A DEPOSITION MODELING TOOL FOR ELECTROCHEMISTS

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Copper films formed by electrochemical deposition have found wide use in on-chip interconnects. The uniformity of a plated film and its thickness evolution over time can be examined using computational modeling of the current flow in the electrolyte, seed layer, and barrier layer. Such models have been described previously [1-4], and have been implemented in general-purpose computational fluid dynamics (CFD) software packages [2-4]. Unfortunately, commercial CFD packages are very expensive and require extensive training to use. To take advantage of these tools, the electrochemist must work closely with a CFD expert to create, run and finally analyze a set of models. While such an approach can be very fruitful, and we have used it extensively at Novellus, there is also a need for the electrochemist to have a simple, yet physically accurate tool for modeling these cells. In this paper, we describe the development of such a tool and contrast it to the capabilities of the CFD approach.

Like earlier models [1-4], the current flow is modeled in the electroplating system by solving for the electric potential in the bath and seed, under the approximation that the bath is well mixed. The polarization resistance at the seed-bath interface is computed from an experimentally derived Tafel plot. Since many bath chemistries do not follow Butler-Volmer kinetics, this ability to handle arbitrary chemistries provides greater flexibility than some other implementations. To eliminate the need to re-mesh during the run, the growth of the deposited film is accomplished by maintaining a fixed seed thickness and increasing the effective conductivity of the film. In this way the potential field is accurately computed while minimizing model complexity. The model has been validated against experimental data as well as a more comprehensive model implemented in CFD-ACE [4].

Once the model has been created, the electrochemist can alter it, by changing values in a small text file. All aspects of the model are accessible through this file, although the user would be most interested in changing the geometric parameters, the bath chemistry (through the conductivity and polarization curve), the anode current and run time. Unlike conventional CFD packages where mesh generation can take hours or days, this model has an automeshing capability. Thus once the text file has been edited, all the user must do is push the run button, and the code creates the mesh (Figure 1) and begins computing the solution. With this model, 1μm thick films can typically be deposited in less than one hour on a 500 MHz Pentium III PC. This enables several configurations to be run per day. Additionally, a batch capability allows good use of computer resources overnight. Plots of interest, and Excel-compatible data files are generated automatically. An example output, for the potential field, is shown in Figure 2 (Geometry from Ref [4]).

The more complex CFD models are better suited to research work, as more detailed geometries can be modeled, and 3D models are more easily created. Additionally, the general-purpose CFD approach lends itself nicely to tertiary current models, where solutions for turbulent flow and diffusion would be added to the electrical current flow model, to predict rates in cases where the bath is not well-mixed. However, for quickly trying a variety of anode currents or conducting a parametric study of bath conductivity vs. film uniformity, the simplified model has the advantage of putting a simple, accurate tool in the hands of the electrochemist.

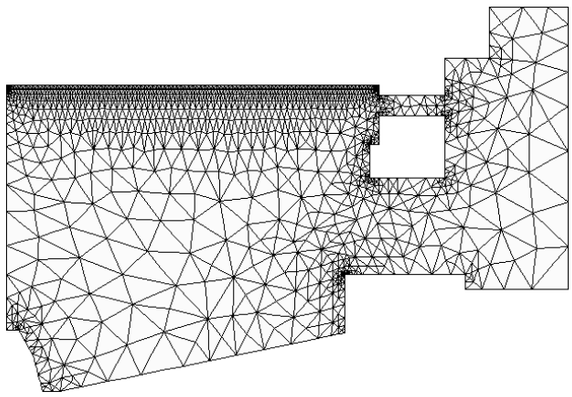

Figure 1. Example of computational mesh.

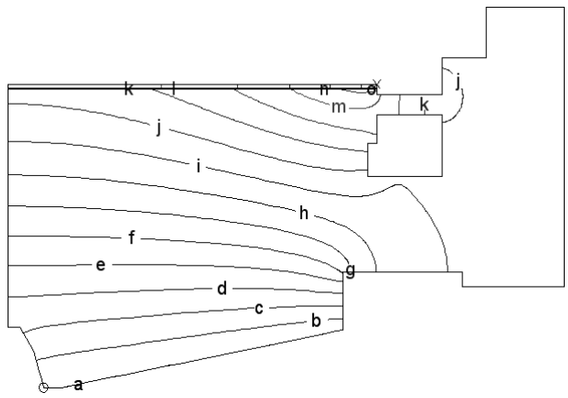

Figure 2. Output plots are generated automatically.

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