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Tertiary Current Distributions on the Wafer in a Plating Cell

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Introduction: The reciprocating paddle cell is a known practical method for depositing alloy films on wafer substrates. Recently, the mass transfer boundary layer within an industrial wafer plating cell was studied based on the measurement of limiting current [1]. In this work, we coupled the calculations of fluid flows and current distributions. The tertiary current distributions on the wafer were presented.

Computational Methods: The model geometry used in this work is shown in Fig. 1.

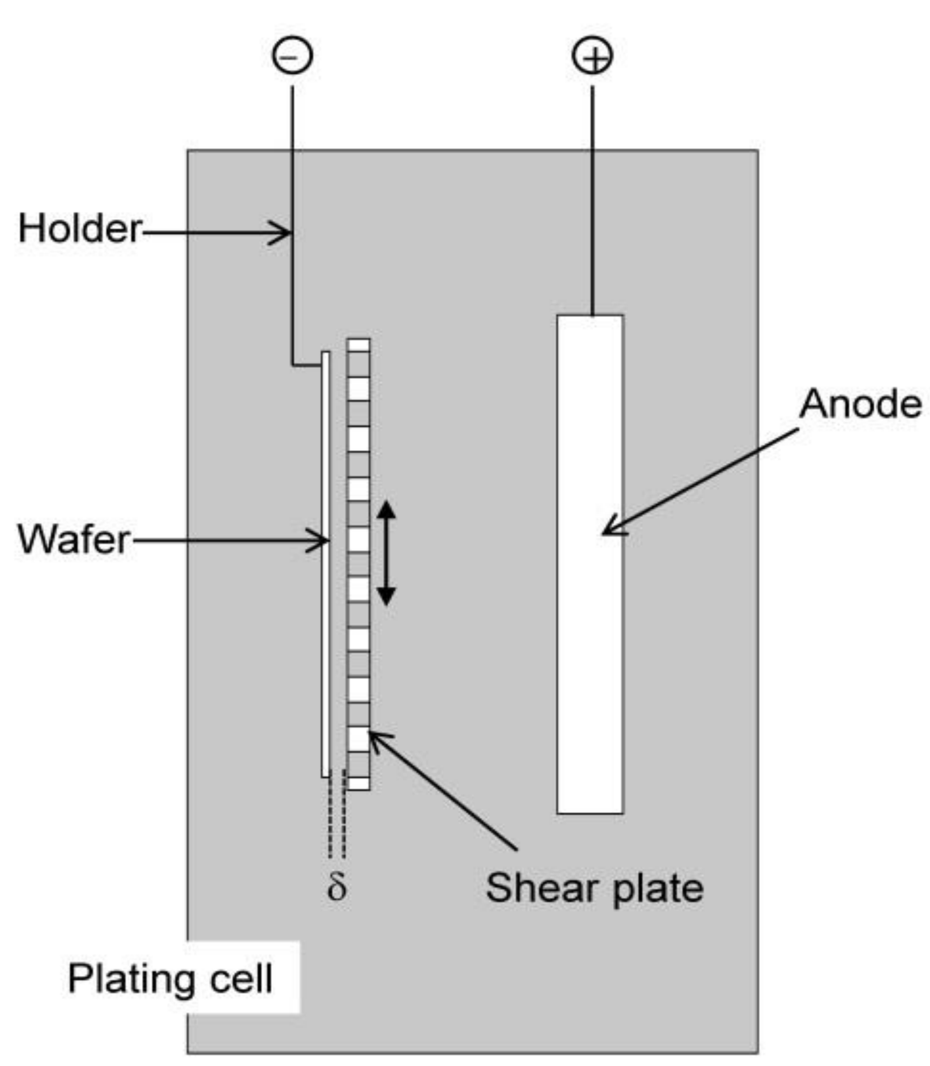

Figure 1. Schematic of the plating cell with shear-plate fluid agitation

The laminar flows are taken into account by

Continuity equation

$$\nabla \cdot (\rho \mathbf{u}) = 0, \tag{1}$$

Momentum equation

$$\rho \frac{\partial \mathbf{u}}{\partial t} + \rho \mathbf{u} \cdot \nabla \mathbf{u} = -\nabla p + \nabla \cdot \left(\mu\left(\nabla \mathbf{u} + (\nabla \mathbf{u})^T\right) - \frac{2}{3}\mu(\nabla \cdot \mathbf{u})\mathbf{I} \right) + \mathbf{F}. \tag{2}$$

The material balance equation for the species *i* in the electrolyte is calculated by

$$\frac{\partial c_i}{\partial t} + \nabla \cdot \left(-D_i \nabla c_i - z_i u_{m,i} F c_i \nabla \phi_l + c_i \mathbf{u}\right) = R_{i,tot}. \tag{3}$$

