

Tribological, Kinetic, Thermal and Flow Characteristics of PPS and PEEK Retaining Rings

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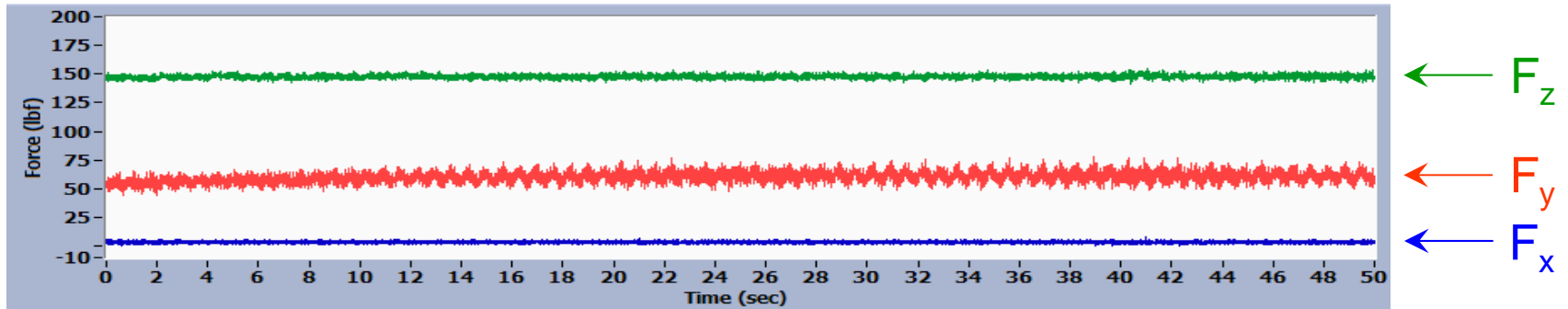
Outline

- 1. Introduction & Objectives**
- 2. Polishing Apparatus**
- 3. Wear Studies**
- 4. Slurry Entrainment (i.e. Mean Residence Time) Studies**
- 5. Summary**

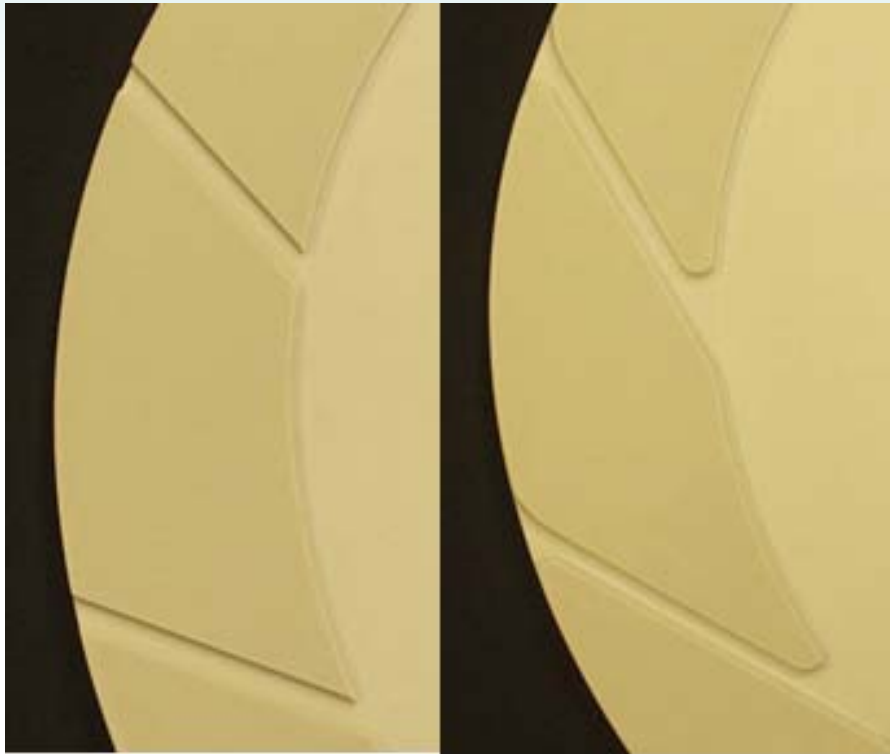
Introduction & Objectives

- The effect of **retaining ring design and materials of construction**, and their interaction with various aspects of the CMP process, have not been widely reported in the literature
- In the past 8 years, the number of direct references are 20 – 30X less than their slurry or pad counterparts
 - Appx. 55 US patents
 - Appx. 15 US patent applications
 - Appx. 10 articles in technical journals and trade magazines
- Our goal is to **develop methods and perform experiments** to determine how ring design and materials of construction affect:
 - Shear force (average and variance)
 - Wear rate
 - Temperature
 - Pad micro-texture
 - Slurry entrainment

Araca APD – 500 Polisher & Tribometer



Retaining Ring ... Types



Design - 1

Design - 2



Design - 1



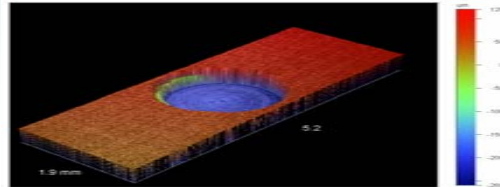
Design - 2

Material - 1 ... PPS (polyphenylene sulfide) ... Design - 1 only

Material - 2 ... PEEK (polyetheretherketone) ... Design - 1 and - 2

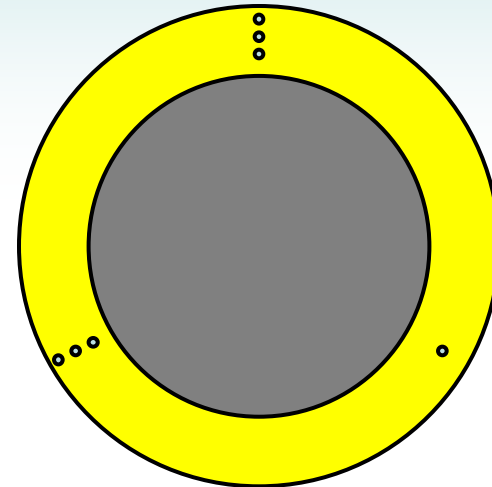
Wear Studies ... Experimental

– Interferometry

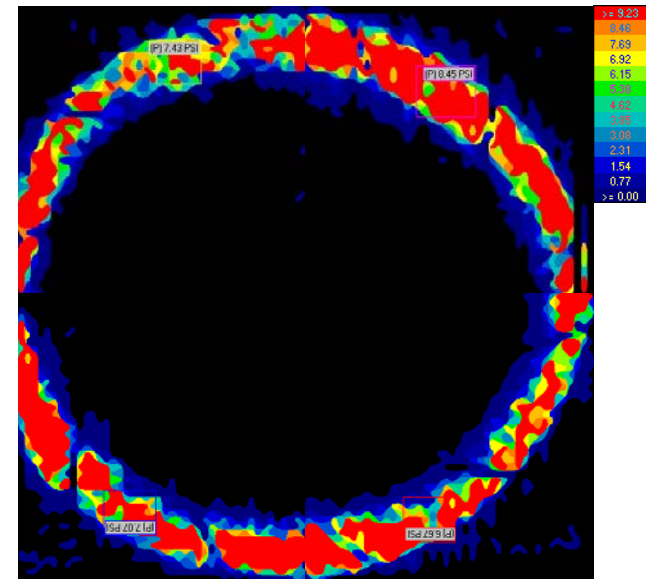
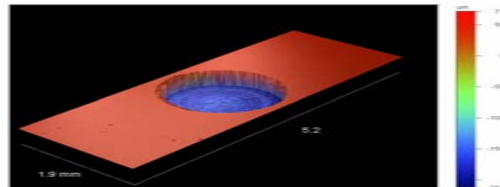


– Wear Test (includes real – time temp. & force)

