Task ID: 425.032
Task Title: Fundamentals of Advanced Planarization: Pad Micro-Texture, Pad Conditioning, Slurry Flow, and Retaining Ring Geometry

Deliverable: Use dual emission UV-enhanced fluorescence (DEUVEF) technique to quantify slurry film thickness in pad-wafer interface.

I. Summary/Abstract.

This report summarizes recent study on the effect of retaining ring slot designs on the slurry film thickness within pad-wafer interface region during chemical mechanical planarization using dual emission UV-enhanced fluorescence (DEUVEF) technique. A 200-mm quartz wafer was assembled with a polyetheretherketone (PEEK) retaining ring. Two retaining rings with “Standard” and “Alternative” slot designs were tested. The slurry film thickness between wafer and pad was measured *in-situ* during at different slurry flow rates, pressures and pad-wafer rotational rates. Results showed that the slurry film thickness generally increased with the slurry flow rate, while higher polishing pressure and faster pad-wafer rotational rate generally reduced the slurry film thickness. As the “Alternative” ring had more and larger slots, the “Alternative” ring exhibited thicker slurry film by approximately 30 percent in average compared with the “Standard” ring under the same polishing condition.

II. Technical Results and Data.

All experiments were performed on a 200-mm polisher and tribometer. Two PEEK retaining rings with “Standard” and “Alternative” slot designs were tested on the Cabot Microelectronics Corporation D100 concentrically grooved polyurethane pad. Prior to data acquisition, the pad was conditioned at the pressure of 3.45 kPa for 30 minutes using DI water by a 4-inch diamond disc which rotated at 30 RPM and oscillated at 0.33 Hz. The same rotational velocity and oscillation frequency were used for *in-situ* pad conditioning during polishing.

The retaining ring was attached to a polishing head consisting of a 200-mm quartz wafer. Figure 1 shows the retaining ring-quartz wafer assembly. The retaining ring with the “Standard” slot design, as shown in Fig. 1, has 12 equidistant 3-mm wide parallelogram slanting slots on its contact surface. In comparison, the “Alternative” slot design has 36 equidistant 11-mm wide trapezoid slanting slots.

The retaining ring-quartz wafer assembly was polished at applied pressure of 1.8 and 3.6 PSI and sliding velocities of 1.0 and 1.5 m/s (i.e. 80 and 120 RPM). Both the retaining ring-quartz wafer assembly and platen rotated counterclockwise at the same rate during polishing. Slurry was injected on top of the pad center at a flow rate of 150 and 220 ml/minute. The thickness of the slurry film between the land area of the pad and wafer was measured using DEUVEF technique. During the test, UV light was projected on the interested area under the quartz wafer to excite the dyed slurry underneath, and then the emitted fluorescence was captured by the dual camera system consisting of two

Photometric Sensys cameras. Those two cameras were filtered to record the light in different bandwidth emitted by two dyes, and they were aligned orthogonally to assure each of them could capture the same projection. The emitted light captured by the two CCD cameras from the same location, but in different bandwidth, was correlated to fluid film thickness.

Figure 2 shows an example image taken during polishing. The bright color areas correspond to concentric grooves and the dark color areas correspond to pad land areas between the grooves. The slurry film thickness in the land areas was calculated from the extracted light intensity ratio. The area of interest was divided into two $1.4 \times 2.1\ \text{cm}^2$ regions where region A was near wafer edge and region B was towards the pad center as shown in Figs. 2 and 3.

Figures 4 and 5 show the measured slurry film thickness between the pad and quartz wafer for the “Standard” and “Alternative” retaining rings, respectively. The error bars in the figures indicate the standard deviation of measured slurry film thickness. Results indicate that for both retaining rings, the slurry film thickness generally decreases with an increase in the platen rotational rate. This phenomenon is related to the centrifugal force applied to the slurry. At the higher platen rotational rate, more slurry is spun off towards the outside of the pad. As a result, less slurry is available to fill the gap between the retaining ring-quartz wafer assembly and pad surface.

