Effect of Conditioner Wear on the Tribological, Thermal, Kinetic and Pad Microtextural Characteristics in ILD CMP

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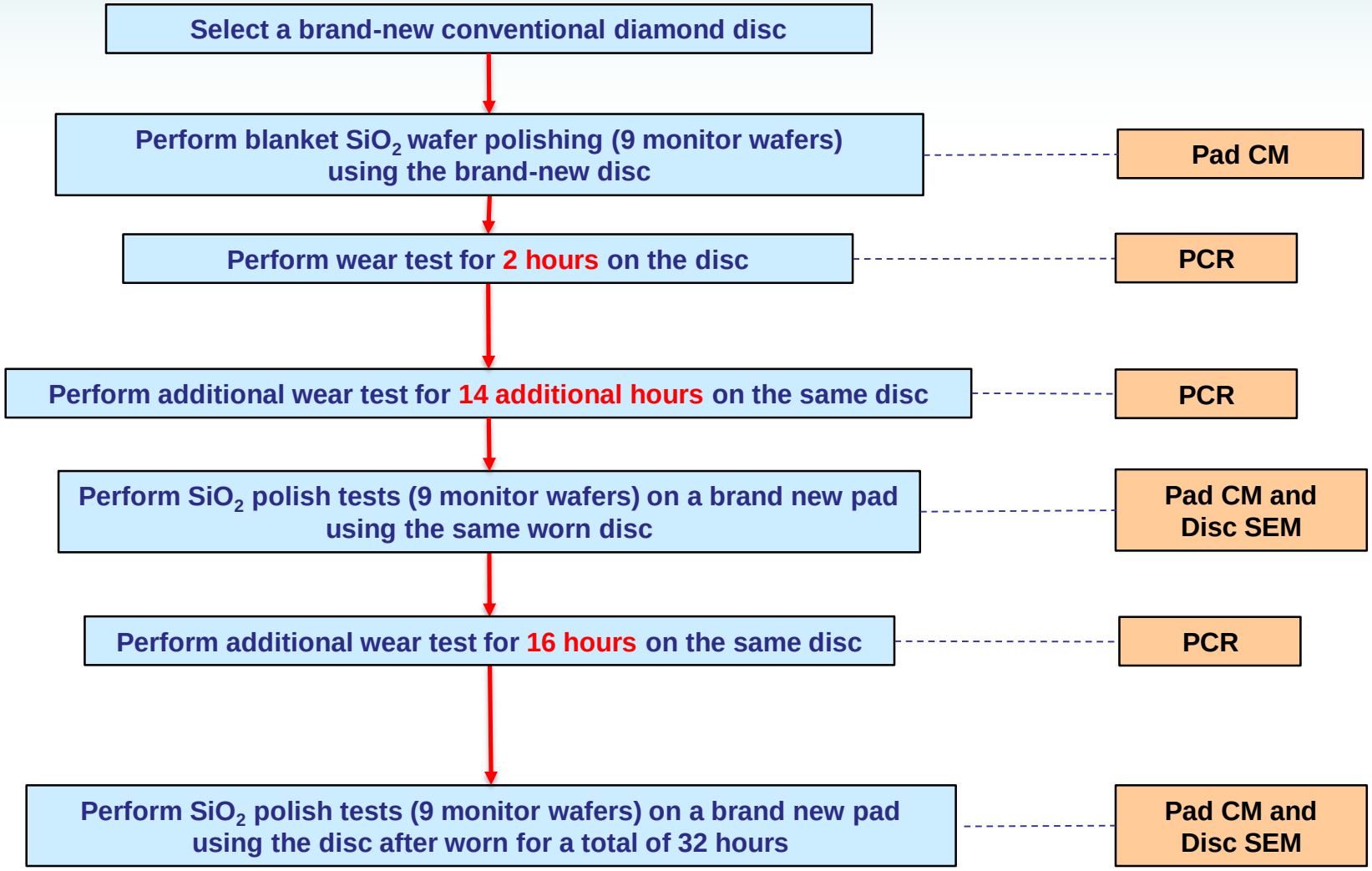
Problem Statement and Objective

- **In HVM, conditioners wear over time. This causes changes in:**
  - ✓ **Disc life and pad life**
  - ✓ **Pad micro-texture**
  - ✓ **Material RR**
- **To the best of our knowledge, there have been no published systematic studies whereby polish performance has been correlated to the degree of disc wear.**
- **As such, we set out to investigate how a conventional diamond disc, in various stages of its life, impacts:**
  - ✓ **Diamond micro-wear**
  - ✓ **Pad cut rate**
  - ✓ **Surface micro-texture**
  - ✓ **COF**
  - ✓ **Tribological mechanism of the process**
  - ✓ **Pad surface temperature**
  - ✓ **Silicon dioxide RR**

