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CMP OPTIMIZATION AND CONTROL THROUGH REAL-TIME ANALYSIS OF PROCESS EFFLUENTS

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Optimization of CMP processes has previously been carried out using test or monitor wafers with off-line analysis of wafer surfaces for defects and quality coupled with yield and reliability data from product wafers. The effectiveness of this iterative, partly indirect optimization process is dependent on consistent, time independent CMP process conditions. However, typical CMP processes are moving targets; operating in a constant state of decay. For example, polishing stages are challenged by the continuous dilution of starting chemistry, and the decay of pad and wafer surfaces. The pad and wafers are rinsed with copious amounts of DI water between wafers, resulting in process instability and excessive water consumption. It is well recognized that microscratches are a fundamental problem for ILD and STI, resulting in yield loss (i.e., high leakage current) and reliability issues (i.e., insufficient TDDB).[1] It has also been noted that CMP debris is responsible for surface scratches.[1] Confluense has developed a pad conditioning system which transforms the utilization efficiency of CMP consumables by dramatically reducing the ‘mean residence time’ of these spent materials.[2] Conceptually simple, yet a highly sophisticated enhancement, the Pad Surface Manager (PSM) system cleans the pad surface immediately after passing under the wafer.[3] A PSM can be used to condition the pad, flush the pad, supply fresh slurry, deliver supplemental chemistries, and vacuum process and conditioning debris from the pad. Consequently, it is now possible to analyze the process effluent in real-time for a variety of parameters (i.e., pH, conductivity, ionic content, solids content, particle size distribution, slurry composition, etc.). Preliminary studies have been performed using a PSM to measure pH and conductivity of effluent versus polish time and capture particles for composition and size distribution analyses. Figure 1 contains a photograph of a PSM pad conditioner head.

Figure 1. Photograph of the pad conditioner head.

Figure 2 contains pH and conductivity data for samples of slurry (Cabot SS11) taken at 10 second intervals through a PSM during an STI polish. Note that the conductivity required nearly

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[1] K. Gotkis, “A Couple of Considerations on the Dynamics of Defectivity Generation in CMP Technology”, CMP UG Meeting (April 2007). J. G. Park, “CMP Process; Its Challenges and Future”, SPCC (March 2009). C. L. Borst, et al, “A Case Study: Topographic and Spectroscopic Analysis of Slurry Particle Retention for Cu CMP”, Levitronix CMP Users Conference (2007).

[2] A. Philipossian and A. Mitchell, “Mean Residence Time and Removal Rate Studies in ILD CMP”, Journal of The Electrochemical Society, 151, (6) G402-6407 (2004)

[3] S. J. Benner and D. Dance, “CMP Productivity Improvement Using Pad Surface Management”, ISMI Symposium on Equipment-Related Productivity Improvement Activities (March 2006).

2 minutes to return to a value near that for the reference, shown at time zero. The variation of an order of magnitude in the conductivity over this time interval indicated that there was a significant time variation in ionic content in the waste stream. The pH variation appears to be less dramatic; however, changes of several pH units could significantly alter surface potentials and passivator effectiveness, yielding altered chemical activities with a resultant variation in removal rate and film uniformity.

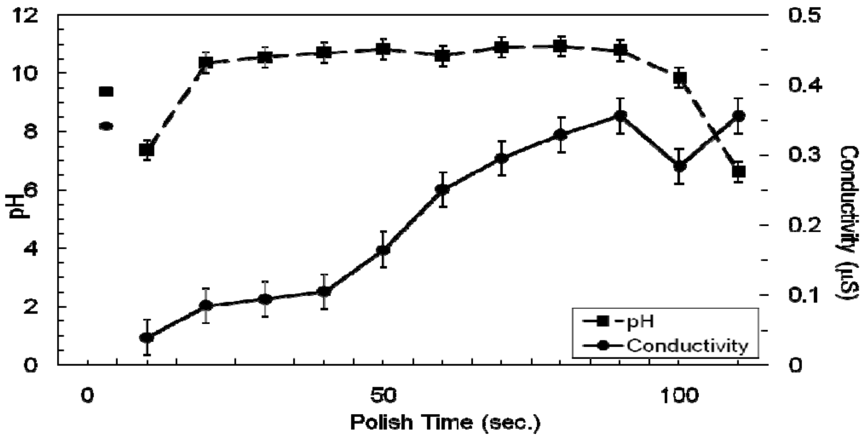

Figure 2. Analysis of pH and conductivity versus polish time. The data at zero polish time are reference points.

Figure 3 contains conductivity data over time from a Cu polish which shows the ability to endpoint the polish process by analyzing the effluent. Inflection points occurred near 200 and 300 seconds, corresponding to Cu removal and barrier removal, respectively.