The current density $\mathbf{i}_l$ in the electrolyte is

$$\mathbf{i}_l = F \sum_{i=1}^{n} z_i \left(-D_i \nabla c_i - z_i u_{m,i} F c_i \nabla \phi_l\right). \tag{4}$$

The local current density on the electrode is related to the local overvoltage, η on the electrode, which is approximated by a linear expression from the Butler-Volmer equation at low current density [1,2]

$$\eta = \frac{i}{i_0} \frac{RT}{(\partial_a + \partial_c)2F}, \quad \text{in which} \quad i_0 = \left(\frac{c_w}{c_b}\right)^{\gamma} i_0(c_b).$$

Results: The simulation results include the velocity and pressure of fluid flows, ion concentration, potential, and current density at the different phases of the reciprocating cycle.

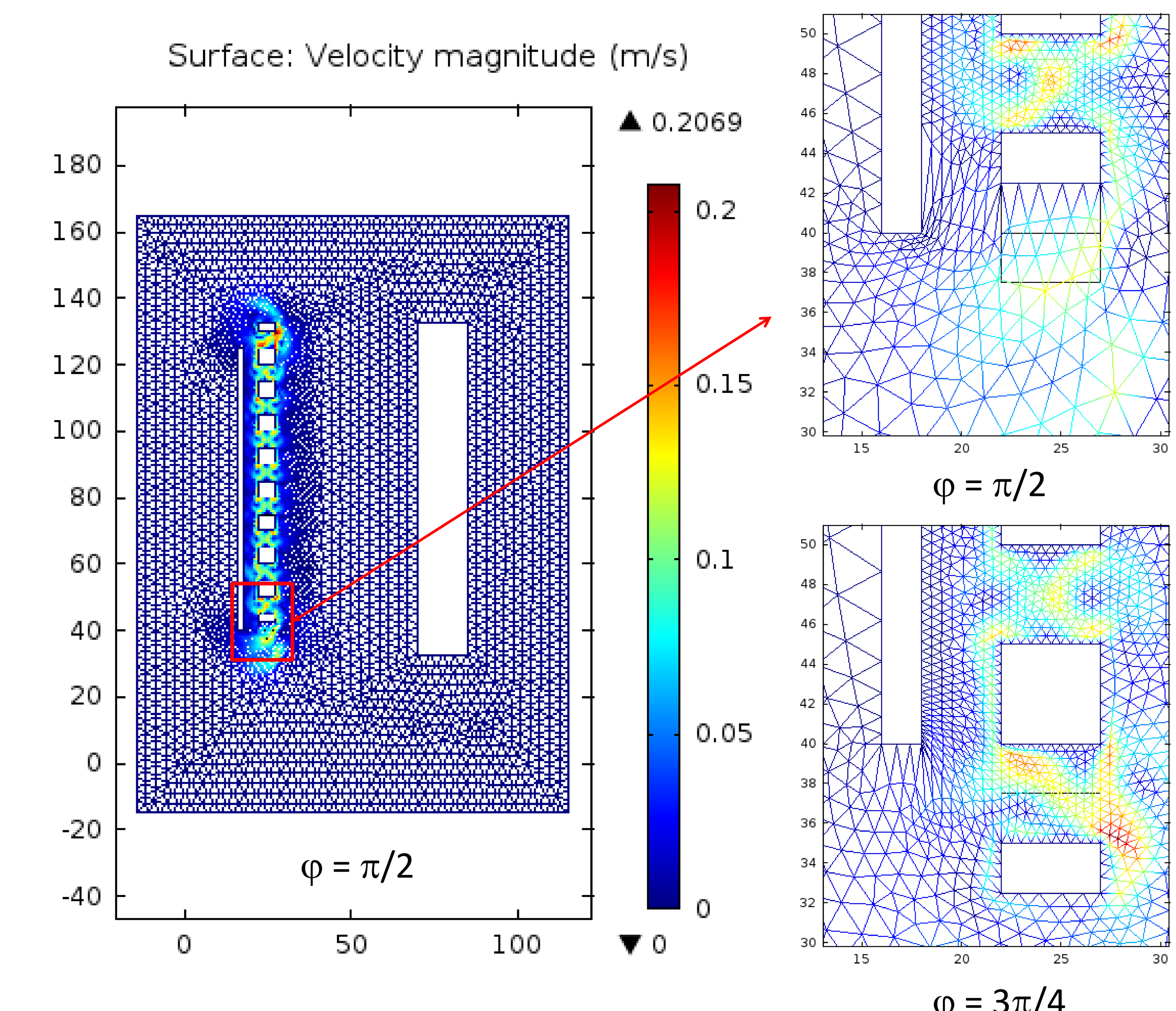

Figure 2. Flow velocity for δ = 4 mm