- 200 – mm blanket wafer
- RHEM IC1020 A4 M – groove pad
- Fujimi PL – 4217 ILD slurry at 150 cc per minute
- 4 – inch MMC TRD 100 – grit diamond disc rotating at 30 RPM and sweeping at 10 times per minute
- In-situ pad conditioning at 5.8 lb_f
- 7 PSI ring pressure
- 81 RPM platen velocity
- 76 RPM wafer & retaining ring velocity
- 4 hours



– Interferometry

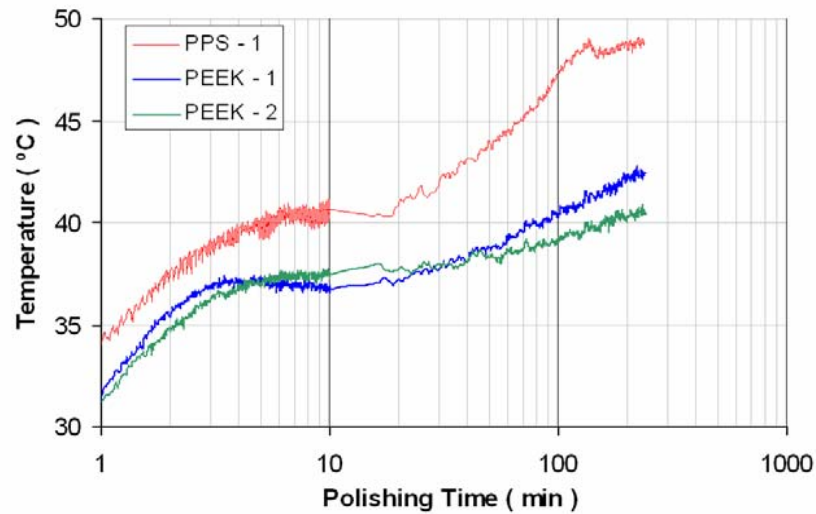
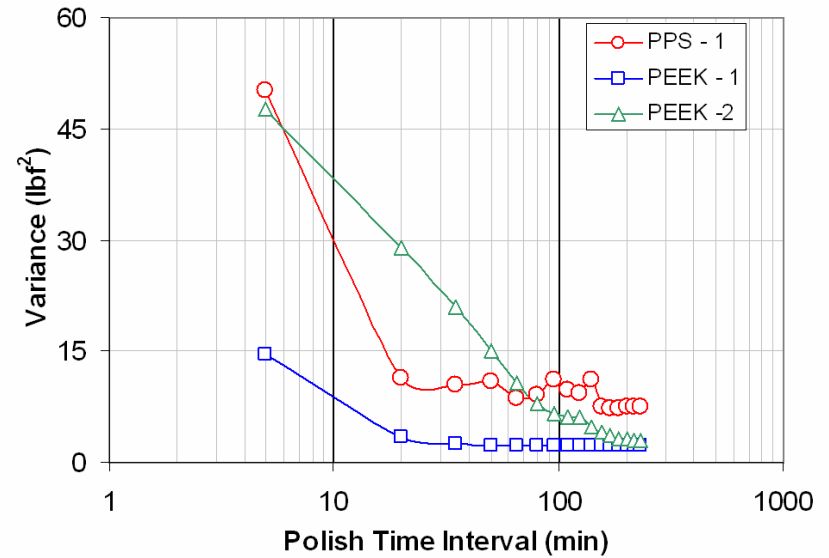
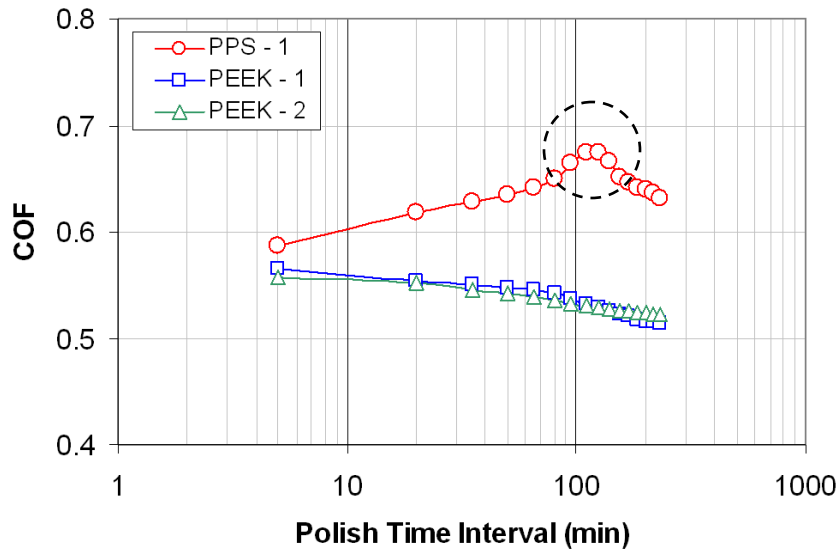


Wear Results

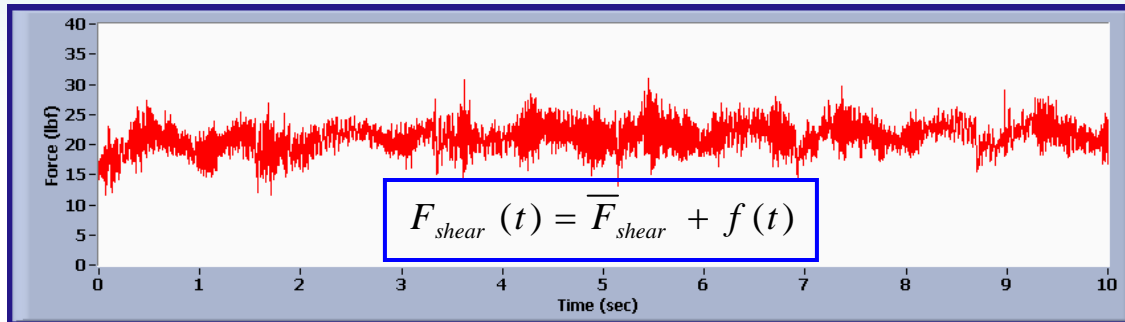
- Pre – and post – interferometry results from the micro-machined trenches indicates the following wear rates:
 - PPS – 1 28.2 microns per hour
 - PEEK – 1 24.0 microns per hour
 - PEEK – 2 23.5 microns per hour
- Micrometry results (taken from areas adjacent to the micro-machined trenches) indicate a difference of ± 13 percent compared to interferometry results



