Task ID: 425.032

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

Deliverable: Effect of retaining ring geometry design on slurry flow and pad micro-texture for Rohm and Haas pads

I. Summary/Abstract.

This report summarizes the recent study on the effect of retaining ring geometry design on retaining ring wear rate and pad micro-texture for Rohm and Haas (currently Dow Electronics) IC1010 M-groove pads. In this study, retaining rings made of polyphenylene sulfide (PPS) and polyetheretherketone (PEEK) with two different slot designs were subjected to a 4-hour wear test under the pressure of 7 PSI and sliding velocity of 1.22 m/s. While the retaining ring slot design did not significantly affect coefficient of friction (COF) and retaining ring wear rate, retaining rings with sharp slot edges resulted in higher pad surface abruptness.

II. Technical Results and Data.

Wear experiments were performed on a 200-mm polisher and tribometer using three retaining rings with two different materials and two slot designs. The first retaining ring made of PPS with slot Design – 1 is referred as PPS – 1 retaining ring, the second retaining ring made of PEEK with slot Design – 1 is referred as PEEK – 1 retaining ring, and the third retaining ring made of PEEK with slot Design – 2 is referred as PEEK – 2 retaining ring. Figure 1 shows the two retaining ring slot designs tested in this study. Design – 1 has sharp edges at both the entrance and exit of the slots and Design – 2 has rounded edges at both the entrance and exit of the slots. The slot angle (i.e. the acute angle between the retaining ring outer periphery and slot edge) is 52º and 38º for Design – 1 and Design – 2, respectively. For both designs, the width of the retaining ring land area is 24 mm.

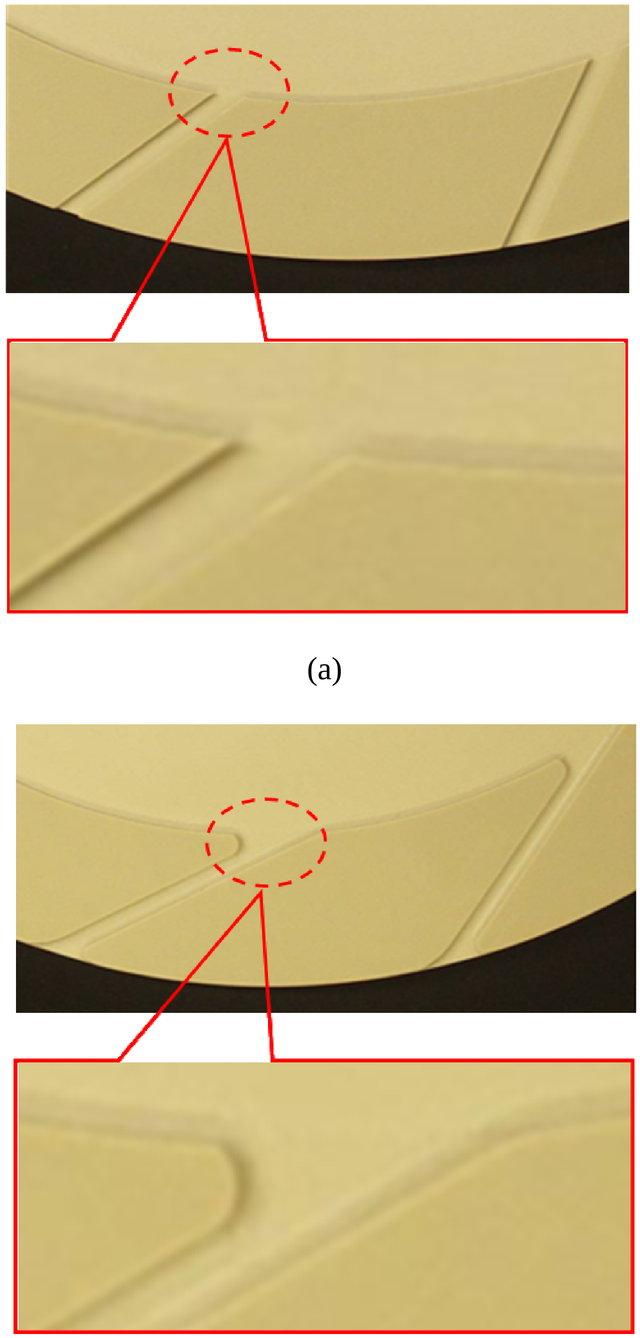
During the wear tests, the retaining rings were polished on IC1010 M-groove pads. A 100-grit diamond disc manufactured by Mitsubishi Materials Corporation with triple ring dot design was used to condition the pad during the wear test at the down force of 25.8 N. The diamond disc rotated at 95 RPM and swept across the pad 10 times per minute. Fujimi PL-4217 slurry with 10 weight percent of fumed silica abrasives were injected on the pad center at the flow rate of 150 ml/min. The pressure and sliding velocity of the retaining ring were kept constant at 7 PSI (48.3 kPa) and 1.22 m/s, respectively. For each retaining ring, the total wear time was 4 hours. During the 4-hour wear test, shear force and down force were measured in real-time at the frequency of 300 Hz. A pad sample was taken from the center of the pad radius after the wear test for each retaining ring. White light interferometric analysis was performed on the pad sample (2.1×2.1 mm^2) to determine the pad surface height probability density function (PDF) and pad surface abruptness. The retaining ring wear rate was measured by white light interferometry and micrometry.

