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

Deliverable: Pad micro-texture analysis with laser confocal microscope.

I. Summary/Abstract.

This report summarizes the recent development on pad micro-texture analysis using laser confocal microscopy. A laser confocal microscope was used to measure the pad surface contact area and topography under dry and static condition. A custom-made pad sample holder with a sapphire window and a miniature load cell was used to collect pad surface contact images at controlled loads. By extracting the black spots in the collected images, pad contact area and contact summit density were obtained. 3-D pad surface topography was obtained when no load was applied on the pad surface and pad surface height probability density function (PDF) was established.

II. Technical Results and Data.

A Zeiss LSM 510 Meta NLO microscope is used to measure pad-wafer contact area with a 488-nm-wavelength laser as the light source. A sample holder with a sapphire window (with quarter-wavelength flatness) is used to apply known pressures on the pad surface, which allows us to investigate the effect of pressure on contact area. As shown in Fig. 1, the pad sample rests on a miniature stage, which has the same diameter as the sapphire window. Diameter matching is required for the correct loading of the sample. The sample is larger than the stage and the window. Since the window protrudes slightly from the window-mounting ring, the sample may have an irregular shape and edge burrs without affecting the loading of the surface. This is a major advantage of the design since otherwise the sample must be precisely cut and the edge must be carefully deburred.

Experiments are performed on the surface of a post polishing pad (Rohm and Haas IC1000 pad with concentric grooves) at three pressures: 2, 4, and 6 psi. The pad sample is rinsed with deionized (DI) water to remove slurry residue from the pad surface and dried in air naturally. A 10-mm-diameter portion of the pad sample is visible through the sapphire window. In a scan of a diameter, a series of nine contiguous, non overlapping images are taken. Each image size is 921×921 μm^2. Images are numbered from left to right, with each image displaced 921 μm to the right of the previous image. Each image contains 2048×2048 pixels and the image resolution is therefore 0.45 μm/pixel. The contact area fraction is the contact area within the set of images divided by the total area of the images, including the grooves. Similarly, pressure is the load divided by the area of the sapphire window, including the grooved area. In addition, eight pad surface topography images are collected on the pad land area without any load, and surface height PDFs are determined. In the three-dimensional pad surface topography analysis, each optical slice is 1.2 μm thick, indicating that the resolution in the Z-direction is 1.2 μm.

Figure 2 shows an example of a reflection image collected at the pad-wafer contact region using the laser confocal microscope. In the image, areas with an even gray color are located substantially below the sapphire interface. A groove is included in this image, as indicated, and also appears as an even gray color. Contact areas are black spots, as predicted by the interface reflection-refraction theory. Although the black spots appear to be small, they are not necessarily a single contact area but may be a cluster of contact areas. An enlargement of a contact area is also shown in Fig. 2. It can be observed that this particular black spot contains several contact areas. Constructive and destructive interference in the near-contact areas produces “zebra stripes”, which are associated with relatively flat areas of the pad.

Figure 3 summarizes the average pad contact area values calculated from the nine images at different pressures (2, 4, and 6 psi). The contact area increases from 0.026% to 0.045% when the pressure increases from 2 to 4 psi and increases further to 0.059% when the pressure increases to 6 psi.

Contact summit density (η_c) is the number of contact points per unit area under the wafer. This is one of the most difficult quantities to measure in tribology. From the extracted contact area contours, the contact summit density was evaluated, as summarized in Fig. 4. The contact summit density increases from 73 to 91 mm^{-2} when the pressure increases from 2 to 4 psi and increases further to 110 mm^{-2} when the pressure increases to 6 psi. Similarly to the pad contact area, the contact summit density increases nearly linearly with the applied pressure.

Figure 5 shows the eight pad surface topography images collected using the laser confocal microscope. The high resolution of the images allows the extraction of surface height PDFs as shown in Fig. 6. All eight images give similar PDFs in the contact region (the right side of the curves), as the PDFs in the contact region are determined by pad conditioning and polishing conditions. In comparison, the variation on the left side of the PDF curves originates from the distribution of the pores created during the pad manufacturing process.