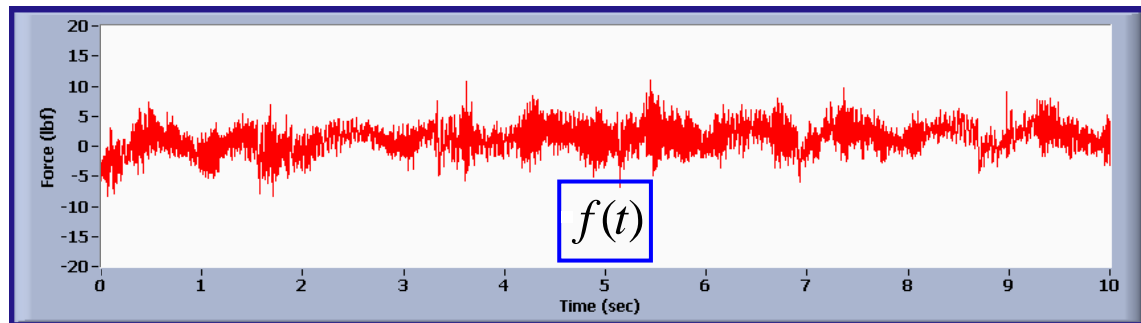
COF, Variance and Temperature Results



Spectral Analysis of Raw Shear Force Data

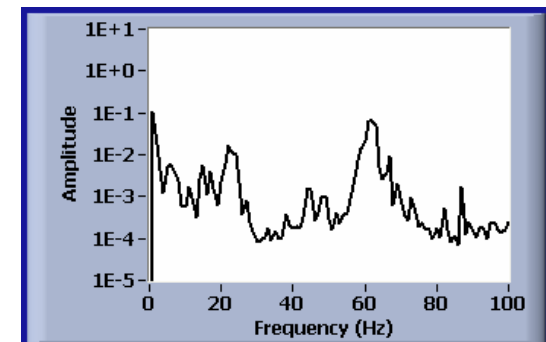


Subtracted by \bar{F}_{shear}



Time domain \rightarrow Frequency domain

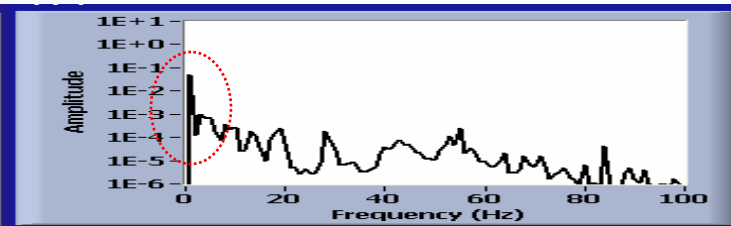
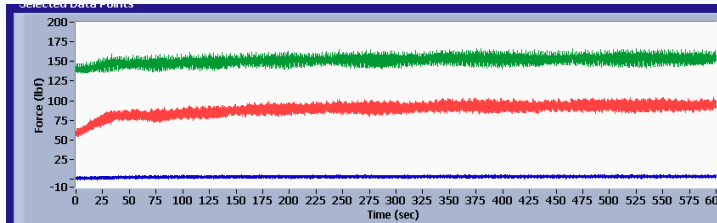
Fast Fourier Transform



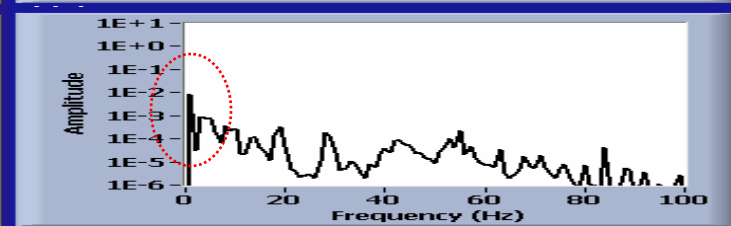
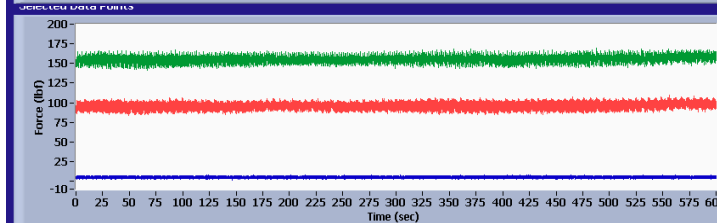
Shear Force Spectral Analysis

PPS ... Type - 1

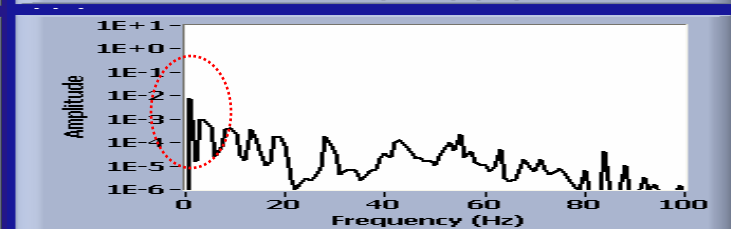
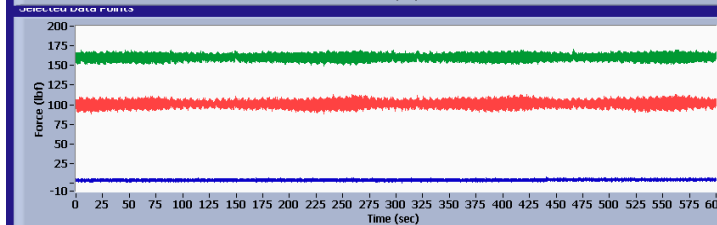
0 – 10 min



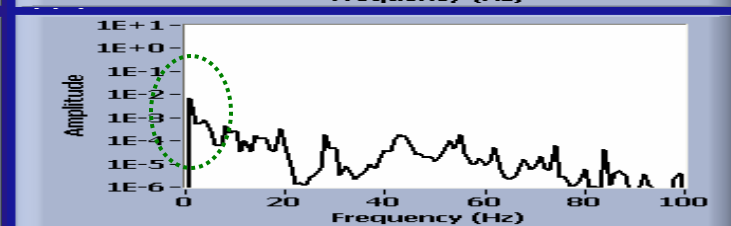
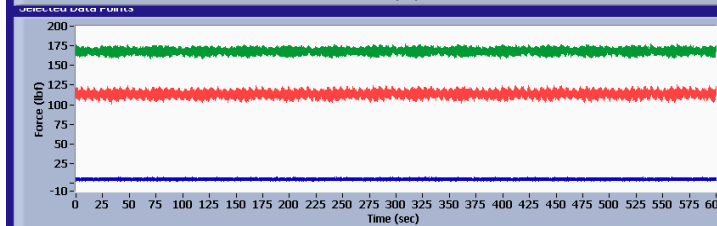
15 – 25 min



30 – 40 min



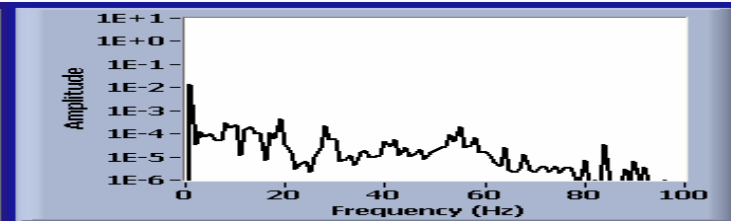
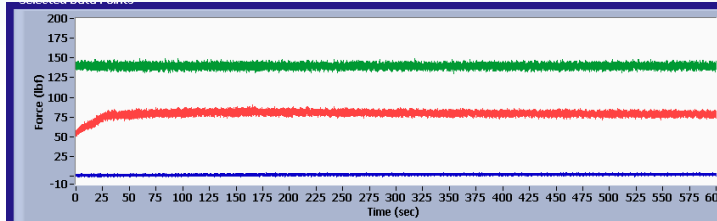
105 – 115 min



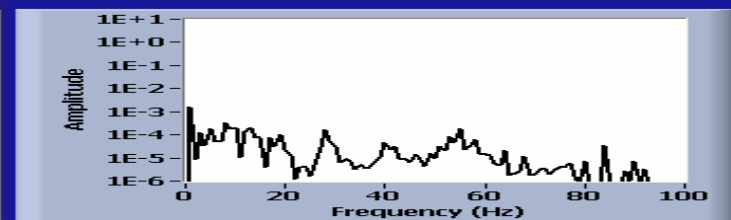
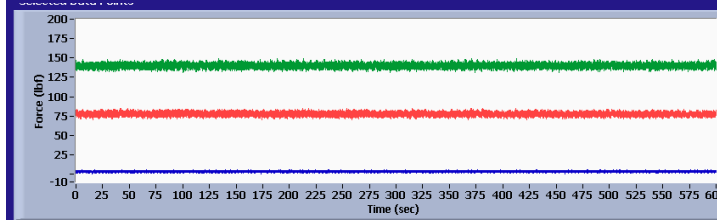
Shear Force Spectral Analysis