Process Flow Diagram



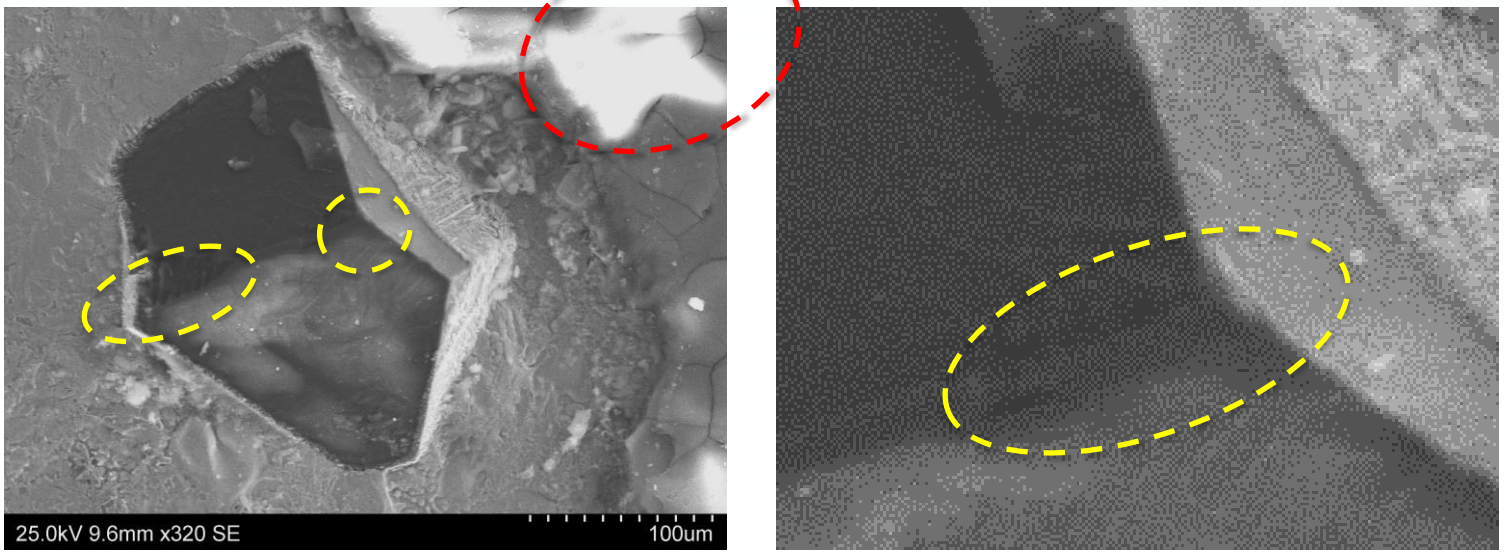
Experimental Conditions – Wear Tests

- **Pad**
  - DowDupont IC1000 K Groove (total of 3)
  - Platen rotation rate at 42 RPM
- **Slurry**
  - No slurry was used – Instead, we used pH adjusted UPW (spiked with KOH to reach a pH level of appx. 10.5)
  - Flow rate at 250 cc per min
- **Wafers**
  - No wafers were polished
- **Conditioner**
  - Conventional diamond disc used in HVM
  - Disc rotation at 95 RPM
  - Down-force at 10 pounds to accelerate wear
  - Sweep rate at 10 per minute
  - Wear time for total of 2, 16, and 32 hours

Experimental Conditions – ILD Polishing

- **Pad**
  - DowDupont IC1000 K Groove (total of 3 new pads)
  - Break-in for 30 minutes with UPW with platen rotating at 45 RPM
- **Wafer**
  - Polished 10 dummy wafers for 30 secs each until we reached SS (total of 30)
  - 300 mm blanket SiO_2 wafers (total of 27)
- **Slurry**
  - Fujimi PL 4217 with 10 percent (by weight) of fumed silica particles
  - Flow rate at 300 cc per min
- **Conditioning**
  - New, 16-hr and 32-hr worn conventional diamond disc
  - Rotation at 95 RPM
  - Down-force at 10 pounds
  - Sweep rate at 10 per min
- **Polishing Conditions**
  - Pressure at 3, 4 and 5 PSI
  - Velocity at 0.7, 1.1, and 1.5 m/s
  - Polish time at 30 secs
- **2,000 cc per min UPW rinse at RT between each polish**

