Advanced Planarization Modeling

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The process of Chemical Mechanical Planarization (CMP) is well established in the semiconductor industry for planarization in front and back-end processing. In previous work, a die-level CMP model was proposed that predicts dual layer removal based on layout pattern density and step-height reduction [3]. In this work, a more efficient and accurate model for planarization of shallow-trench isolation (STI) structures is proposed, with a focus on die-scale and feature-scale uniformity in oxide CMP. This model captures the fundamental limitation of CMP, pattern dependency, and its evolution to more accurately model and physically represent STI structures of product size range over time as shown in Figure 1. We model, for the first time, the evolution of pattern density as a function of time and step-height, and use layout biasing (β) to account for deposition profile evolution for the accurate prediction of die and feature-scale CMP. Additionally, we explore the use of this new model with a non-traditional slurry, cerium oxide, and novel layout techniques.

Electrochemical mechanical polishing (ECMP) is an emerging technology in semiconductor processes, used for Cu interconnecting layer planarization. Our group previously proposed a non-ohmic ECMP model to understand the exponential dependence of current on overpotential at the electrode/electrolyte interface and to calculate the Cu removal rate [2]. Based on electrochemical theory and process physics, the model has been improved and extended to 3D, thereby accounting for lateral voltage/current distribution and Cu-layer resistance change during the process. The calculation is simplified by using equivalent circuit elements to simulate the electrochemical reaction. Data from pad voltage zone experiments is fitted well by the model. Figure 2 shows Cu removal amounts due to each voltage zone. The RMS error of this fitting is 31.3nm.

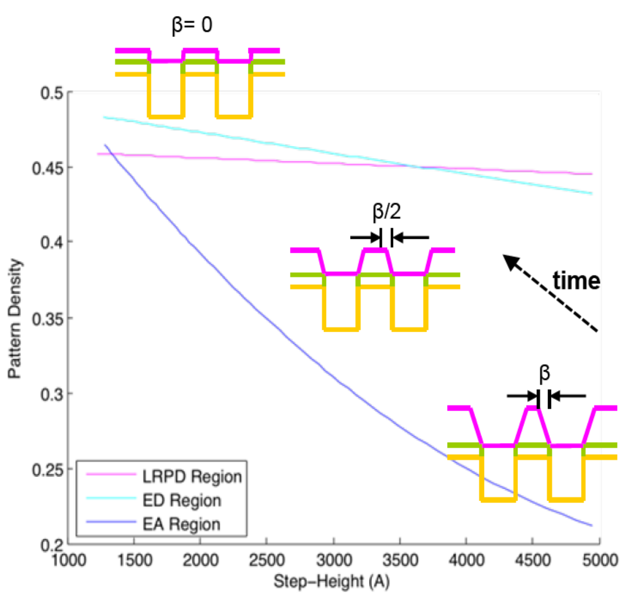

Figure 1: Comparison of pattern density range versus step-height (Å) for three different feature sizes: (Long Range Pattern Density) LRPD Region (70-100 µm), (Erosion/Dishing) ED Region (30-60 µm), (Edge Acceleration) EA Region (1-10 µm). The insets show evolution of step height and density with polishing time.

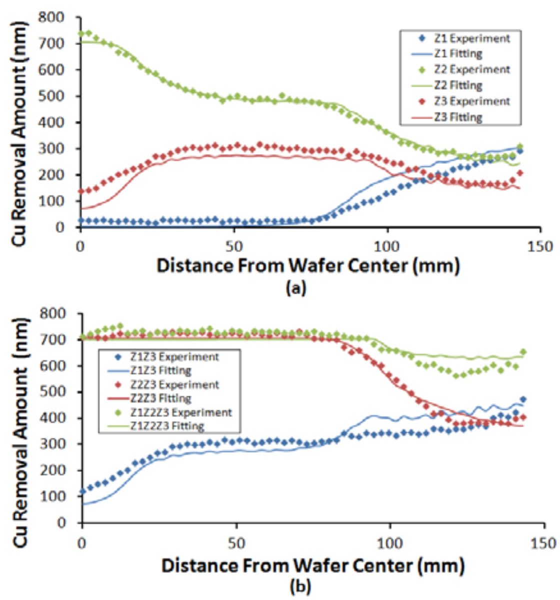

Figure 2: Cu removal amount for 1 minute ECMP. (a) 3V applied in single voltage zone on the pad. (b) 3V applied in multiple voltage zones on the pad.

References

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[3] X.Xie, "Physical Understanding and Modeling of Chemical Mechanical Planarization in Dielectric Materials," Doctoral dissertation, Massachusetts Institute of Technology, Cambridge, 2007.