PEEK ... Type - 1

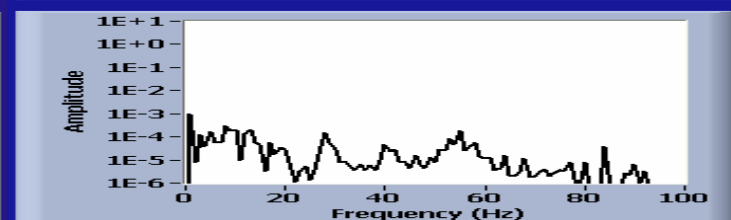
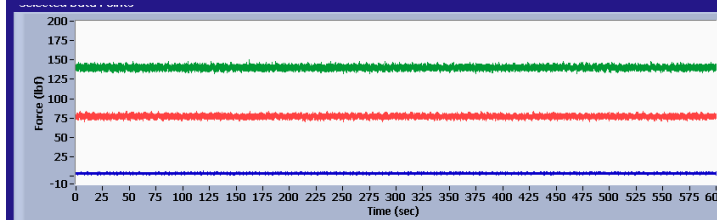
0 – 10 min



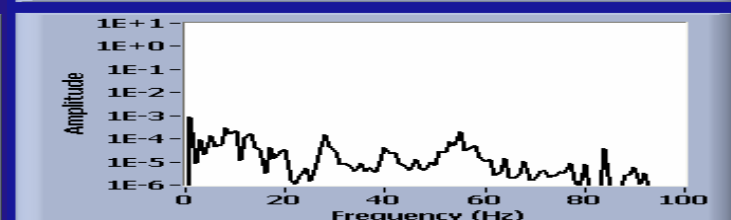
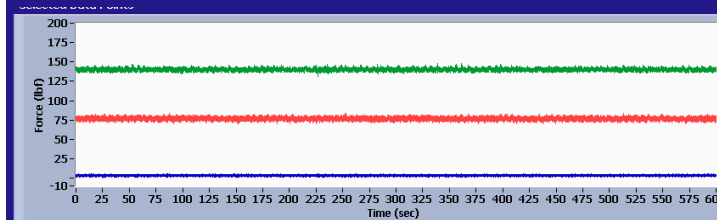
15 – 25 min



30 – 40 min



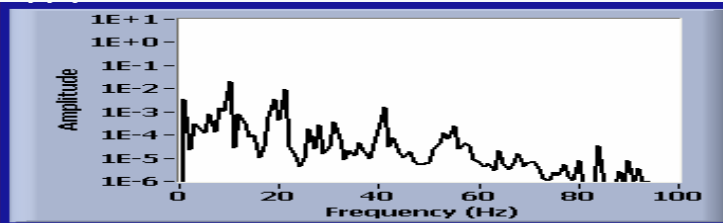
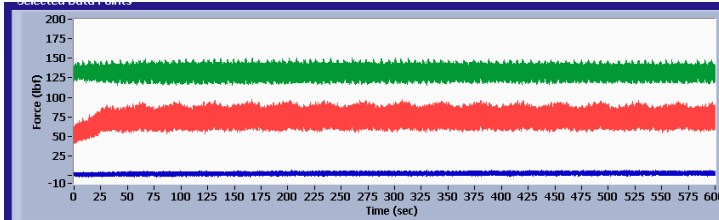
45 – 55 min



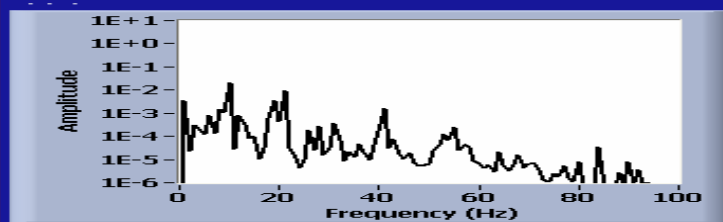
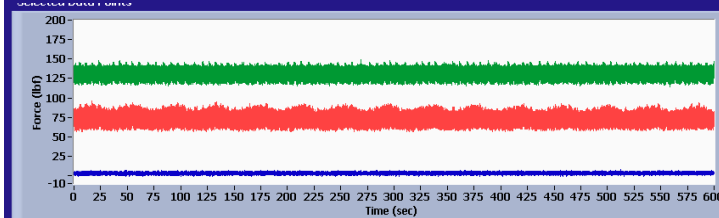
Shear Force Spectral Analysis

PEEK ... Type - 2

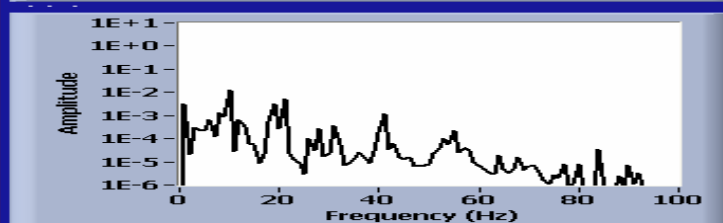
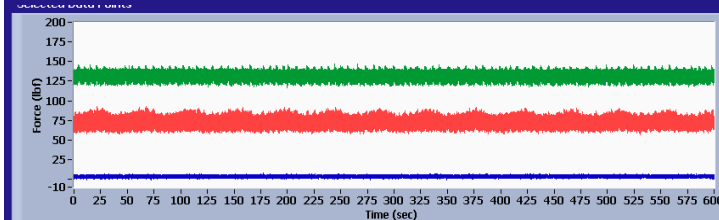
0 – 10 min



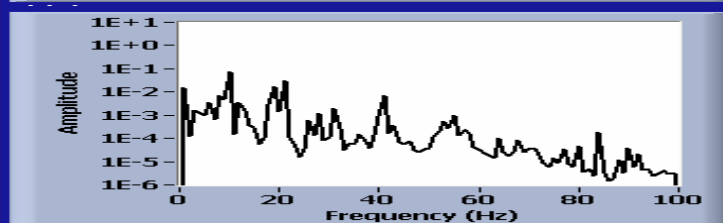
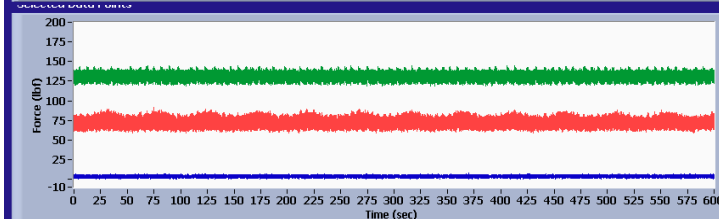
15 – 25 min