SEM Image of a Diamond after 16 hours of Wear

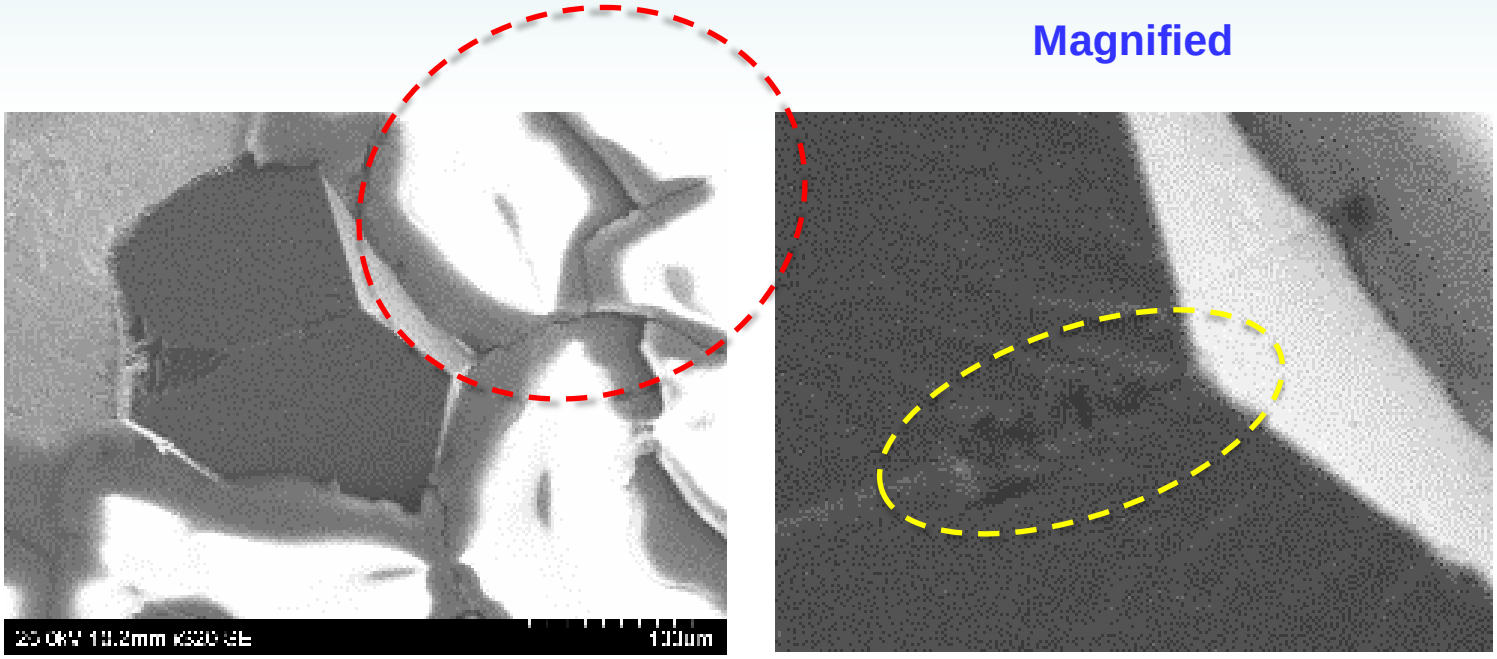


There are large micro-cracks on the edge separating the top LHS and bottom facets.

There is dried slurry adhering to the substrate surface.

Note: This is just one of many diamond tips that we have studied

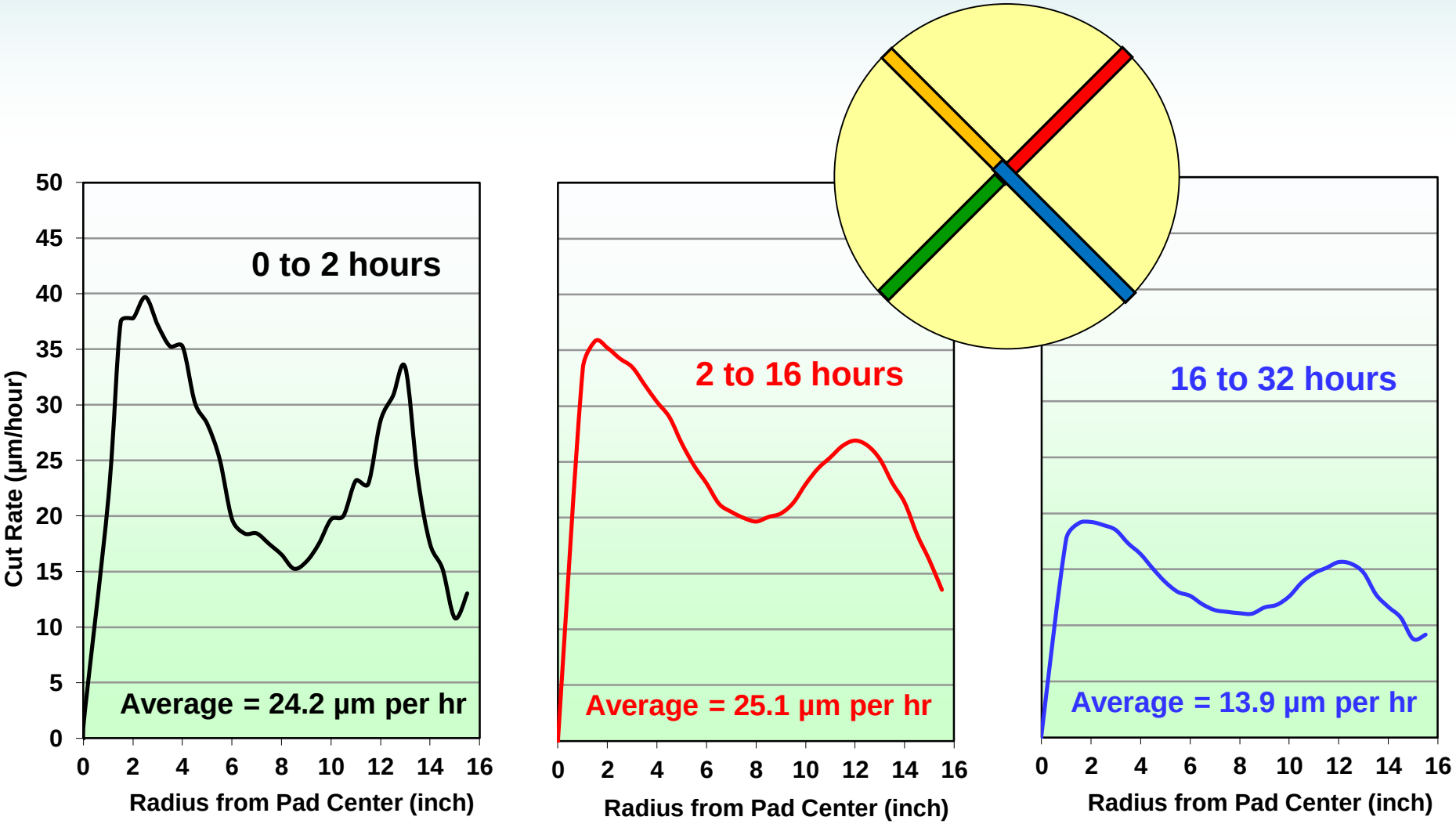
SEM Image of a Diamond after 32 hours of Wear



