Multi-Scale Modeling of Through-Mask, Electrochemical Deposition

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Modeling electrochemical deposition processes associated with selective through-mask deposition presents significant challenges, mostly due to the wide disparity in length scales that must be resolved. Wafer-scale electric field and flow field variations can lead to different plating conditions across a wafer. Similarly, the die-scale pattern of active openings in the mask can influence the local electric field and the ion concentration distribution. These wafer-scale and die-scale variations coupled with the feature geometry dictate the shape evolution of the deposit within an individual feature [1]. Hierarchic approaches [2] and functional approximations [3] have been used to reduce the computational complexity of including all of the aforementioned scales. Other researchers have assumed that the workpiece scale conditions are known in order to focus on the feature-scale [4-5]. Modeling of multi-scale through-mask plating can also be simplified by assuming two-dimensional axisymmetric geometries [6]. For example, Figure 1 shows predicted radial variations in the normalized mass-transfer limited current density for different active-area density patterns.

This paper builds on the multi-scale modeling of Ref. 5 to include tertiary current distribution models of three-dimensional patterned wafers [7]. These models study the current density variations caused by electrolyte flow, wafer rotation, die pattern, open area distribution, and feature dimensions. Figure 2 depicts the mass-transfer-limited current density across a sample die that is centered on a rotating wafer. The die pattern has a 25% open-area density and 125μm square features with no feature depth. The mass-transfer-limited, secondary, and tertiary current densities in each feature of the die pattern is plotted in Fig. 3. These models are restricted to small diameter substrates (i.e., multiple die) to control the computational cost. Predictions from detailed three-dimensional models will be used to develop simpler analysis tools for cell design.

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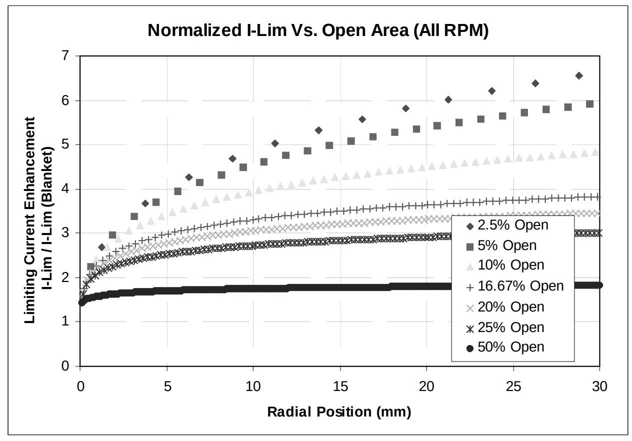

Figure 1. Axisymmetric modeling of the mass-transfer-limiting current for various active-area patterns

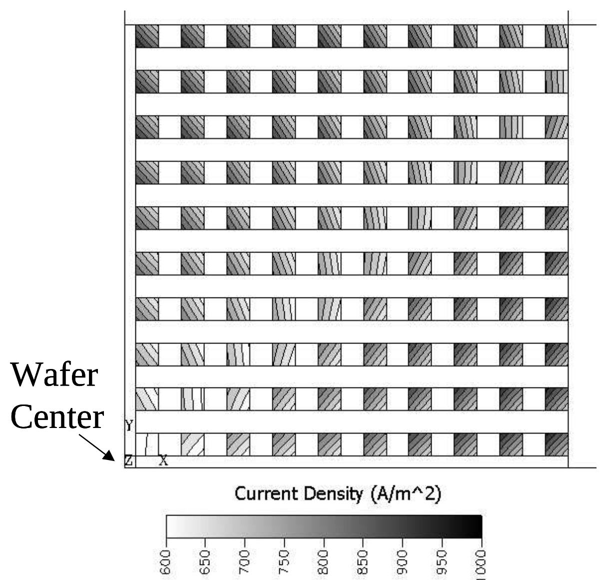

Figure 2. Predicted mass-transfer-limiting current density on one quadrant of a die placed at the center of a wafer rotating at 20rpm (20x20 array of 125μm square via openings).

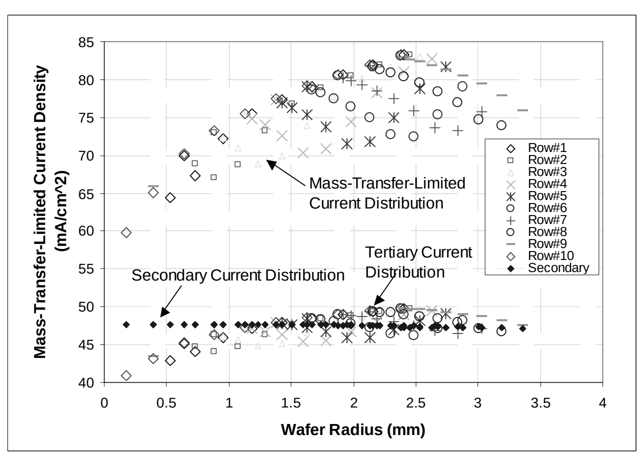

Figure 3. Predicted mass-transfer-limit, secondary, and tertiary, current-density distributions from each feature on the 25% active area density pattern of Fig. 2.