FEATURE-SCALE MODELING FOR CHIP-SCALE MODELS OF COPPER ELECTROCHEMICAL DEPOSITION

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Electrochemical deposition (ECD) is an important technique for the deposition of copper in the fabrication of interconnects for ultra large-scale integrated devices. In this process, bath additives are widely used to produce bottom-up filling, and pattern density effects can influence the shape and size of the deposited film. Thus, these effects can have a large impact on post-ECD processing, particularly on surface planarization using chemical mechanical polishing (CMP)[1,2].

The topography of the films deposited during ECD processes, as used in the multilevel metallization steps of IC fabrication, can depend on the underlying pattern of trenches and/or vias (features) to be filled. This dependence is mainly caused by bath additives that are often used for “bottom-up” filling of trenches and vias, in addition to other desirable process and film characteristics [3-6]. The filling enhancement due to these additives can be strong enough that they can actually cause a bump in the copper deposit over the trench, in a phenomenon called “bumping” (Figure 1) [3-6]. This effect can be accentuated by neighboring features, and the pattern density can influence the shape and size of the deposited film [1].

We present feature scale simulation results for pattern density effects during ECD to provide inputs to chip-scale simulations of CMP [1,2]. We use a 2-additive, curvature-enhanced deposition model of bumping, that is based on the work of West *et al.* [3], in the ECD module of EVOLVE [7,8]. In this model, the interaction of additives such as accelerators and suppressors with the feature geometry causes superfilling or bumps over features of trenches and vias. The effect of the accelerator varies with its accumulation and depletion, which depend strongly on geometric parameters such as the local curvature. Mechanisms based on this model can allow us to predict pattern density effects on ECD with additives. Pattern density effects result in higher bumps over high-density trench arrays than on identical isolated trenches. Figure 2 show that high pattern density can also enhance the superfilling effect for larger banks of features. Over a group of five features, accelerator accumulates in the valley between the bumps that form after feature closure. At lower densities, this causes the bumps to merge somewhat with those of neighboring features (Figure 2, left cluster). At higher pattern densities, rather flat regions form (Figure 2, right cluster). This trend is observed experimentally at least qualitatively, as demonstrated by the deposits pictured in Figures 1b, c, and d.

We predict the degree of these effects as a function of trench size and spacing between trenches for chip level simulation of CMP across an entire die. Our results are used to produce model inputs for chip level simulations. These inputs are obtained from the final geometry information of the feature scale simulations. This connection of feature scale to chip scale simulations can be used to better characterize and understand post-ECD CMP processing.

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8. EVOLVE is a topography simulator developed under the direction of Timothy S. Cale. EVOLVE 5.1 was released in 06/1999. ©1991-2002 by Timothy S. Cale.

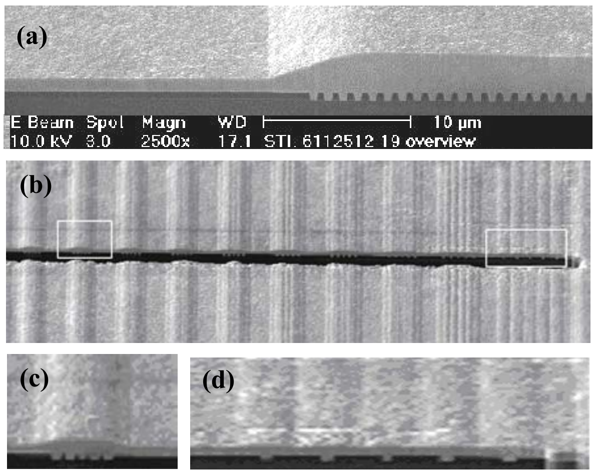

Figure 1. (Courtesy of Semitool, Inc.) (a) SEM image of ECD copper in a bank of trenches next to a flat region. (b) SEM image of multi-feature clusters; trench spacing increases toward the right. The deposit has been cut with a focused ion beam and imaged at a 45 degree angle. White boxes indicate portions of (b) that are expanded in (c) and (d). (c) Expanded image of closely spaced cluster from left side of (b). (d) Expanded image of widely spaced cluster from right side of (b).

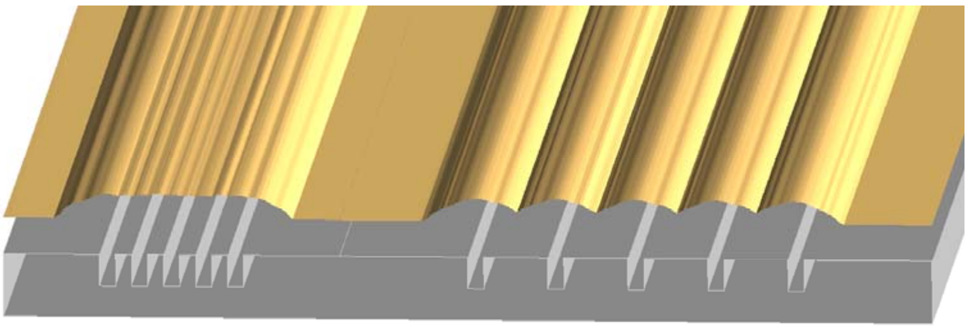

Figure 2. EVOLVE [7,8] simulation results for 2-additive deposition of copper with into identical, aspect ratio 2.0, trenches set on a pitch of (left cluster) 5.0 times the trench spacing, and (right cluster) 2.0 times the trench spacing.