The micro-crack on the edge separating top LHS and bottom facets has grown.

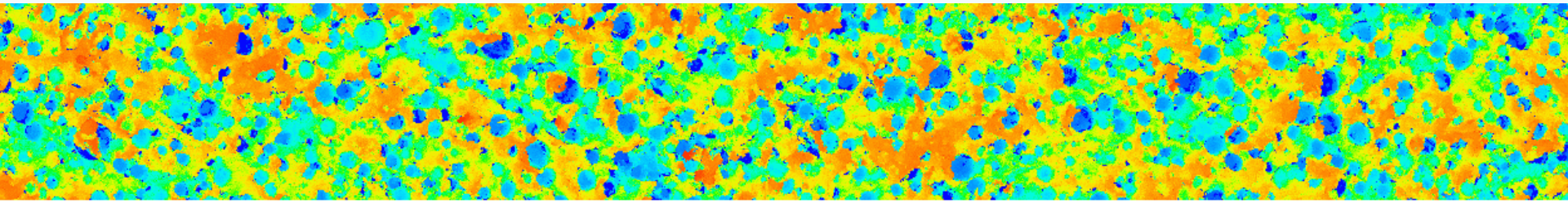
Dried slurry has accumulated and is now adhering to a large portion of the substrate as well as the top RHS and bottom facets