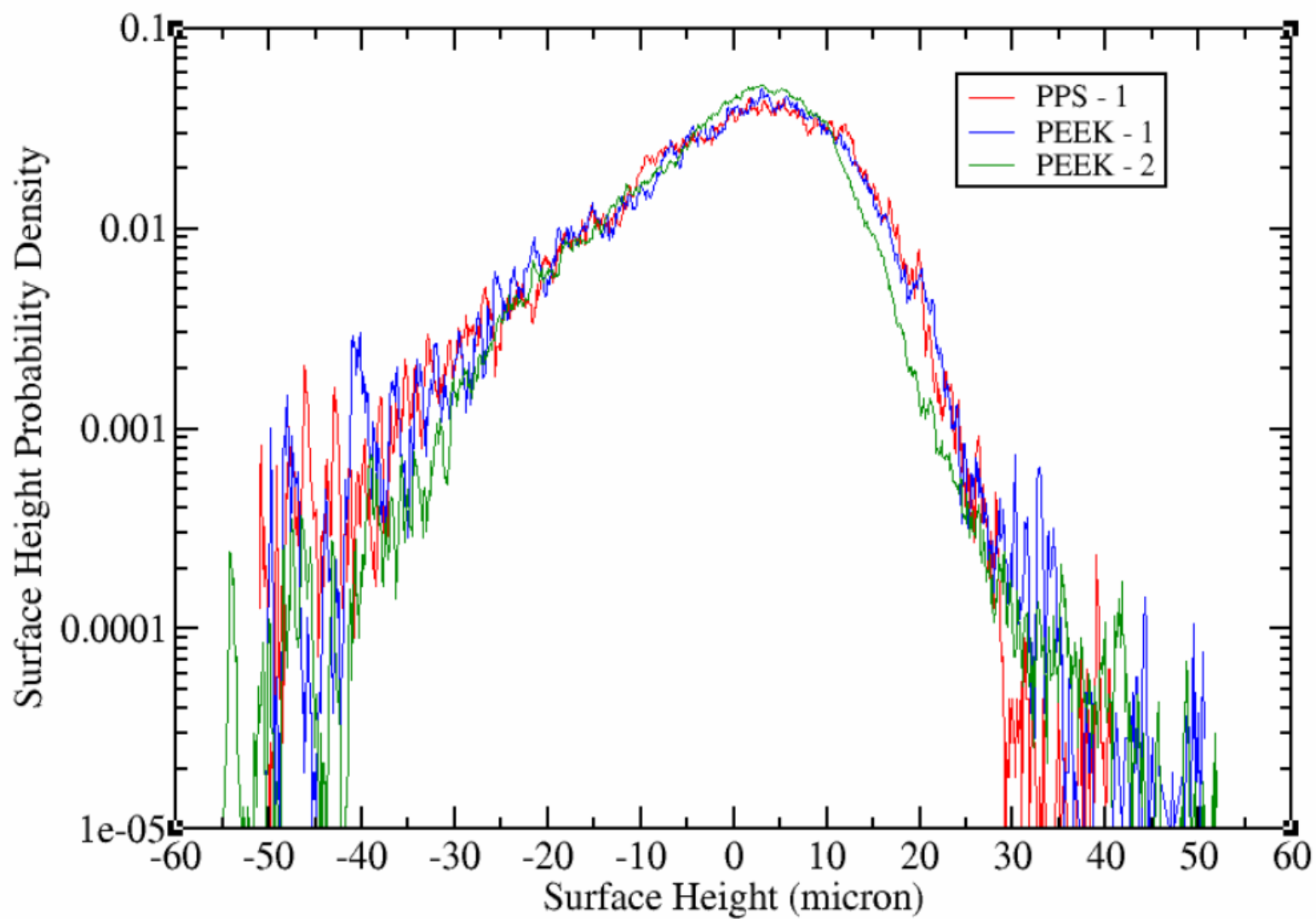
30 – 40 min



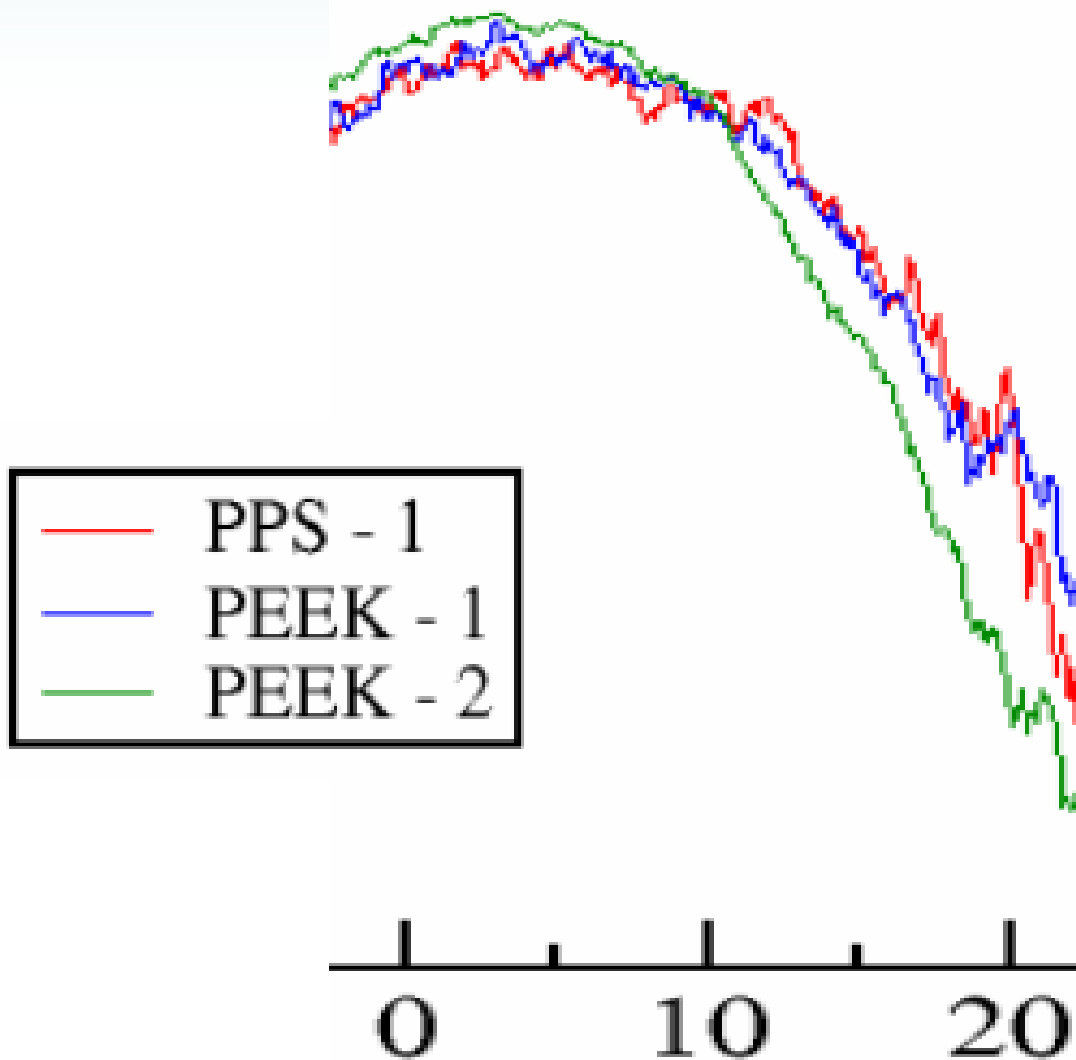
45 – 55 min



Post-Wear Pad Surface Height PDFs



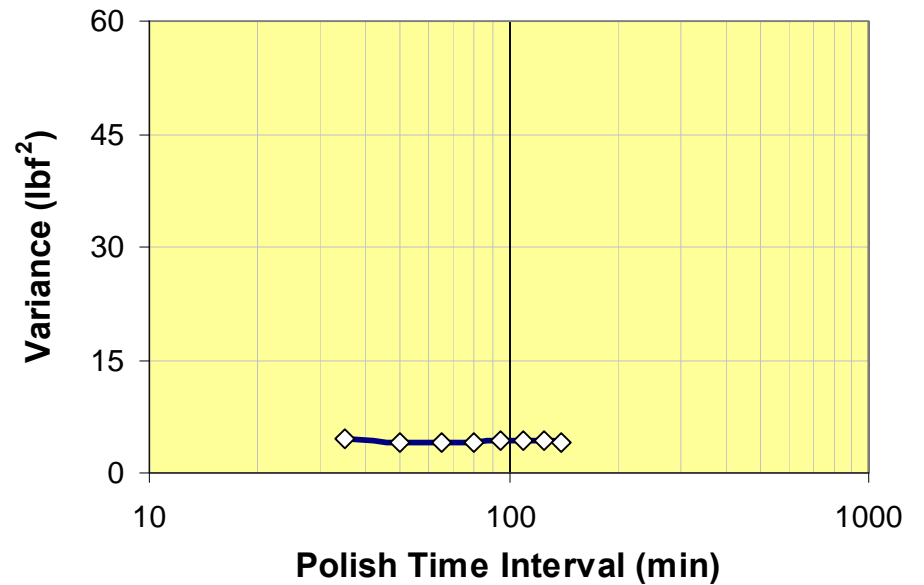
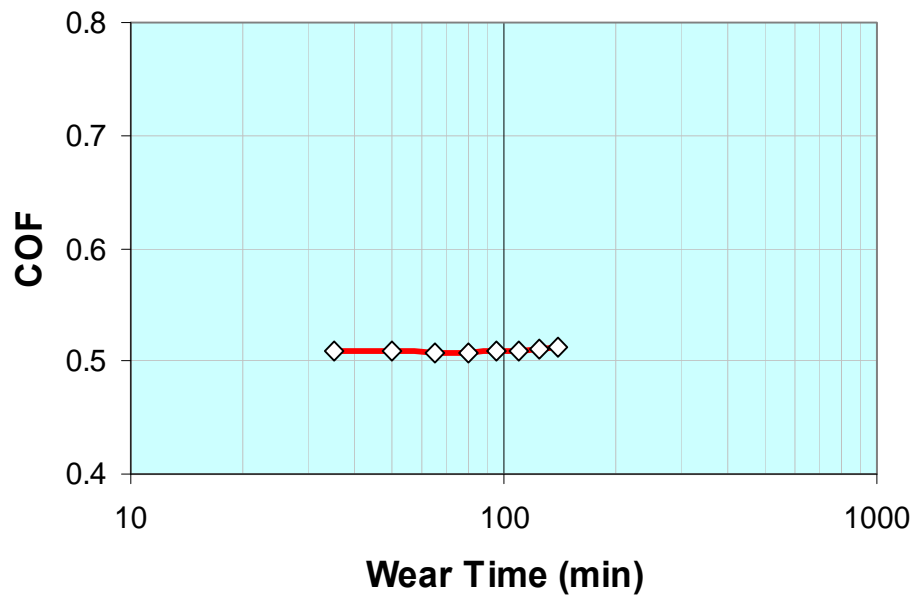
Post-Wear Pad Surface Height PDFs