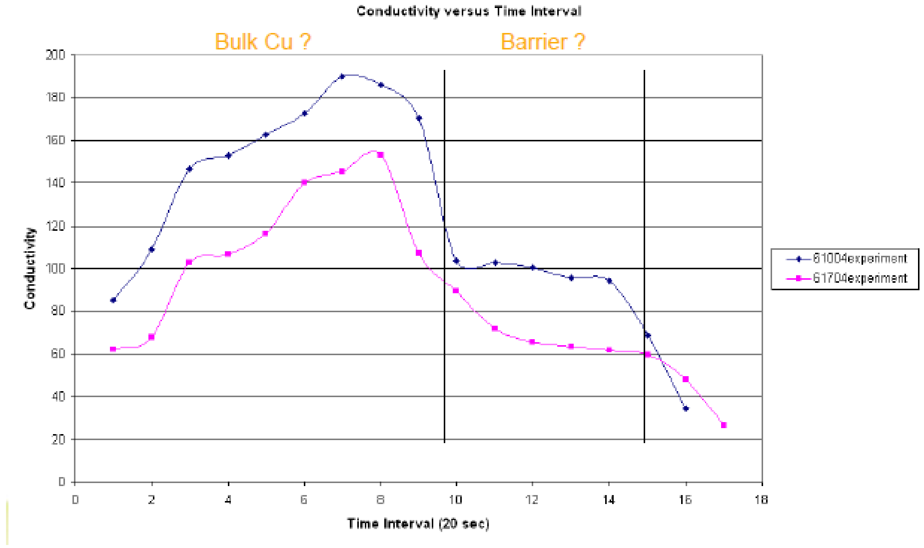

Figure 3. Conductivity data for effluent obtained during a Cu polish. The Cu endpoint is clearly seen near 200 seconds. The barrier layer endpoint is near 300 seconds.

Figure 4 contains SEM images of particles isolated from a PSM sample obtained during an oxide polish process using a urethane pad. The SEM images show slurry, agglomerates, and pad particles. The latter two can cause microscratches on ILD or STI.

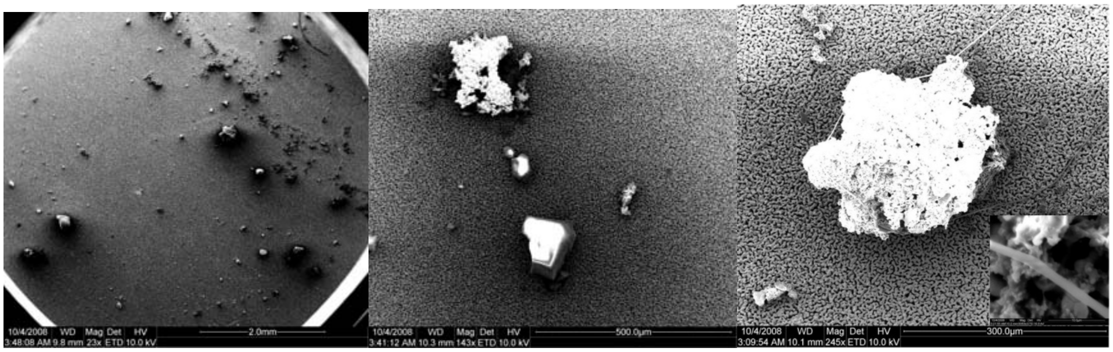

Figure 4. Various particles isolated from an effluent sample taken with a PSM during an oxide polish process on TEOS wafers. Both pad and slurry particles were observed.

Data from experiments have been reported indicating that it is possible to perform both the Cu and barrier layer polishing process on a single platen by using the PSM to flush the pad, vacuum process residues, and change the polishing chemistry.[4] Slurry carryover between the Cu and barrier polish steps for a typical process would be near 70%, potentially causing agglomeration or reduced removal rates. In these experiments, less than 10% carryover was observed, clearly showing the potential for PSM to allow use of a single platen for a Cu/barrier polishing process.[4] Furthermore, a PSM could be used to introduce Cu passivators in a single platen process to eliminate the need for a third platen for a rinse/buff step. One could easily vacuum slurry from the pad and introduce a dilute triazole solution for Cu passivation while performing a buff step.

The introduction of PSM technology offers the ability to acquire new insights into the CMP process, a reduction in cost of consumables, the ability to perform Cu and barrier layer polishing processes on a single platen, and an opportunity to implement real-time control loops for more consistent and uniform polishing results with a reduction in added defects and microscratches in particular.

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[4] C. Burkhard, J. Zhao, P. Wu, M. Fox, S. V. Babu, and Y. Li, “Wafer Characterization and Spent Slurry Evaluation with a Novel Pad Conditioner”, CMP-MIC (2004).