Figures 4 and 5 also indicate that for both retaining rings, the slurry film thickness generally decreases with an increase in the retaining ring-wafer pressure. Higher pressure squeezes out the slurry within the pad-wafer interface region, resulting in a thinner slurry film thickness. The effect of pressure on the slurry film thickness is more significant at the lower platen rotational rate (i.e. 80 RPM). Since the slurry film within the pad-wafer interface region is thicker at the lower platen rotational rate, more slurry is available to be squeezed out at the higher polishing pressure, rendering a larger decrease in the slurry film thickness.

Figures 4 and 5 also show that for both retaining rings, the slurry film thickness generally increases with an increase in the slurry flow rate. However, it must be noted that the increase of slurry film thickness is not proportional to the increase in the slurry flow rate.

Comparison between Fig. 4 and Fig. 5 shows that the “Alternative” ring achieves thicker slurry film than the “Standard” ring by an average of 30 percent. As the “Alternative” ring has more and larger slots than the “Standard” ring, the “Alternative” ring facilitates more slurry flow into the pad-wafer interface region, achieving higher slurry utilization efficiency than the “Standard” ring.

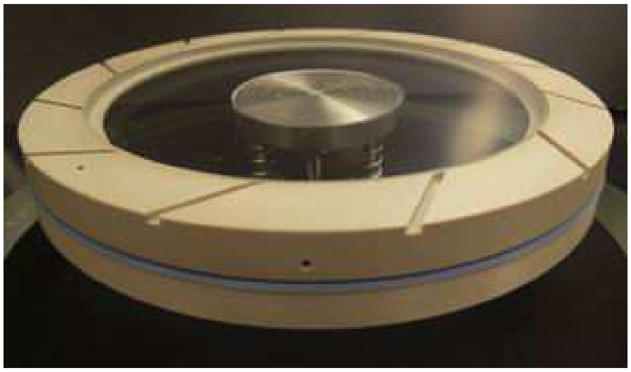

Figure 1: Contacting surface of the “Standard” retaining ring-quartz wafer assembly.

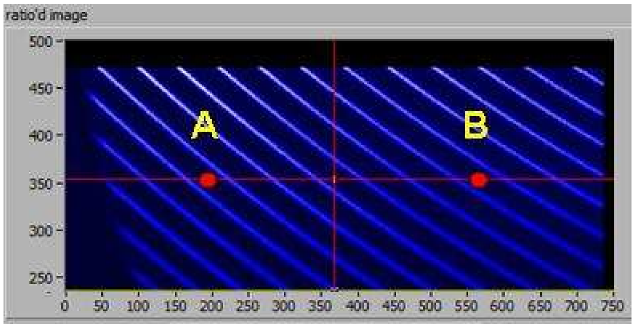

Figure 2: Dual emission UV enhanced fluorescence image of pad-wafer interface.

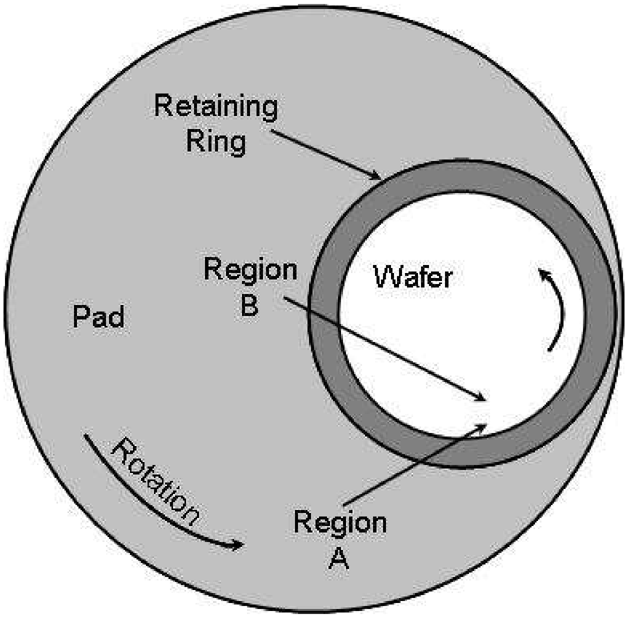

Figure 3: Top view of polishing system and region A and region B locations.