Preliminary COF and Variance Results

PEEK ... Type – 3

A new design ... please contact Entegris for details



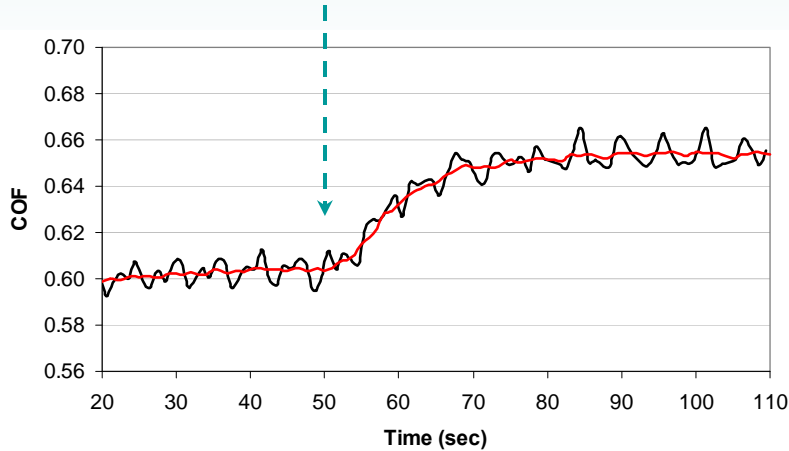
Slurry Entrainment Studies ... Experimental

- PEEK – 1 and PEEK – 2
- 2 and 4 PSI ring pressure
- 100 and 200 cc per minute slurry flow rate
- 0.6 and 1.2 m per second sliding velocity

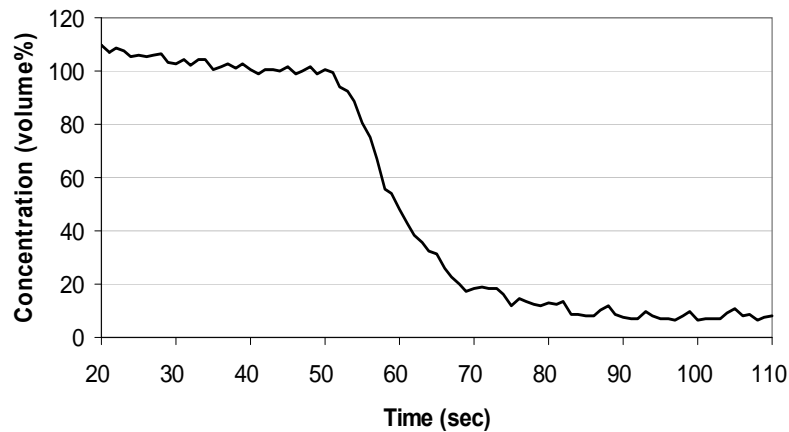
- 1 min polish
- RHEM IC1020 A4 M – groove pad
- Undiluted CMC iCue600Y75 copper slurry as 'INITIAL' slurry
- 9 : 1 (water : CMC slurry) as 'FINAL' slurry
- 4 – inch 3M full-face A165 diamond disc rotating at 95 RPM and sweeping at 11 times per minute
- In-situ pad conditioning at 5.8 lb_f

Residence Time Distribution Technique

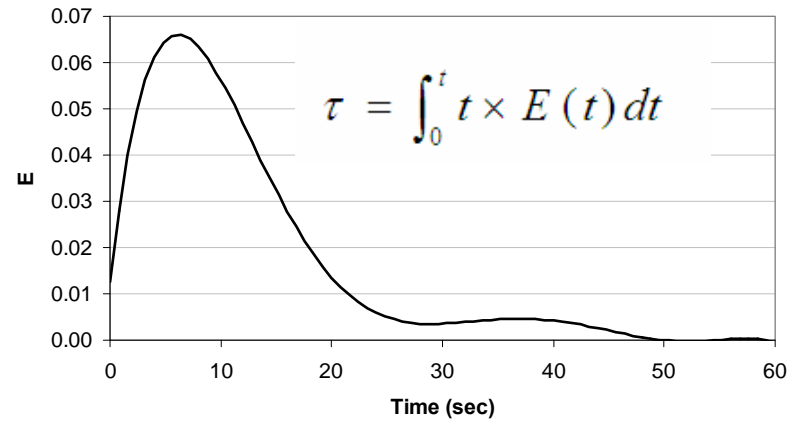
Time of switching from
INITIAL to **FINAL** slurry



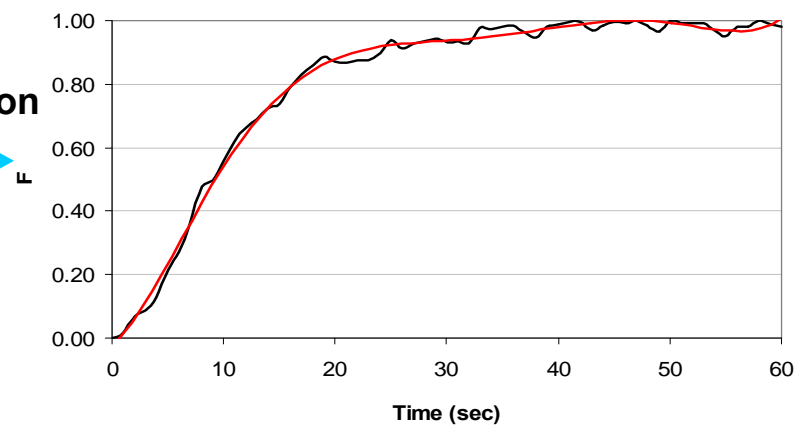
**COF – to – Concentration
calibration**



