Effect of Slurry Dilution and Flow Rate on Coefficient of Friction and Removal Rate for ILD CMP Applications

Ara Philipossian and Scott Olsen

University of Arizona
Department of Chemical & Environmental Engineering
Tucson, AZ 85721

Real-time coefficient of friction (COF) analysis of the pad-slurry-wafer region is used in order to determine the extent of normal and shear forces and help identify the tribological mechanism during ILD CMP process. The study explores a wide range of process and consumables parameters such as relative wafer-pad velocity, wafer pressure, slurry flow rate, abrasive content in the slurry and the groove pattern on the surface of the polishing pad. The ultimate aim of this study is to determine how COF affects the extent of pad wear as well as ILD removal rates.

Figure 1 shows COF as a function of a wide variety of operating pressures and platen velocities for a 25 percent fumed silica system. The shape of the curve indicates the tribological mechanism to be one of 'asperity contact'. A 10-fold decrease in the solids content causes a ~ 10 % increase in COF (Figure 2), without changing the tribological mechanism. This indicates that one can, in principle, study the effect of abrasive content on RR or other metrics without changing the tribological mechanism. It is interesting to note that despite of a 10% increase in COF, it is well known that RR associated with a 10-times diluted slurry is several times lower than its undiluted counterpart, thus suggesting a non-intuitive relationship between RR and COF.

Figure 3 shows the effect of slurry flow rate on COF and removal rate. Depending on the operating pressure and platen velocity, changes in slurry flow rate can significantly affect COF and the tribology of the process. Results indicate a complex relationship between COF & RR: At high Hersey Numbers, 2- and 4-fold increases in flow rate, decrease COF by approximately 25 and 50% respectively. While a 2-fold increase in flow rate does not affect RR, a 4-fold increase in flow rate changes the Preston Constant from 4.14 to 3.45 (~17 % decrease in removal rate). A 15% drop in RR is a good comprise if the 50% drop in COF can be proven to result in longer pad life. It should be noted that the observed dependence of the tribological mechanism on flow rate has not been reported in the literature. This apparent relationship points out an inherent weakness in the application of traditional Stribeck Curve theory to CMP due to the absence of a flow rate argument in the Hersey Number. Non-dimensionalization of the x-axis based on pressure, velocity, slurry viscosity, film thickness, pad and wafer RMS roughness, and pad asperity height will be required in order to fully comprehend various tribological attributes of the CMP process.

Figure 1 (Top): Stribeck curve corresponding to 10% abrasive content fumed silica slurry

Figure 2 (Center): Comparison of COF between 10% & 2.5% abrasive content fumed silica slurries

Figure 3 (Bottom): Effect of flow rate on COF and ILD removal rate (RR=100 corresponds to a Preston's constant of 4.14 Angstrom per psi per revolution over a wide range of pressures and pad rotational velocities)