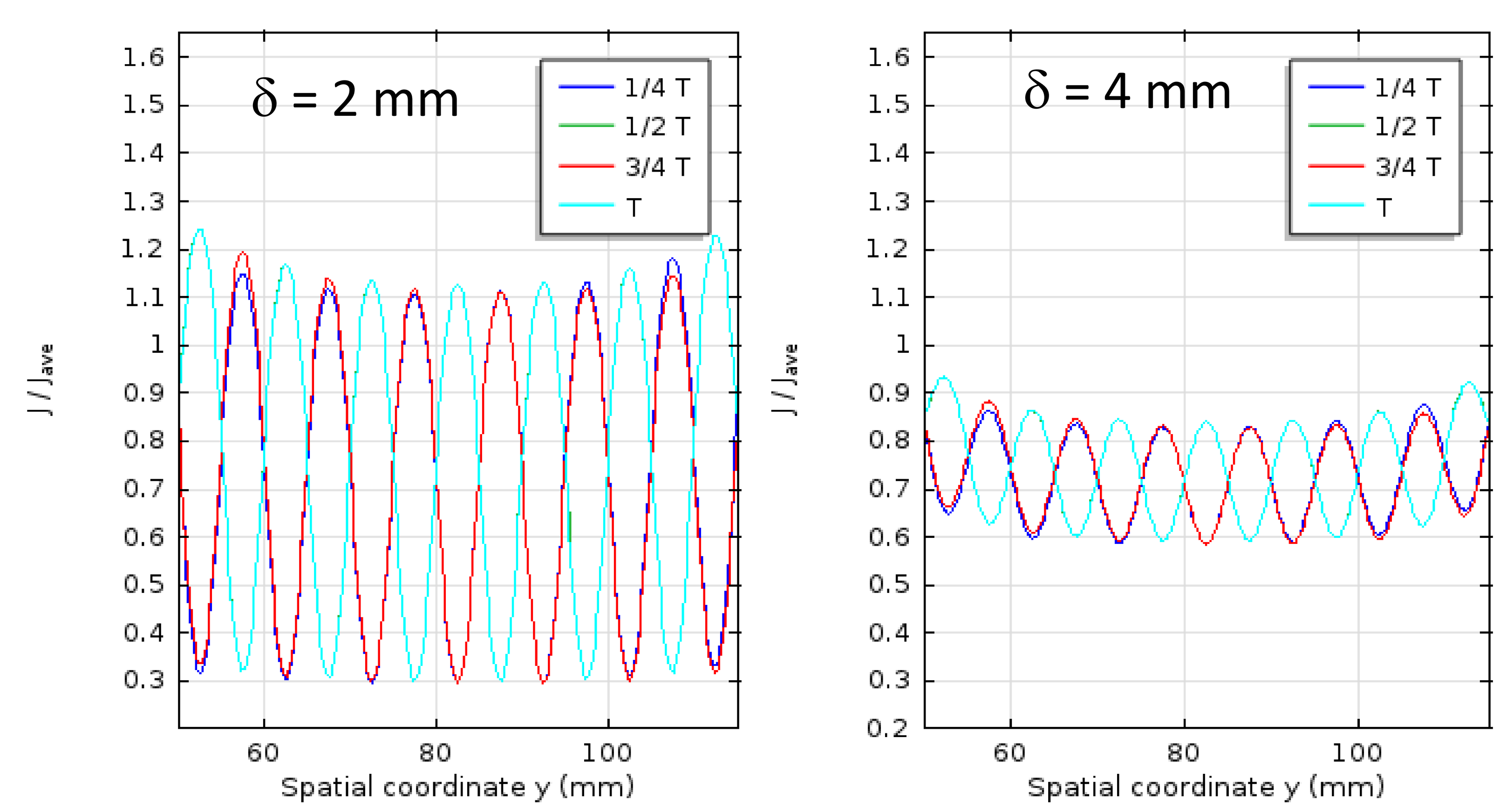

Figure 3. Tertiary current distributions on the wafer

Conclusions: This paper presented the study of tertiary current distributions on the wafer in an industrial plating cell. The coupled solution of fluid equations and mass-transport equations were realized. The calculations were performed for the different distances between the wafer and shear plate, which are beneficial to control the current distributions on the wafer so as to further improve the quality of the deposited film.

References:

1. B.Q. Wu, Z. Liu, A. Keigler, J. Harrell, "Diffusion boundary layer studies in an industrial wafer plating cell", *J. Electrochem. Soc.* **152** (5), C272-C276 (2005)
2. J.S. Newman, K.E. Thomas-Alyea, *Electrochemical systems*, 3rd ed., John Wiley & Sons, Hoboken, NJ (2004)