Average (of 4 strips) PCR Profiles via Micrometry

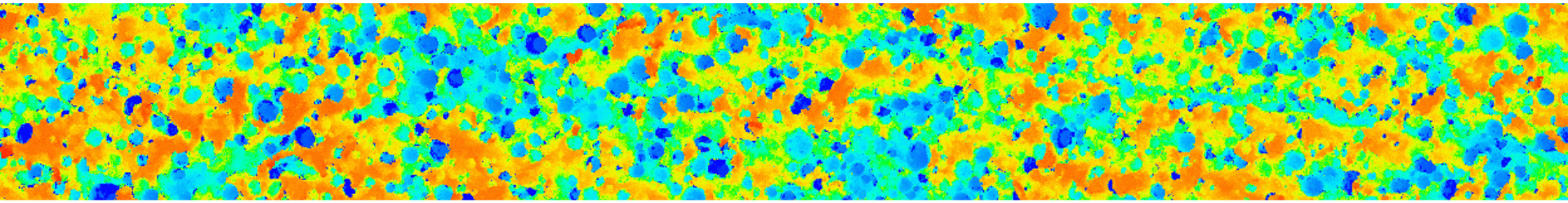


Pad Micro-Textures via Confocal Microscopy

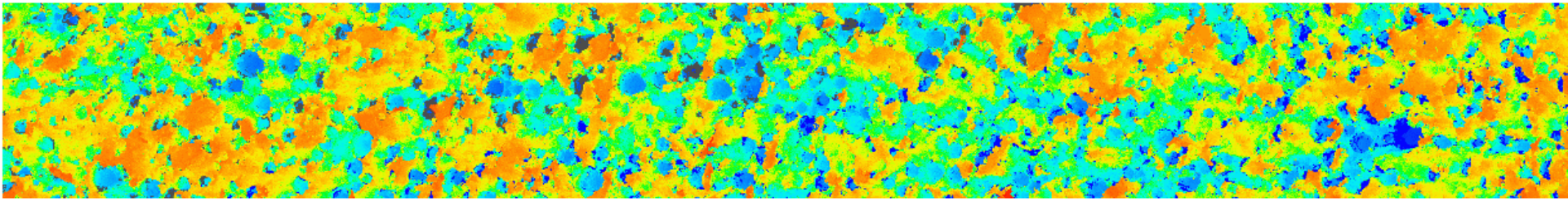
Brand New Conventional Disc



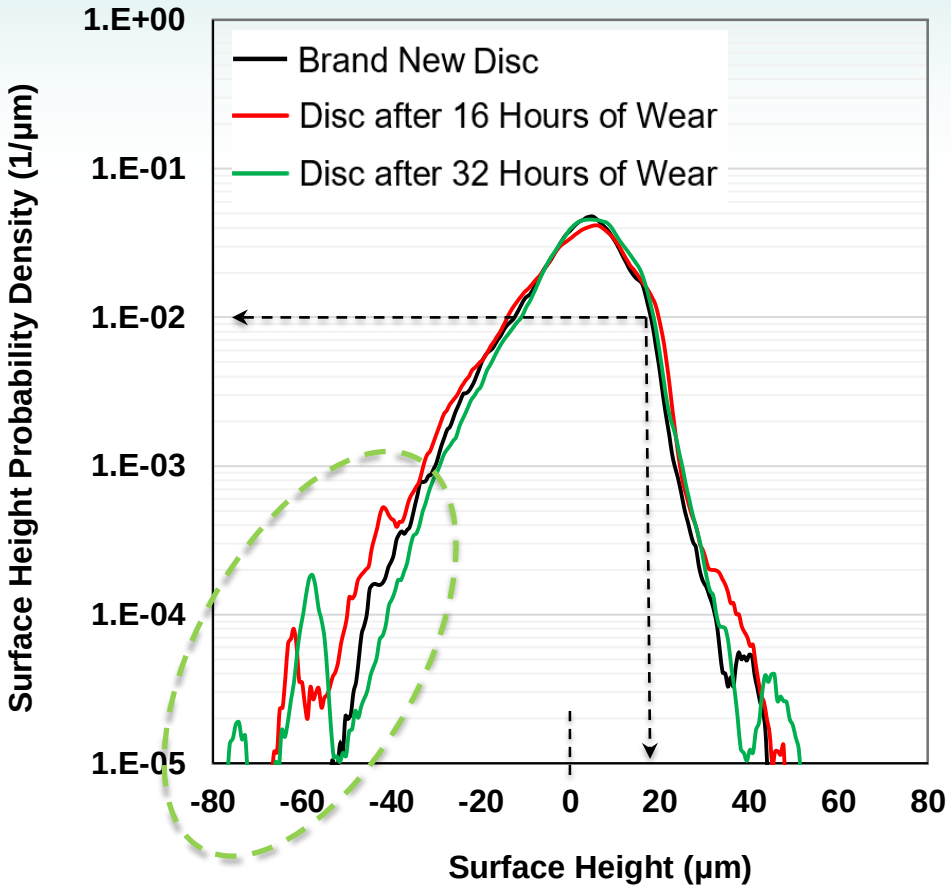
Conventional Disc after 16 Hours of Wear



