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In Situ Characterization of Triboelectrochemical Effects on Topography of Patterned Copper Surfaces

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The topographic response of patterned copper surfaces to chemical–mechanical polishing (CMP) was investigated using a triboelectrochemical approach. Experimental methods include using a combined system containing a tribometer and a potentiostat. Results showed that more step height reduction and lower average surface roughness were obtained via CMP in acidic than in alkaline slurry. The increased contact area between wafer, pad, and abrasives was associated with the increase in friction. It was found that pH-dependent oxide formation and removal dominate the step height reduction for both acidic and alkaline slurries. The *in situ* approach pinpointed interactions between mechanical stimulation, chemical reaction, and electrochemical passivation. This research is beneficial to understanding triboelectrochemistry in Cu chemical–mechanical polishing of patterned wafers, an important application in semiconductor manufacturing.

Key words: Copper, chemical–mechanical polishing, topographic response, triboelectrochemical analysis, patterned wafers

INTRODUCTION

Triboelectrochemistry has played important roles in manufacturing processes.[1] This has particularly been the case in chemical–mechanical polishing (CMP), an important process in fabrication of computer chips.[2] Using the triboelectrochemical approach, we found that metastable oxides of tantalum can be formed through mechanoelectrochemical stimulation.[3–5] Using the same approach, we were able to characterize the electrochemical process *in situ*.[6–8] For the scope of the research discussed in this paper, the focus is shifted toward triboelectrochemical characterization of patterned geometry during copper (Cu) CMP.

One key factor in Cu CMP is the copper oxide formation/removal mechanism. This mechanism varies depending on various parameters, such as the mechanical energy, slurry composition, and pH values. Fundamental studies of mechanoelectrochemical activation of copper surfaces have been carried out.[9,10] When it comes to pattern geometry, the mechanism would be much more complicated. Many studies on the effects of mechanical processing parameters and pattern geometry on Cu CMP have been performed.[11,12] However, these studies have only considered the electrochemical parts, which can be helpful to study slurry effects on Cu pattern CMP. Here, we propose an *in situ* technique using a triboelectrochemical approach. Experimentally, we conducted tribological experiments combined with electrochemical measurements using a potentiostat. This technique is expected to provide insight into the topographical behavior during Cu CMP. Potentiodynamic analysis combined with tribological results, such as the friction coefficient, were investigated in acidic as well as alkaline slurry, and the different slurry chemistry is also considered.

Herein, we report the effect of topographic change on tribological and electrochemical behavior. We found that the contact area between the protruding pattern and polishing pad increased with increase in the friction coefficient. Based on the various electrochemical reactions of copper in slurries of

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