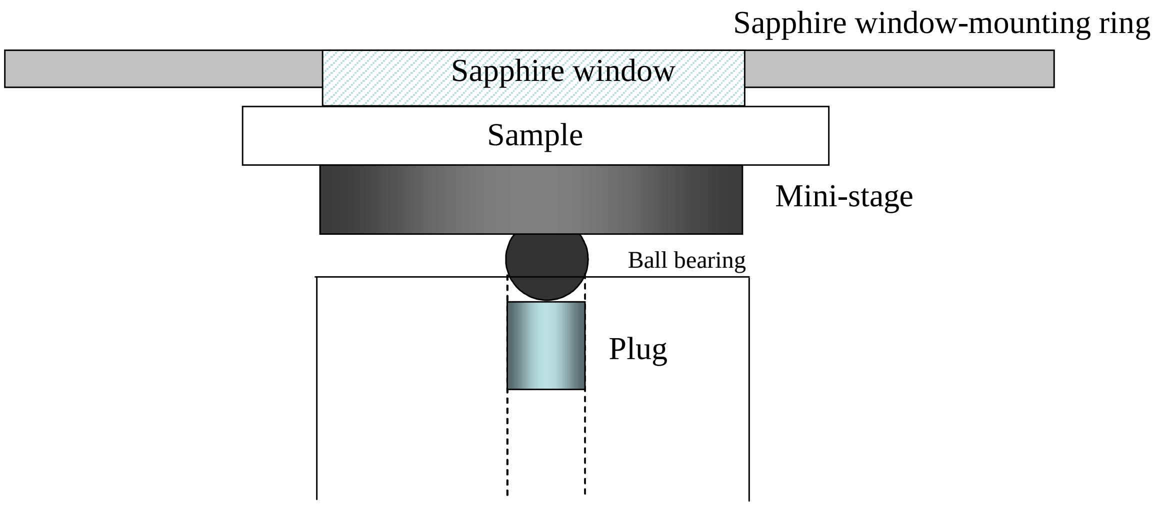

Figure 1: Schematic of sapphire window and sample stage setup.

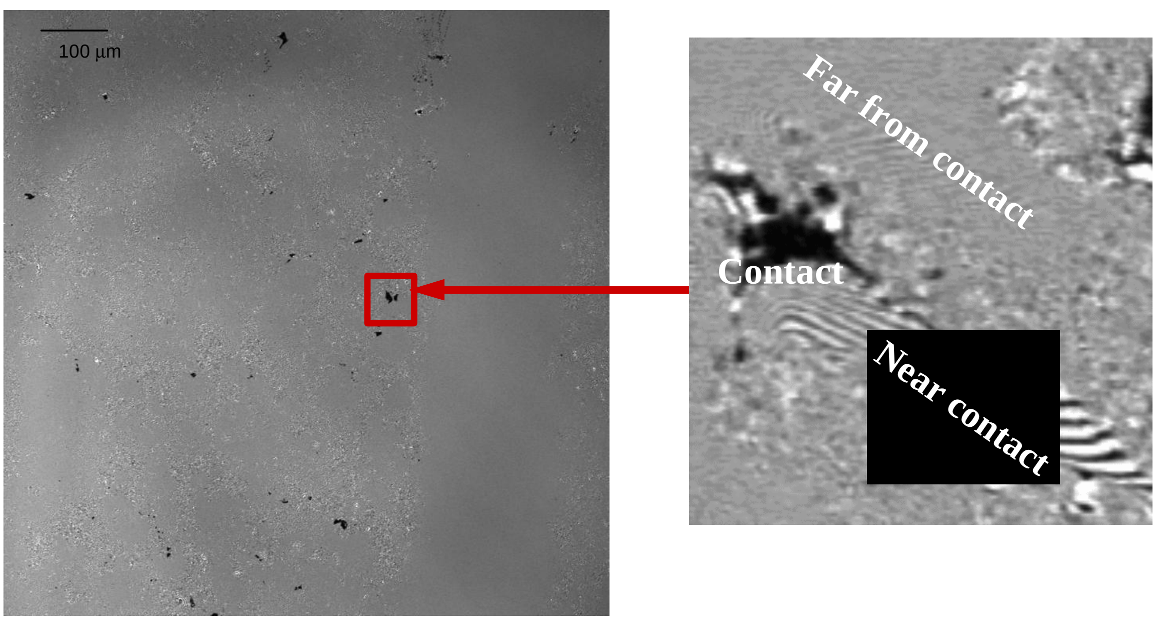

Figure 2: Image collected at pad-wafer contact region using confocal microscope (left) and details of the contact area (right).