Conventional Disc after 32 Hours of Wear



Pad Micro-Texture Results



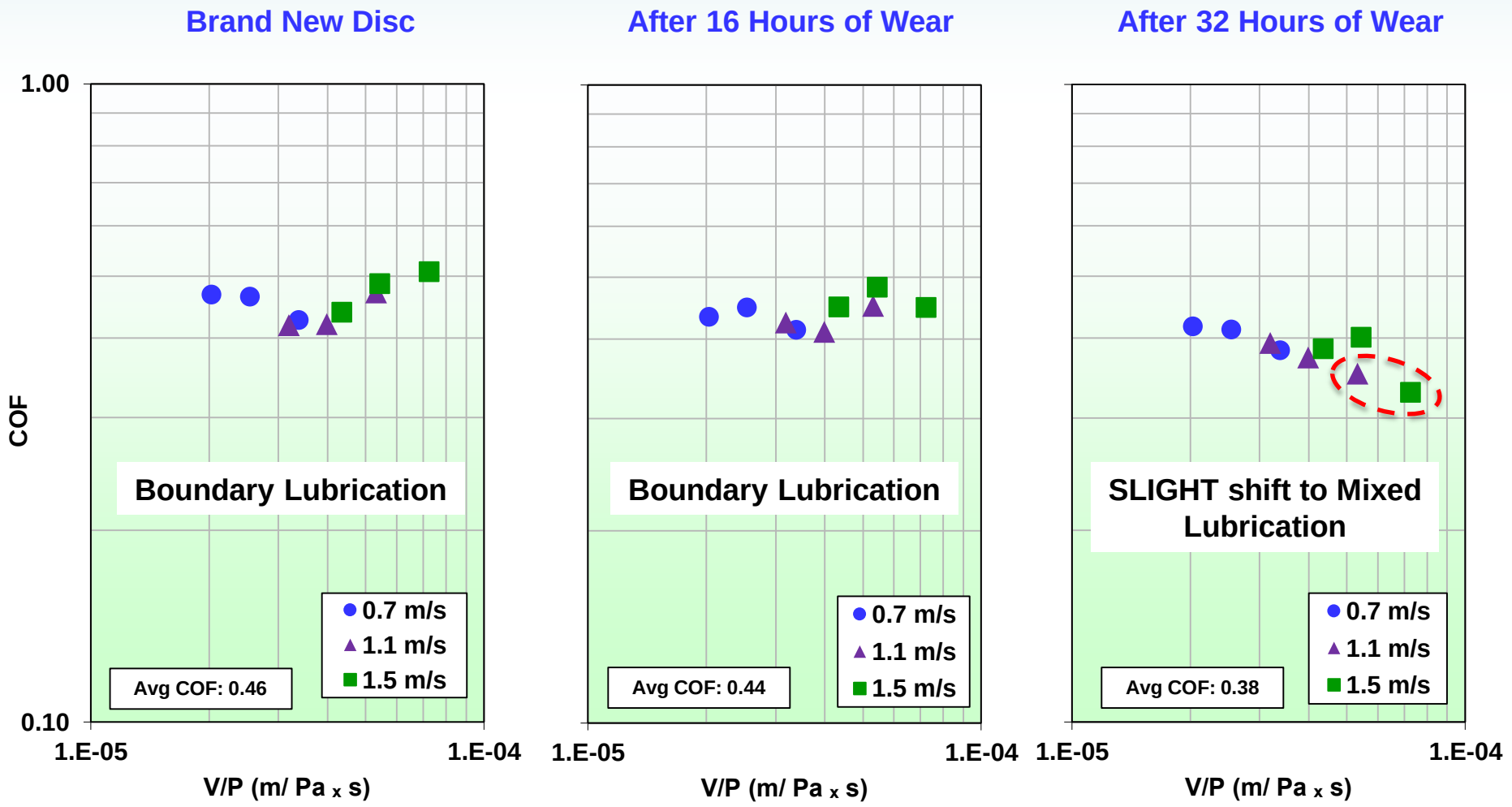
Condition of the Disc	Mean Pad Summit Height (µm)	Mean Gaussian Pad Asperity Curvature (1/µm²)
Brand New	22.0	246
After 16 Hours	22.3	148
After 32 Hours	23.1	211

