**Unintended Catalysis and Defect Formation in Electroless Metallization of Semiconductor Wafers**

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**Abstract**

Additive metallization using electroless plating has emerged as a promising alternative to traditional subtractive approaches in semiconductor fabrication, offering advantages such as reduced material waste, lower process complexity, and improved environmental sustainability. However, reliability challenges—including the formation of unintended metallic nodules—continue to hinder its widespread adoption. In this study, a detailed physical failure analysis (PFA) was conducted to investigate the formation mechanism of metallic nodules observed near metal pads on electroless-plated wafers. A multi-technique analytical approach, including optical microscopy, field-emission scanning electron microscopy (FESEM), focused ion beam (FIB) cross-sectioning, and energy-dispersive X-ray spectroscopy (EDX), revealed that the nodules consist of Ni and Pd, loosely adhered to the passivation layer. Post-delayering analysis and elemental mapping identified trace metal oxide residues as potential catalytic sites for unintended metal deposition. A defect formation mechanism is proposed, involving incomplete residue removal during PVD and etching steps, oxidation of residual metal residue, and subsequent autocatalytic deposition during electroless plating. Ultrasonication was demonstrated to be effective in dislodging the nodules, suggesting a potential mitigation strategy. These findings offer valuable insights into defect prevention and process optimization in electroless metallization for advanced semiconductor applications.

**Keywords:** Electroless Metallization, Metal-Oxide Semiconductor, Failure Analysis, Advanced Characterisation