Normalization

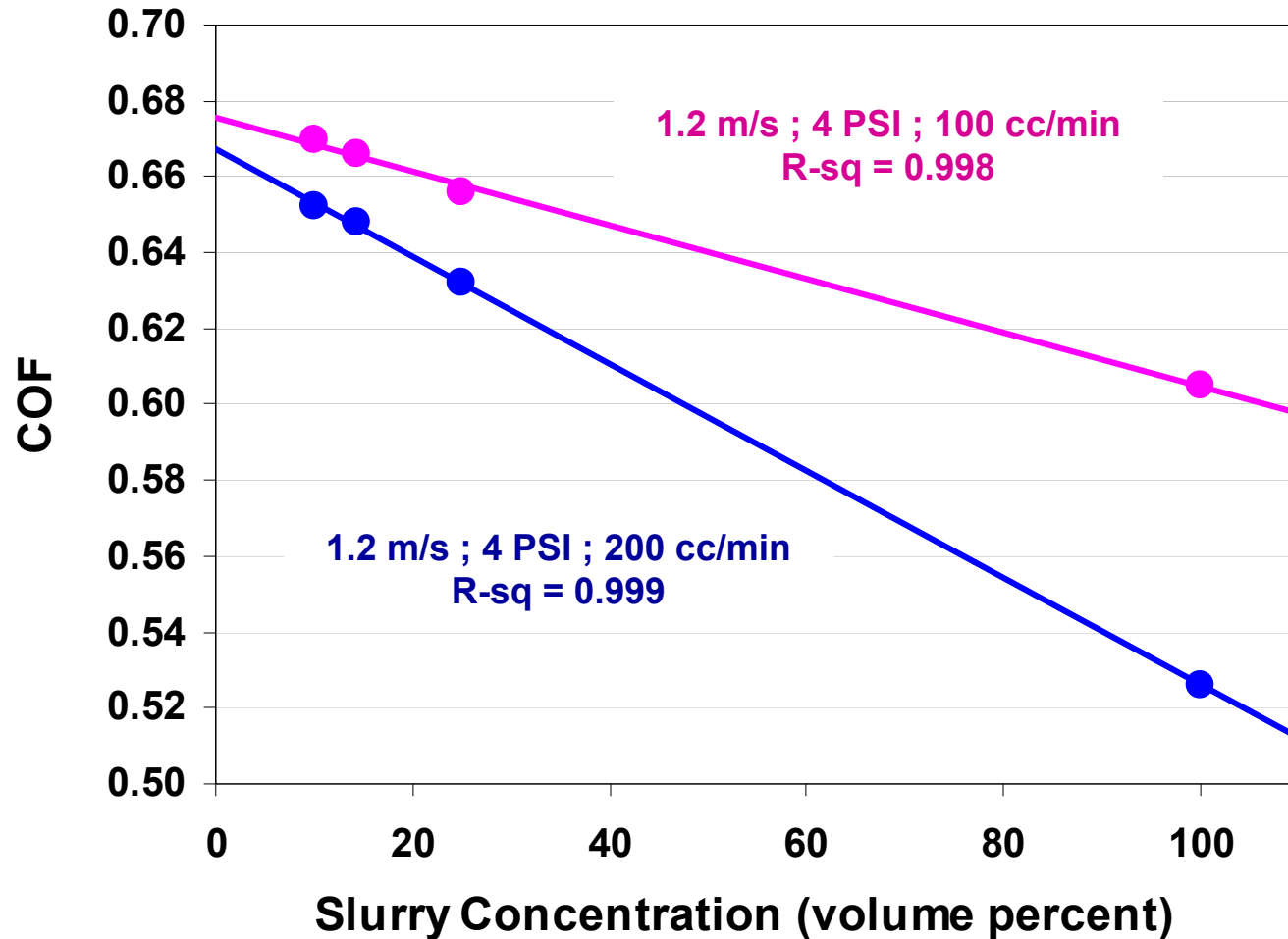


$$E = \frac{dF}{dt}$$



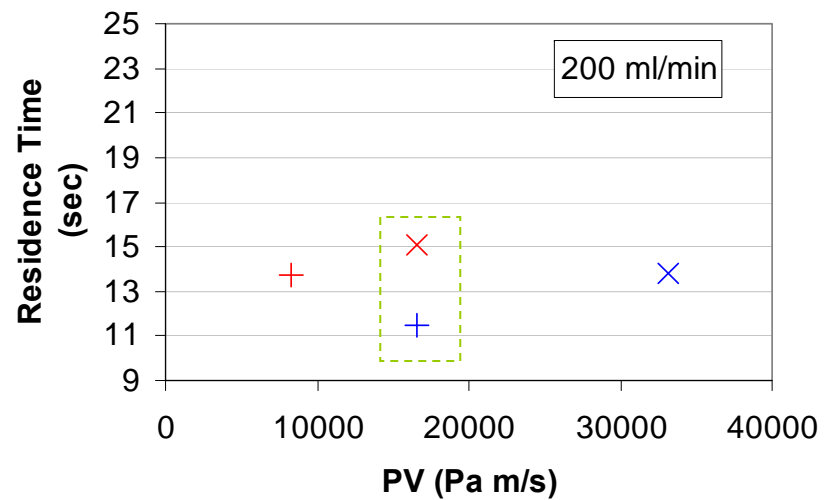
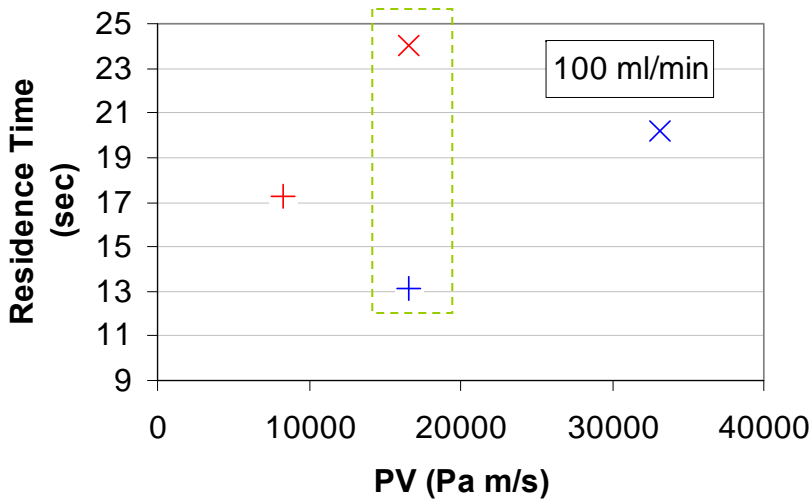
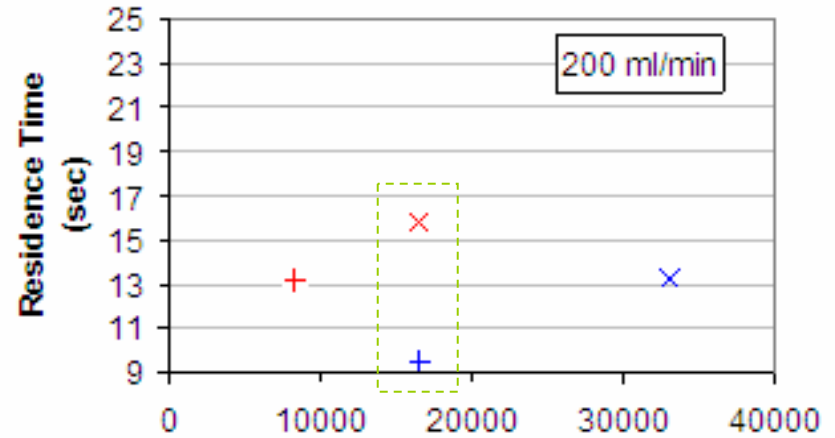
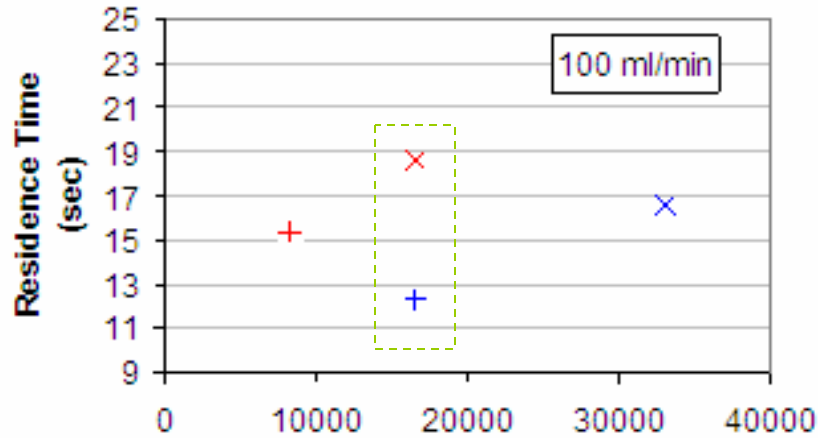
COF – to – Concentration Calibration Curves