There is more VISIBILITY into the pores as the disc wears – As such the pad should have more slurry retention capability

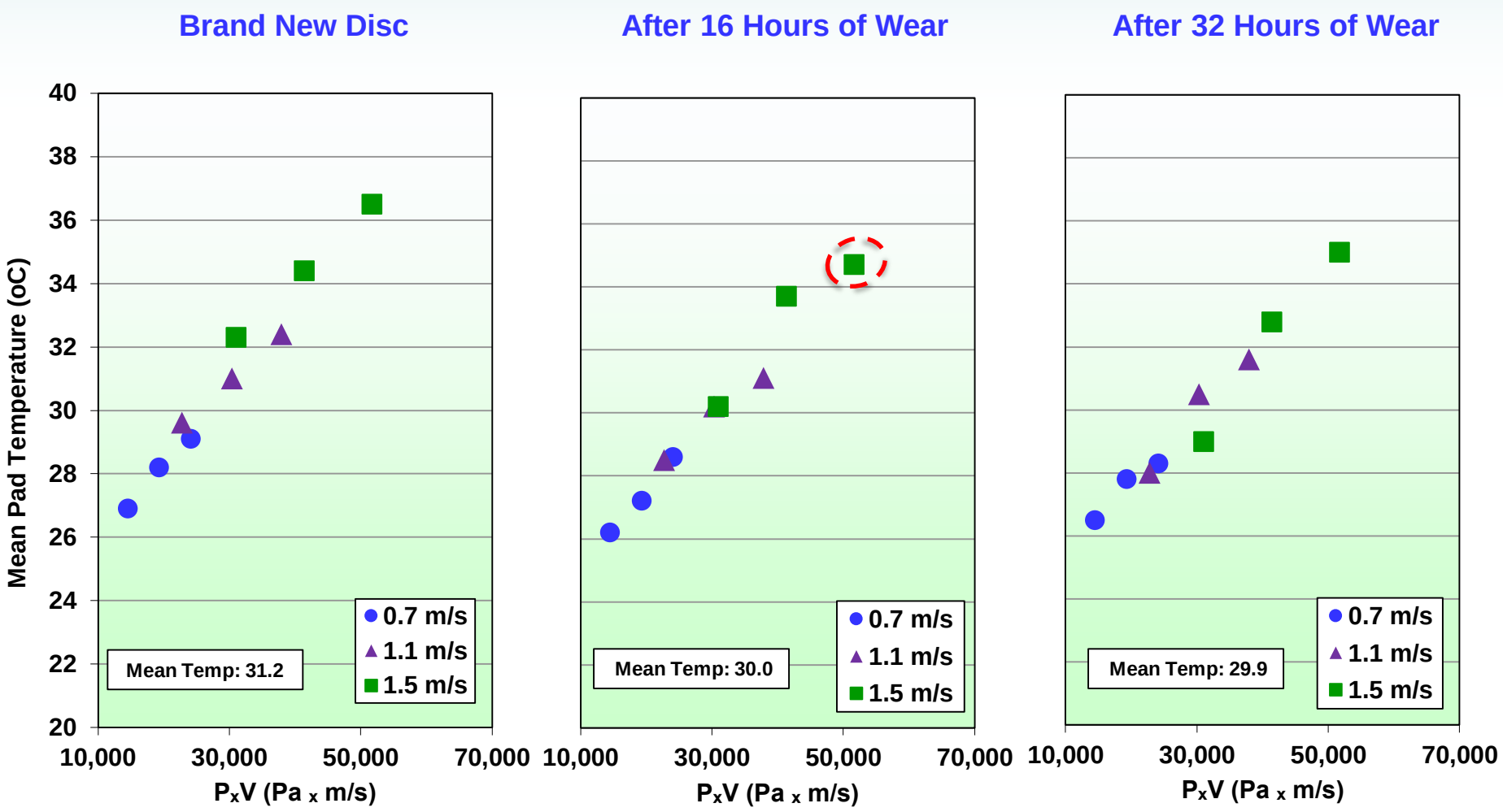
Precision re: measuring mean pad summit height is about ± 2 µm (so no change)!