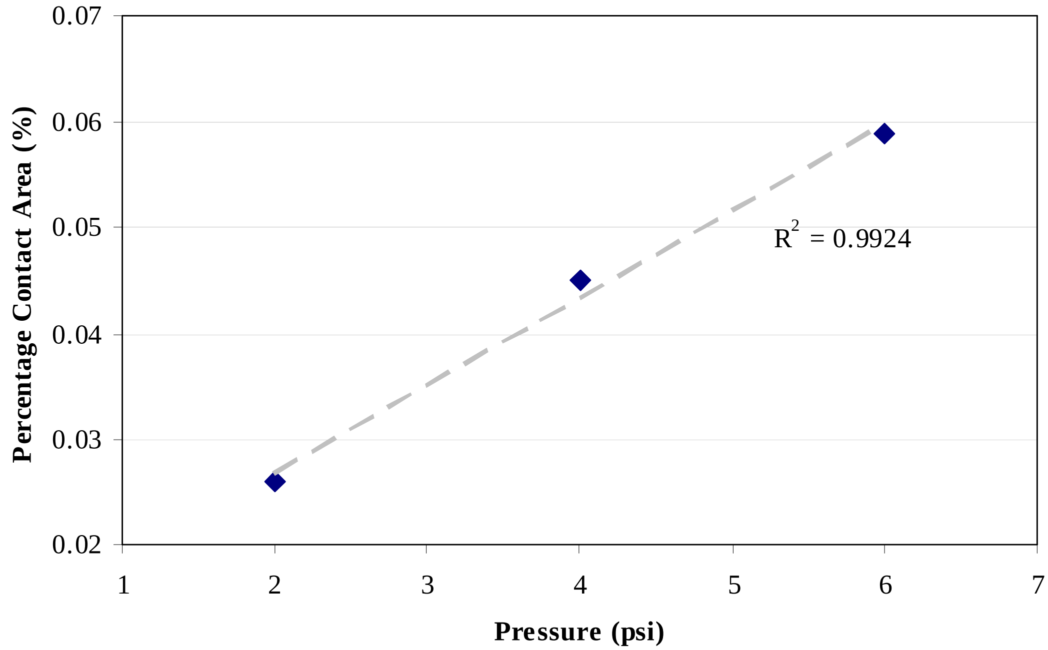

Figure 3: Summary of percentage contact area for different pressures.

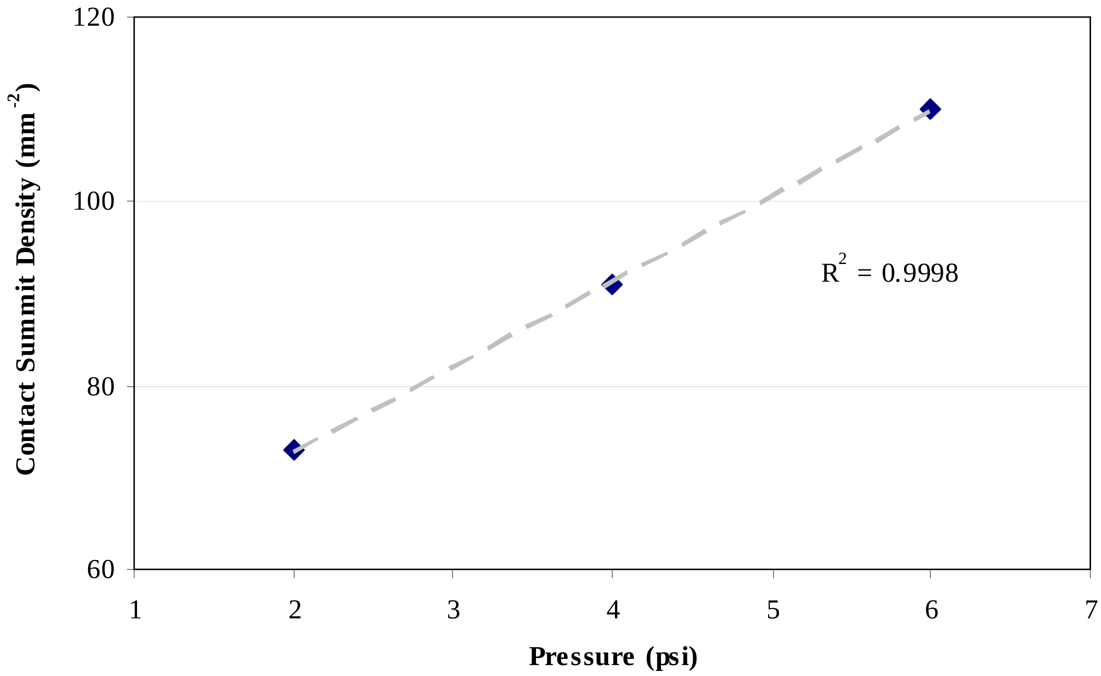

Figure 4: Summary of contact summit density for different pressures.

