Contact Resistance in Copper Plating of Wafers – Analysis and Design Criteria

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A critical issue in copper metallization of semi-conductor wafers is the adequacy of the electrical contacts feeding the plating current to the wafer. If the contact is too resistive and even a minute region on the terminal is exposed, copper dissolution from regions on the wafer adjacent to the contact occurs. In extreme cases, copper dissolution propagates radially towards the center, exposing a bare, ring-shaped region (Fig. 1). This phenomenon has received only limited discussion in the literature[1]. We provide here a critical analysis, including modeling, experimental results and design guidelines.

The source for the dissolution phenomenon is a *bipolar effect:* a relatively large voltage drop across the contact may reverse the overpotential over portion of the wafer causing an anodic shunt current to flow to the exposed portion of the contact. This requires a contact resistance that exceeds an induction threshold and an exposed region on the terminal. Thin copper seed aggravates the effect by dissolving, exposing a propagating resistive region. The contact material, its shape, size and contact pressures are also critical.

First order analysis that neglects the distributive nature of the substrate and the electrolyte resistances leads to an approximation for the shunt current:

$$I_{shunt} \approx \frac{I_{total}/N}{1 + R_{soln}/R_{wafer}}$$

I_{total} is the plating current distributed over N contacts, R_{soln} and R_{wafer} are the lumped resistances of the solution (including reaction kinetics) and of the wafer (contact + seed), respectively. To minimize the shunt current, R_{soln} should be maximized, e.g., by using a less acidic electrolyte, as discussed by Landau et.al.[2] Also, a lower R_{wafer}, a lower current distributed among a larger number of contacts, and a smaller exposed region further away from the contact reduce the shunt current. The approximate nature of the derivation does not account for the threshold contact resistance below which the shunt current is not observed.

CELL-DESIGN[3], a commercial computer-based modeling software that accounts for the distributive nature of the resistances provides a rigorous analysis, indicating the effect of the contact resistance on the current distribution (uniformity and bi-polarity) for a given wafer, contact configuration and plating conditions. Fig. 2 depicts a simulated cell and contact configuration, displaying equi-potential lines. Fig. 3 depicts the corresponding current distributions for three values of contact resistance: 0.25 ohms shows clear evidence of bi-polarity, 0.09 ohms is the threshold, and at 0.01 ohms the bi-polar effect is no longer present.

References:

1. J. Jorne, Abstract No. 728, 196th Meeting of the Electrochem. Soc., Hawaii, Oct. 17-22, 1999.
2. U. Landau, J. D'Urso, A. Lipin, Y. Dordi, A. Malik, M. Chen and P. Hey, Abstract No 263, 195th Meeting of the Electrochem. Soc., Seattle, WA. May 2-6, 1999.
3. "Cell-Design", CAD Software for Electrochemical Systems, L-Chem, Inc., Beachwood, OH 44122

Fig. 1: A 300 mm wafer that has been plated through resistive contacts. The copper seed has been completely stripped off the ring region (dark), and plated only onto the (lighter) region at the center.

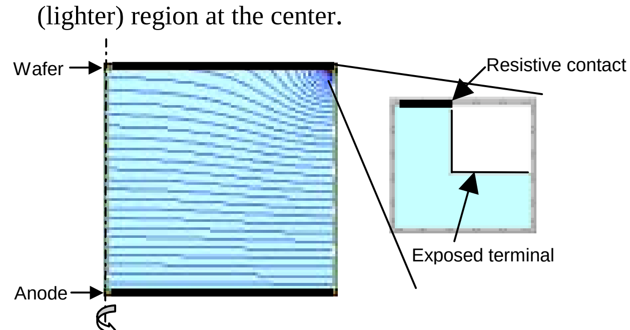

Fig. 2: Computer simulation (CELL-DESIGN©) of copper deposition on a wafer (top) through a resistive (0.25 ohm) contact. Axi-symmetric cross-section is shown with center of the wafer on the left and the resistive contact at the wafer circumference (top right). Inset shows contact details. Equi-potential lines, 14 mV apart are shown.

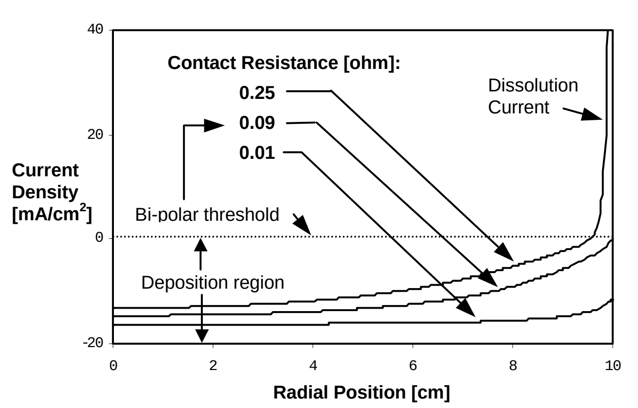

Fig. 3: Current distributions across a wafer plated through a resistive contact (Fig. 2). Dissolution near the edge is evident for the 0.25 ohm contact resistance. The bi-polarity threshold is 0.09 ohms. The effect of contact resistance on the deposit uniformity is noted.