as discussed in references 2 and 4 these steady state analytical models cannot predict the step coverage and the growth rates accurately. At best, these analytical steady state models can be used only for qualitative analysis. In this work, we present analytical solutions for 1D transient diffusion-reaction models, which were simulated numerically in the literature.

The dimensionless equations presented by Varadarajan *et al.*[2] are used in our analysis under the assumption that linear kinetics is valid.

$$\tau \frac{\partial C}{\partial t} = \frac{\partial^2 C}{\partial y^2} - \frac{J}{W} C$$

$$C(y,0) = 1$$

$$C(0,t) = 1$$

$$\frac{\partial C}{\partial y}(H,t) = -JC(H,t)$$

$$\frac{dW}{dt} = -\frac{J}{\tau\chi} C$$

Both pseudo steady state and transient analytical solutions for this moving boundary problem will be developed and presented. A closed form solution is obtained which helps us do case studies and optimize the operating conditions for avoiding void formation during pulse plating.

The analytical solution obtained can also be extended to simulate pulse plating of copper in the presence of buffering agents.[4]

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References

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