Figure 2 shows the COF as a function of wear time for each retaining ring. The COF ranges from 0.59 to 0.68 for the PPS – 1 retaining ring and 0.51 to 0.57 for the PEEK – 1 and PEEK – 2 retaining rings. As the PPS retaining ring has higher COF than the PEEK retaining rings, it generates a higher wear rate than the PEEK retaining rings as shown in Table I. On the other hand, the PEEK – 1 retaining ring has a similar wear rate to the PEEK – 2 retaining ring, indicating that retaining ring slot design does not have a significant effect on retaining ring wear rate. Figure 2 also shows that the COF of PEEK – 1 retaining ring is very close to that of PEEK – 2 retaining ring, indicating that retaining ring slot design does not have a significant effect on COF.

Figure 3 shows the pad surface PDF extracted from the white light interferometric images. Pad surface abruptness, defined as the characteristic distance over which the right-hand tail of the pad surface PDF drops by a factor of *e*, is extracted for each retaining ring. The extracted pad surface abruptness for the PPS – 1 and PEEK – 1 retaining rings are 4.5 and 4.6 µm, respectively. This indicates that retaining ring materials have no significant effect on the pad surface abruptness. In contrast, the extracted pad surface abruptness for the PEEK – 2 retaining ring is 3.3 µm. This indicates that retaining ring slot design impacts the pad surface abruptness as Design – 2 (PEEK – 2 retaining ring) results in a smaller pad surface abruptness than Design – 1 (PPS – 1 and PEEK – 1 retaining rings). Compared with the rounded edges of the PEEK – 2 retaining ring slots, the sharp edges of the PPS – 1 and PEEK – 1 retaining ring slots cut into pad surface and create additional pad conditioning, rendering higher pad surface abruptness.

Table I. Retaining ring wear rate comparison.

Retaining Ring	Wear Rate from Interferometry (µm/hour)	Wear Rate from Micrometry (µm/hour)
PPS – 1	28.6 ± 0.5	28.6 ± 0.0
PEEK – 1	20.6 ± 1.6	21.8 ± 1.4
PEEK – 2	20.5 ± 2.2	21.8 ± 1.6



(a)

(b)

Figure 1. Retaining rings with (a) slot Design – 1 and (b) slot Design – 2.

