Statistical Modeling of Sub-Pad Mechanical Properties Impact on Edge Removal Modulation in Copper CMP

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Copper Chemical Mechanical Polishing (CMP) requires tight control of edge removal to ensure within-wafer planarization and downstream process stability. Among the contributors to edge non-uniformity, the mechanical compliance of the pad–sub-pad stack plays a key role in stress transmission at the wafer boundary [1] [2].

In this work, the influence of sub-pad compressibility properties on copper edge removal was investigated through controlled pressure modulation experiments on 200 mm copper blanket wafers. Three sub-pads with different mechanical properties were evaluated under identical process conditions. Edge airbag and retaining ring pressures were modulated within ±20% of nominal values. Removed copper thickness, extracted from sheet resistance measurements, was analyzed over the full wafer and within the edge region ($R > 80$ mm).

A linear statistical model including main effects and two-factor interactions was applied to the dataset. While the model showed limited predictive capability when considering the full wafer ($R^2 \approx 0.16$), a significant improvement was obtained when restricting the analysis to the edge region ($R^2 \approx 0.64$). Edge pressure and sub-pad type were statistically significant factors ($p < 0.05$), with a clear linear dependence of removal on edge pressure. A significant interaction between sub-pad compliance and edge pressure was observed, whereas retaining ring pressure showed negligible contribution within the explored range.

These results (Fig. 1 and Fig. 2) demonstrate that copper edge removal modulation is predominantly governed by sub-pad mechanical compliance and edge pressure tuning. The proposed statistical framework provides a quantitative basis for consumable selection and localized removal control in advanced metallization processes.

[1] Dipto G Thakurta, Christopher L Borst, Donald W Schwendeman, Ronald J Gutmann, William N Gill, Pad porosity, compressibility and slurry delivery effects in chemical-mechanical planarization: modeling and experiments, Thin Solid Films Volume 366, Issues 1–2, 1 May 2000, Pages 181-190.
[2] Yun-Biao Xin, Modeling of Pad-Wafer Contact Pressure Distribution in Chemical-Mechanical Polishing, Wafer Technology, MEMC Electronic Materials, Inc. St. Peters, MO 63376, USA

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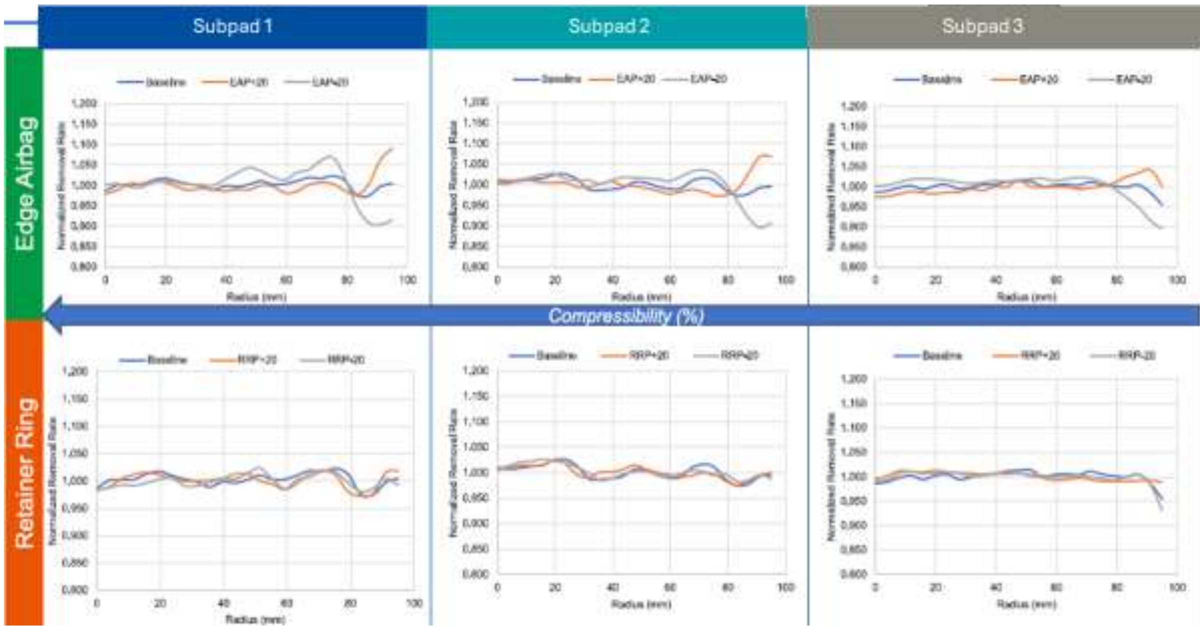
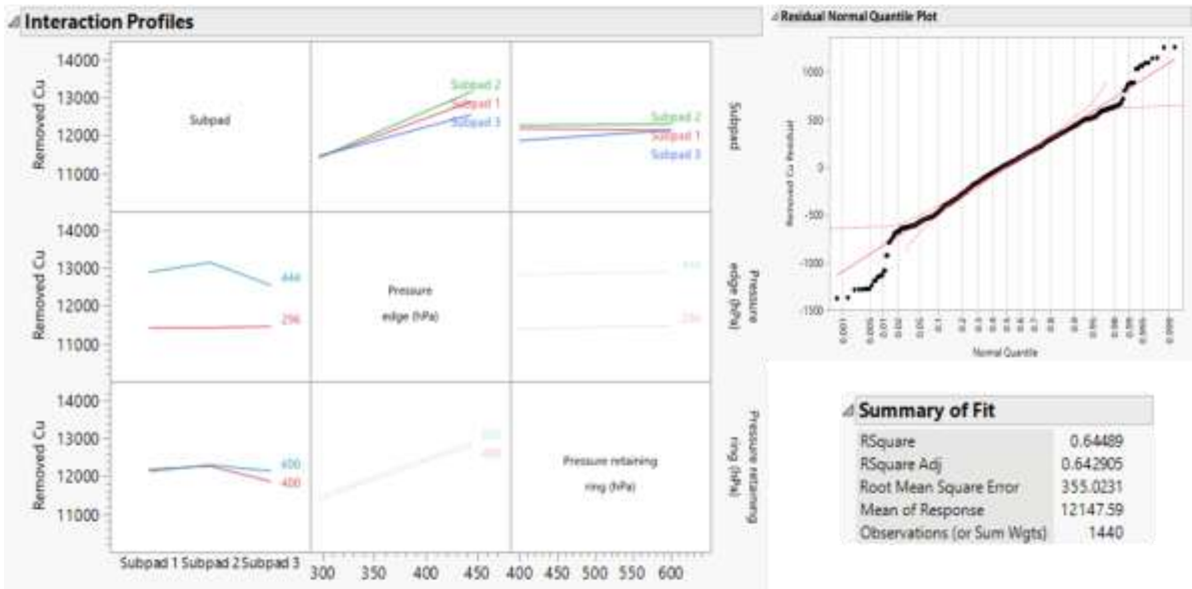


Fig. 1 – Radius Removal Results summary



Summary of Fit	
RSquare	0.64489
RSquare Adj	0.642905
Root Mean Square Error	355.0231
Mean of Response	12147.59
Observations (or Sum Wgts)	1440

Fig. 2 - Statistical Analysis: interaction profiles