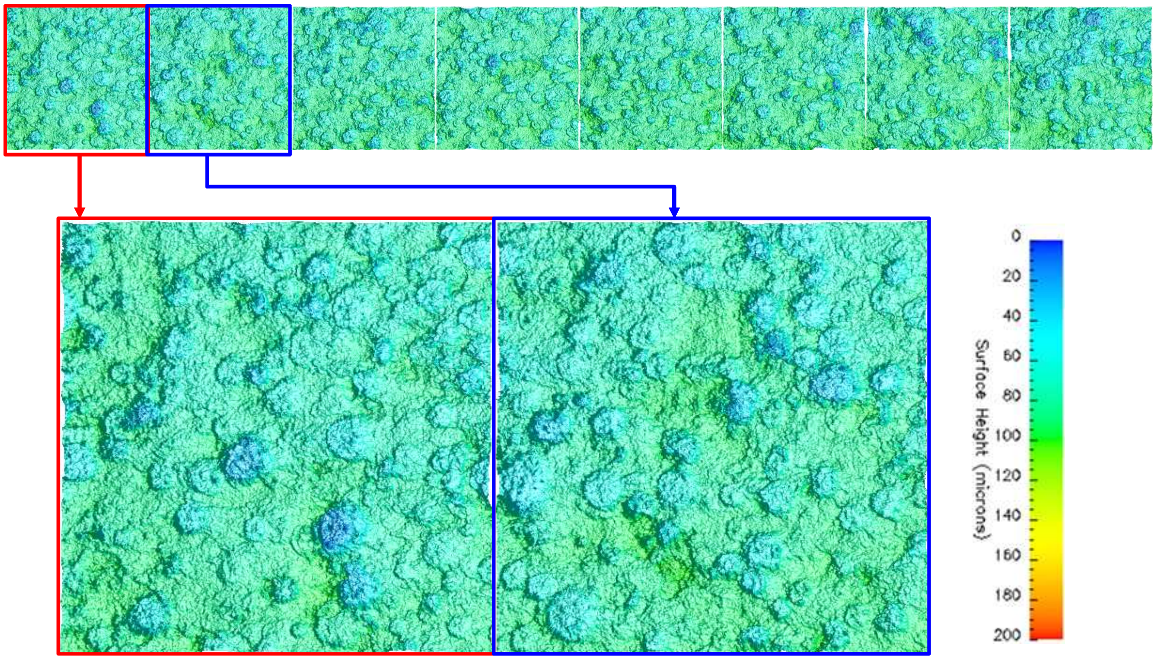

Figure 5: Collected pad surface topography images.

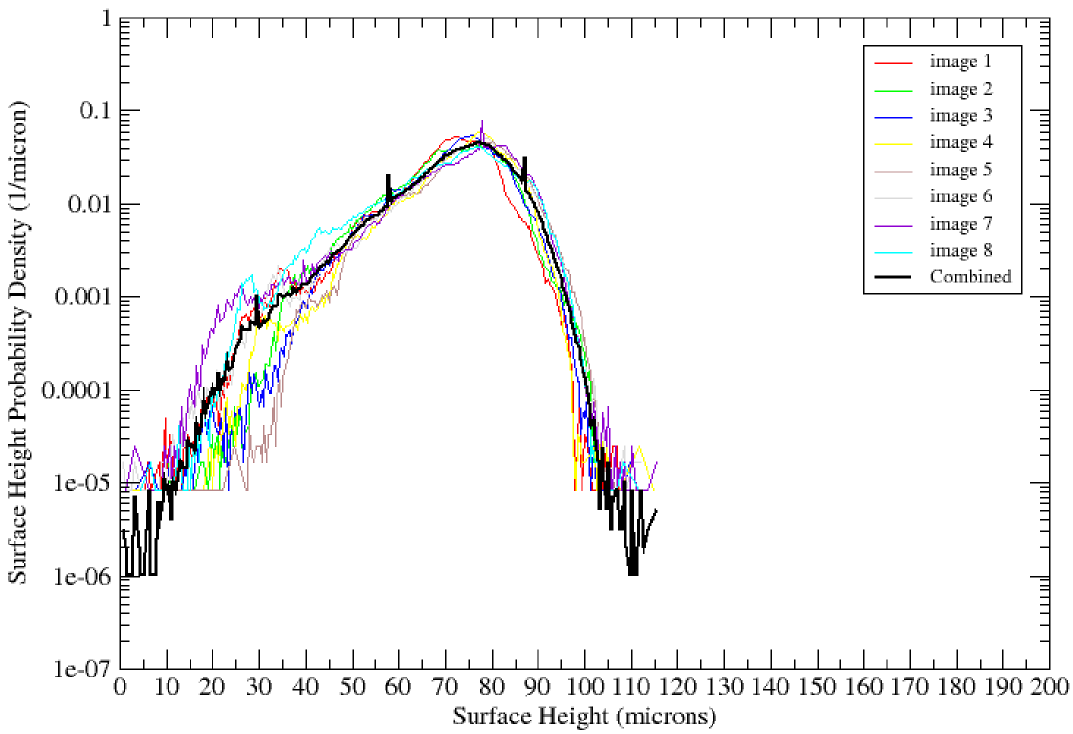

Figure 6: Extracted pad surface height PDFs.