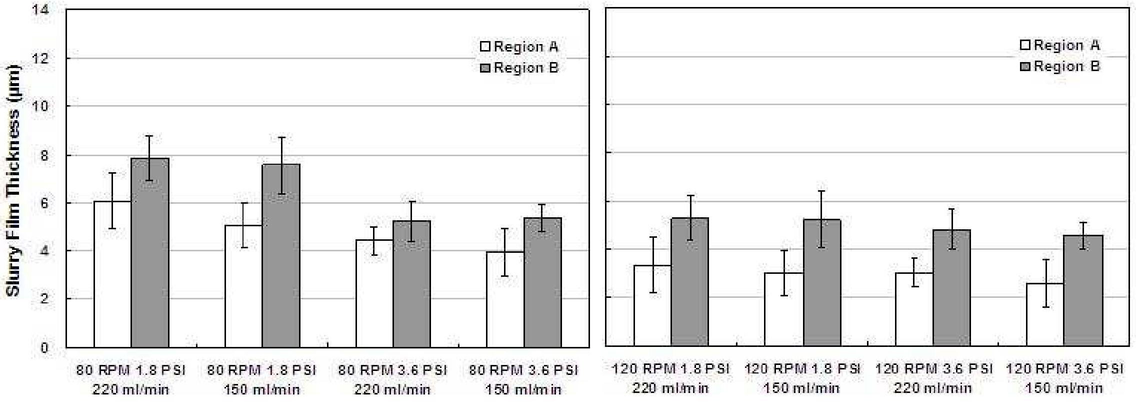

Figure 4: Slurry film thickness measurement for the retaining ring with "Standard" slot design at the platen rotational rate of 80 RPM (left) and 120 RPM (right).

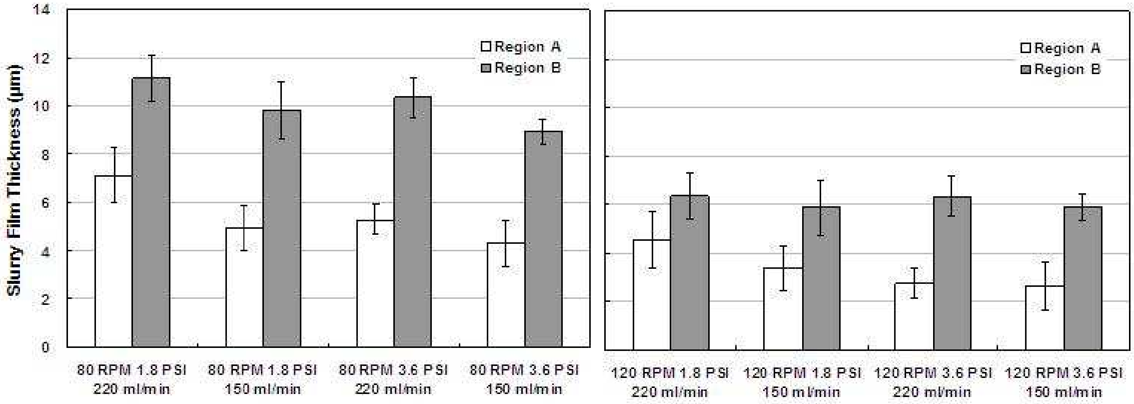

Figure 5: Slurry film thickness measurement for the retaining ring with "Alternative" slot design at the platen rotational rate of 80 RPM (left) and 120 RPM (right).