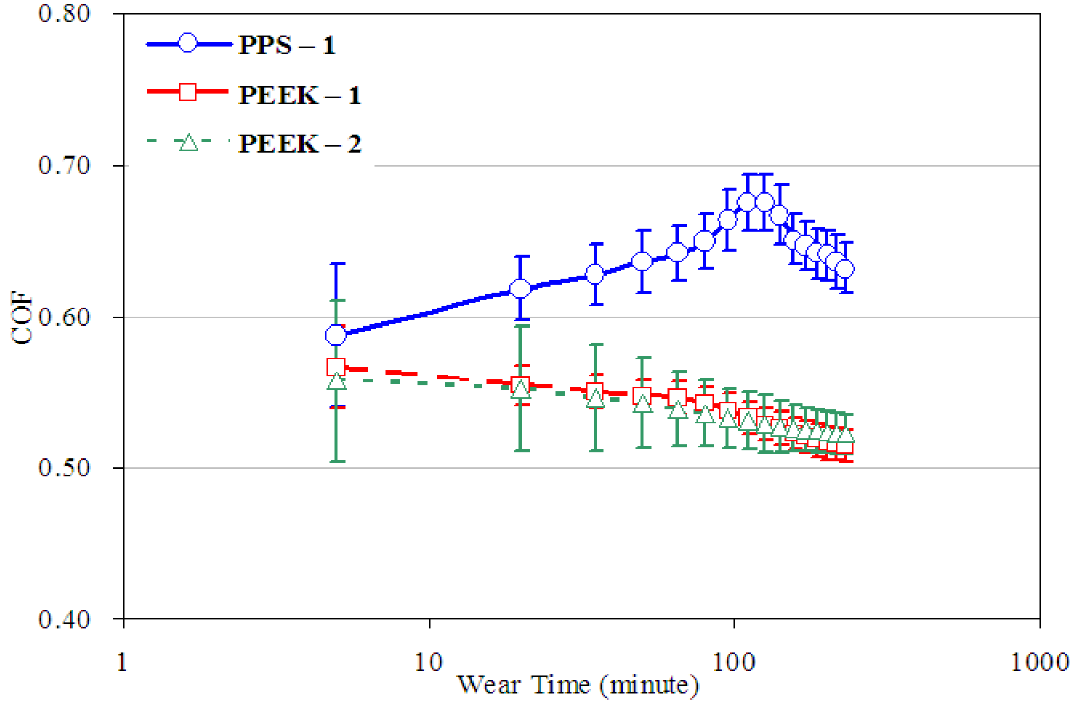


Figure 2. COF as a function of retaining ring wear time.

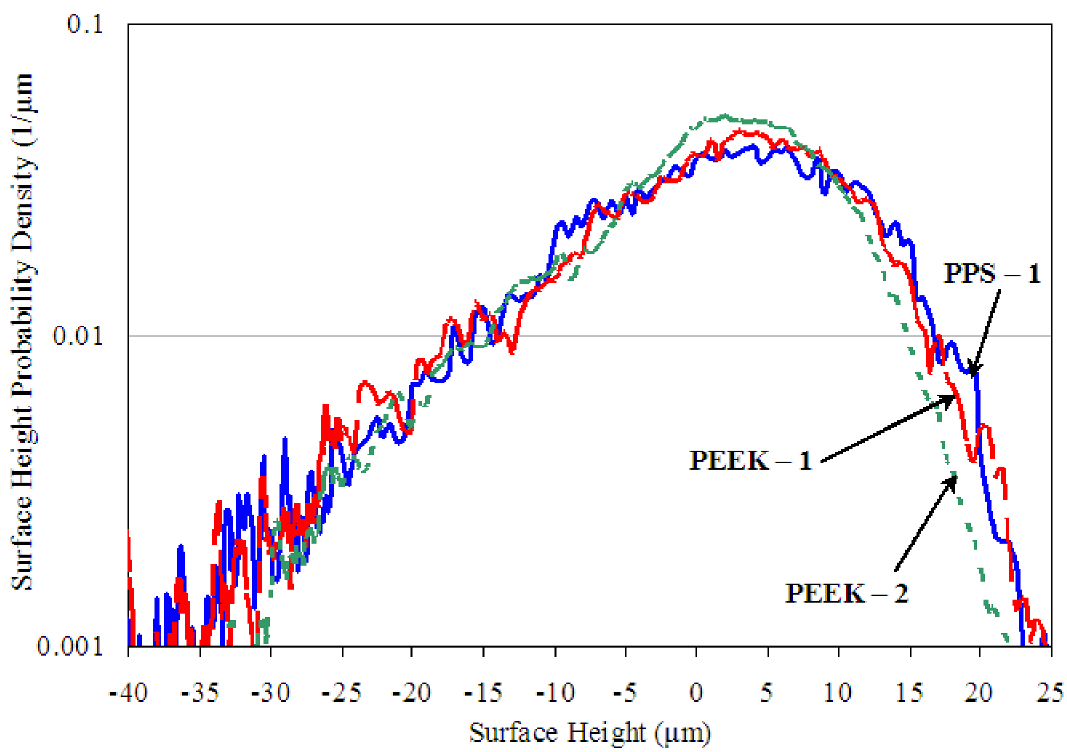


Figure 3. Pad surface height probability density function comparison.