Tribological Properties of Cu/Ultra Low-K Wafers

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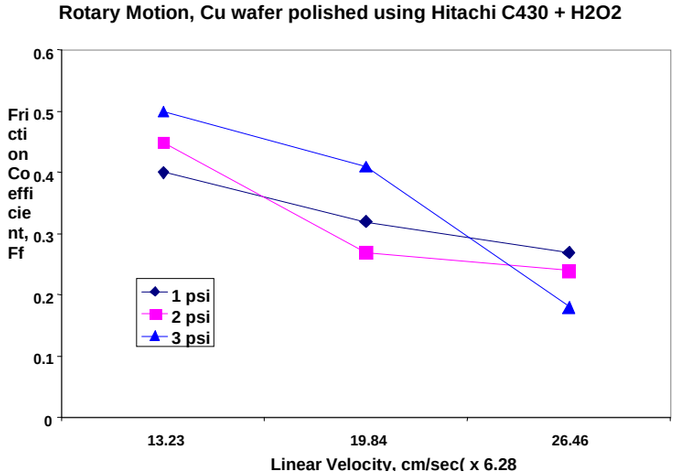
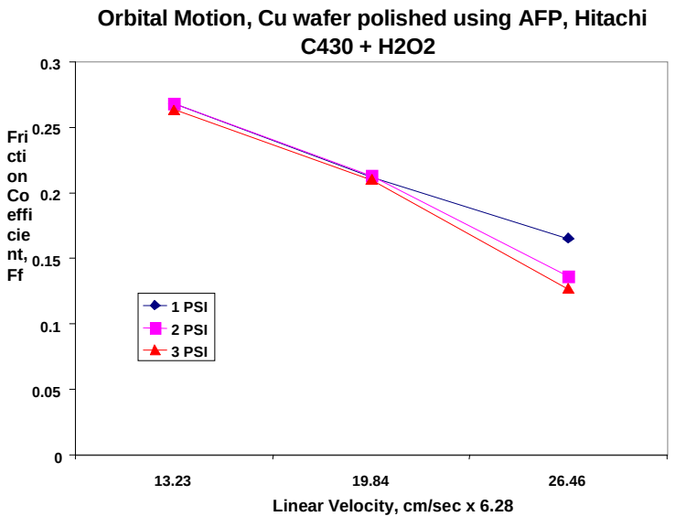
Recent advancement in integrated circuits resulted in need for higher interconnect current densities. As a result copper interconnects, a substitute for aluminum emerged due to its lower sheet resistivity. In order to reduce the RC delay, low-k dielectrics are being explored recently to replace existing oxides. The challenges in integrating low-k (k<2.5) dielectrics in Cu/low-k interconnects are impact of barrier, seed and copper process on interconnect reliability, thin film micostructure and metallization stack, copper electromigration, One of the major challenges is Copper CMP process since the underlying low-k film is porous and highly brittle.

To better understand the shear stresses on the copper/low-k films during chemical mechanical planarization (CMP), knowledge of tribological properties of the surface being polished is required. The frictional forces acting on the surface of the copper film during polishing could be severe that may cause damage to the underlying delicate low-k film.

In this study we have chosen blanket Cu, Ta, SiC, XLK (Dow Corning, k = 2.2) and stack films of Cu/Ta/XLK (k=2.2)/SiC/Oxide and SiC/XLK (k=2.2)/Oxide for tribological property evaluation. We used tribometer to study the frictional forces and dynamic friction coefficient. These wafers were polished at various down forces and different linear velocities in both abrasive free slurry and abrasive slurry. For all polishing process, 80/50 Kgrov pad was used. The tribometer used in our studies has features to generate both orbital motion and rotational motion. For rotational motion, slurry was sent on top of the pad. On the other hand for orbital motion slurry was sent through the pad directly to the wafer during polishing. This simulates the slurry distribution similar to the SpeedFam-IPEC Momentum™ CMP system. The orbital wave generator in this equipment is very similar to the wave form generator at SpeedFam-IPEC Momentum™ so that the orbital radius repeats the orbital radius of the Momentum™ CMP system. Thus we can compare the tribometer results with that of Momentum™.

Figures 1a and 1b show the dynamic frictional coefficient of Copper film in rotational motion and Orbital motion. As linear velocity increases, the frictional coefficient decreases.





The dynamic friction coefficient of Cu film in orbital polishing is less then that of the rotational polishing process at all speeds and at all down forces. This is attributed to the fluid transport and the roll of formation/removal of complex and byproduct formation during CMP process.

Momentum Copper CMP POR

Low k/Copper CMP

High Removal rate of copper at low pressures: AFP Process

Hitachi 430-1 Slurry
Polyurethane pad

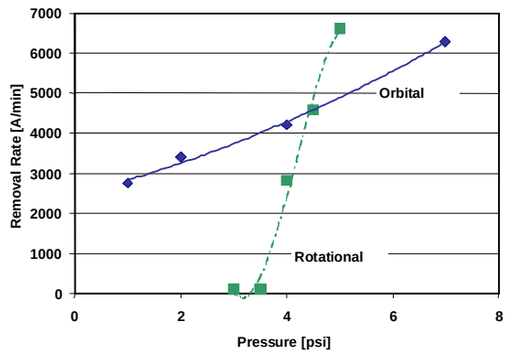


Figure 2 shows the removal rate curves and compares the orbital and rotational CMP process of copper wafer. For rotational CMP process at low down forces, less than 3 psi, there is no polishing occurs. The removal rate is very small even though it has higher frictional forces. On the other hand, the polish rate in orbital motion at low down forces is much higher than the rotational motion. However the frictional forces in orbital CMP is lower than the rotational CMP.

The friction coefficient measurement and the polish rate of Cu film on both rotational and orbital motion indicates that Orbital CMP is conducive to polish delicate Cu/low-k film. The orbital polishing at high speed with low down force has advantage over conventional rotary CMP in both removal rate and frictional forces.