Precision re: measuring mean Gaussian pad asperity curvature is about ± 50 1/µm² (so no change)!

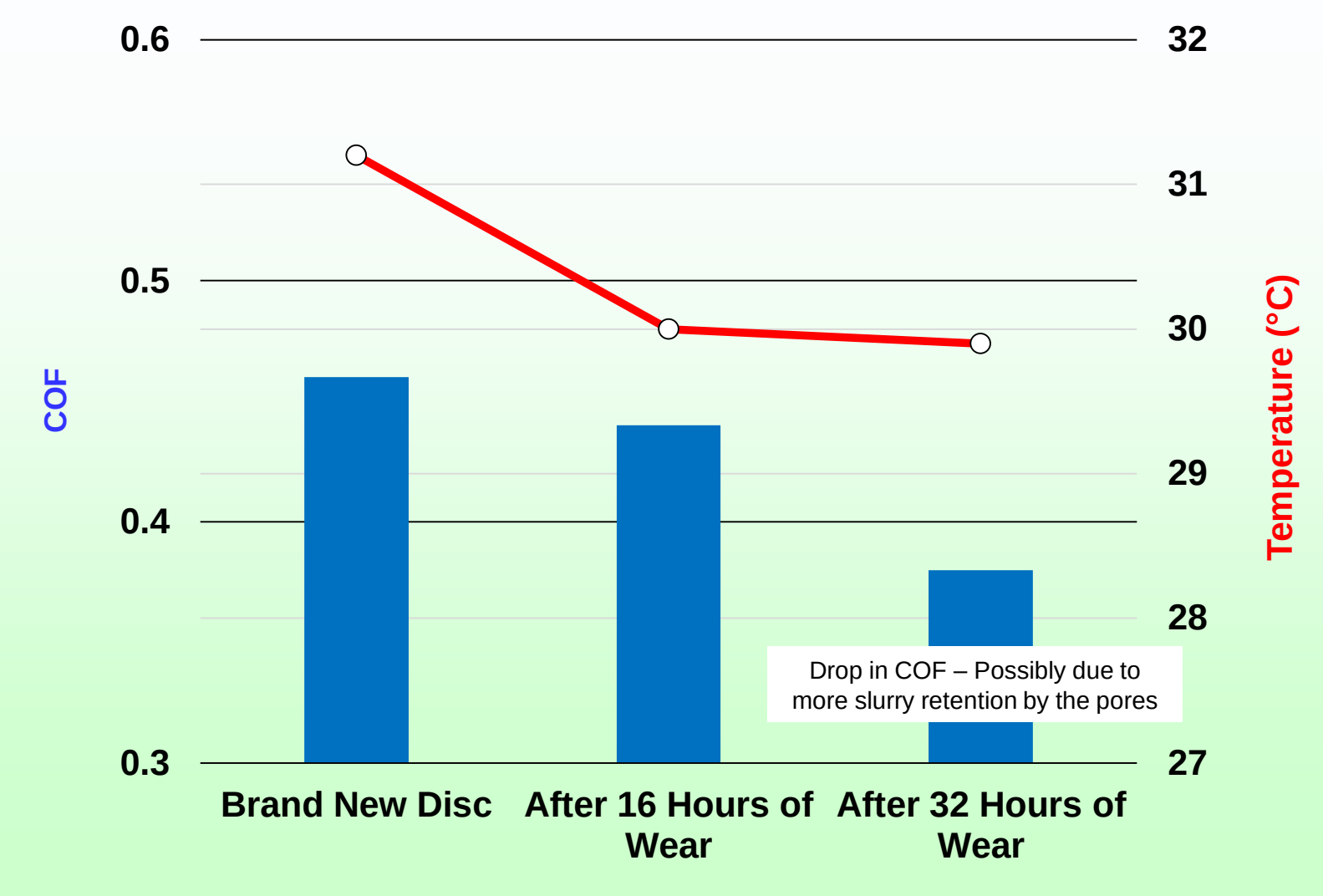
Stribeck Curves



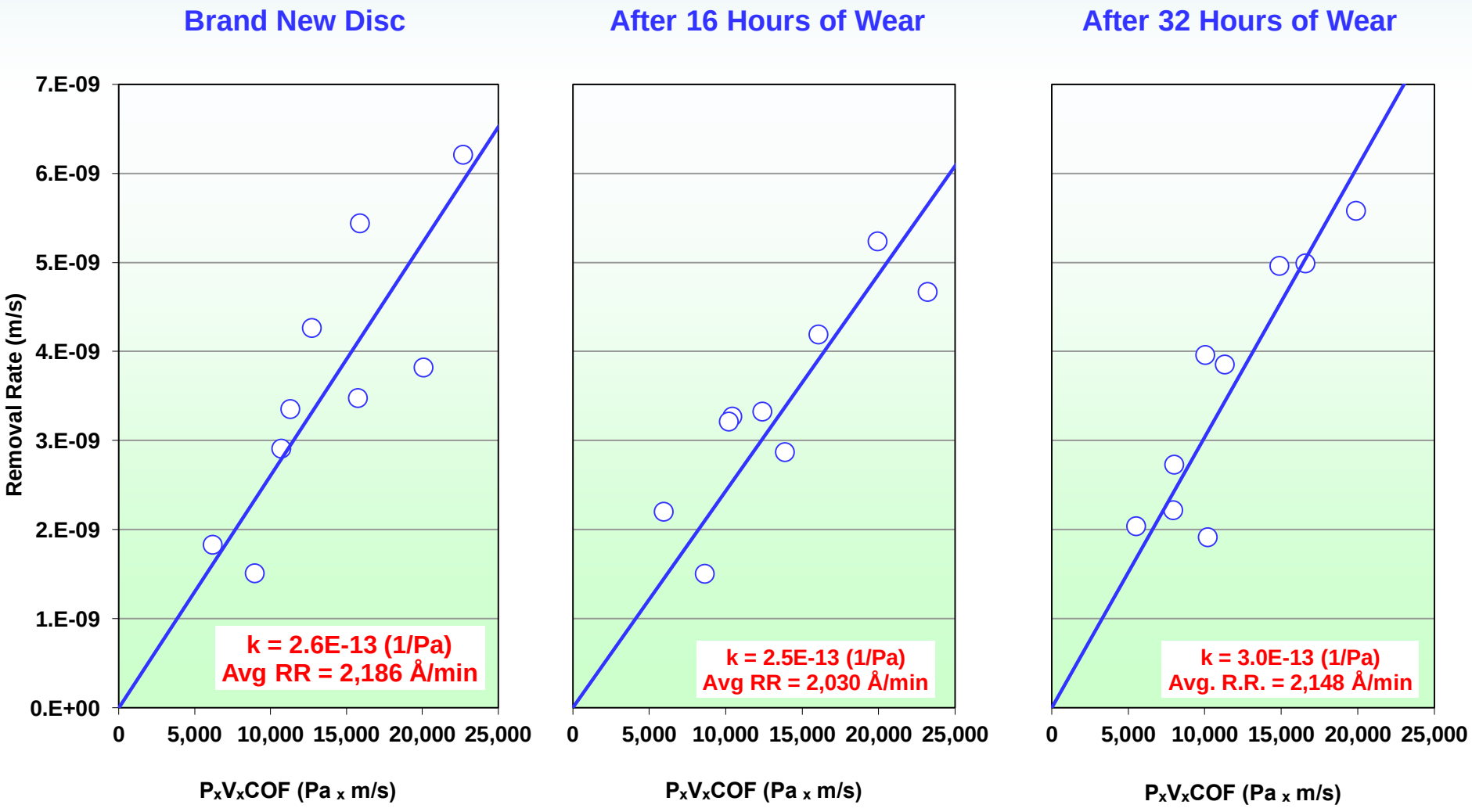
Mean Pad Temperature



Average COF and Pad Temperatures



Removal Rates



Summary of Diamond Wear Studies

- **SEM imaging confirms that diamond tips are experiencing micro-wear and that the substrate surface is seeing slurry build-up over time.**
- **These subtle changes result in nearly a 2X decrease in the average PCR over the 32-hour wear period.**
- **Analysis of pad micro-texture using confocal microscopy shows that there are no statistically significant changes in mean pad summit height and mean pad asperity curvature over the 32 hour period.**
- **This seems to indicate that (at least for 32 hours of wear) PCR and pad micro-texture have nothing to do with one another (this will not be the case for much longer wear times).**

Summary of Polishing Studies

- **Both COF and mean pad temperature decrease as the diamond wears. The changes are very subtle, but they are measurable.**

- **The drop may be due to less pad pore obscuration associated with the worn disc which can retain more slurry and drop the COF (see next bullet). Less PCR usually means less fragment generation and less pore obscuration.**

- **The process remains in boundary lubrication (i.e. 3-body contact) except at high values of Sommerfeld number for the 32-hour worn disc likely due to greater lubricity as a result of slurry retention by the pores.**

- **In all cases, RR trends follow Prestonian behaviors with minimal changes in Preston's constant as the disc ages.**

- **This seems to indicate that (at least for 32 hours of wear) PCR and RR have nothing to do with one another.**

Thank You !