In all 16 combinations of experimental conditions, R-square ranged from **0.916** to **0.999**



Slurry Mean Residence Time Results

PEEK – 1 (top) and PEEK – 2 (bottom)



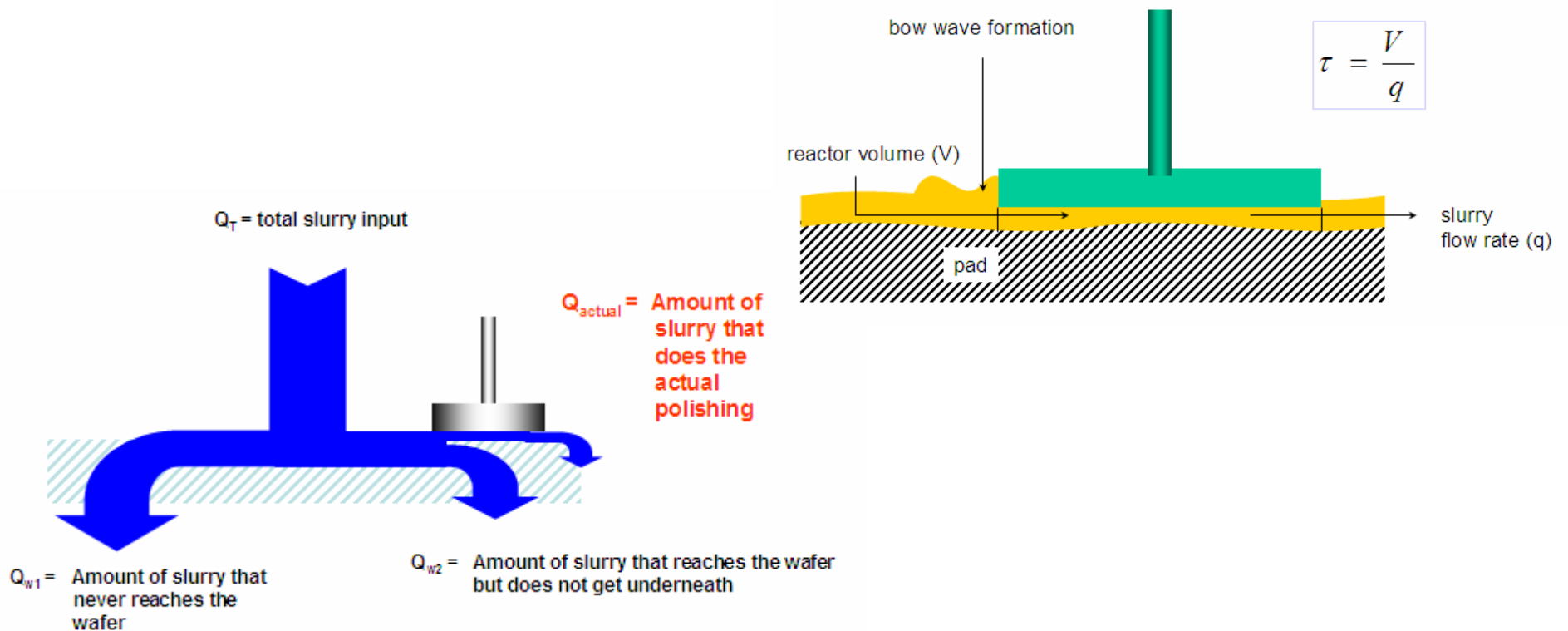
+ 0.6 m/s - 2 PSI	+ 0.6 m/s - 4 PSI
x 1.2 m/s - 2 PSI	x 1.2 m/s - 4 PSI

+ 0.6 m/s - 2 PSI	+ 0.6 m/s - 4 PSI
x 1.2 m/s - 2 PSI	x 1.2 m/s - 4 PSI

Mean Residence Time Trend Analysis

- Effect of Flow Rate

- Higher flow rates **decrease** MRT (on average, a 2X increase in flow causes MRT to **decrease** by only 25 percent)
- CMP is an open system with plenty of slurry being wasted



Mean Residence Time Trend Analysis

- Effect of Sliding Velocity

- Higher sliding velocities **increase** MRT (on average, a 2X increase in sliding velocity causes MRT to **increase** by 30 percent)

Low Velocity (left) and High Velocity (right)

(constant flow rate and pressure in both cases)

... DEUVEF images explain as to why MRT increases as platen speed increases ...

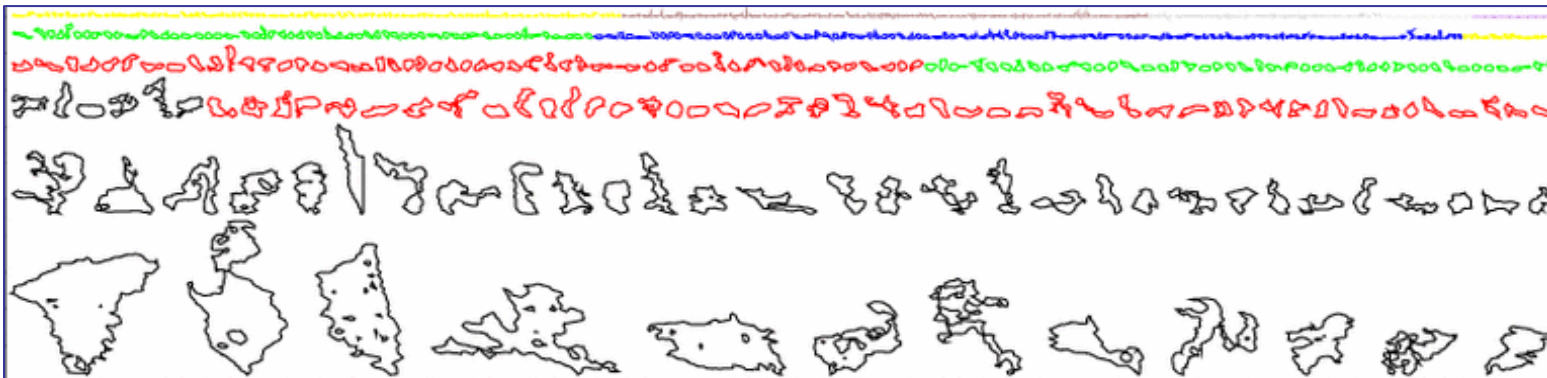
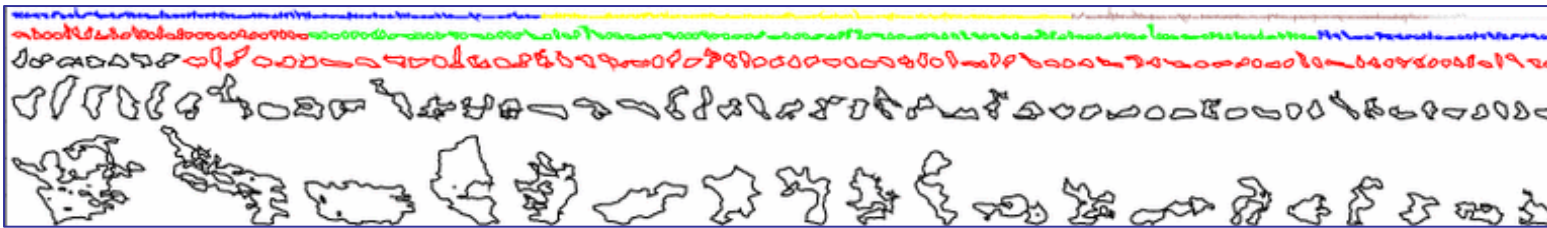


Mean Residence Time Trend Analysis

- Effect of Pressure

- Higher pressures **decrease** MRT (on average, a 2X increase in pressure causes MRT to **decrease** by 15 percent)

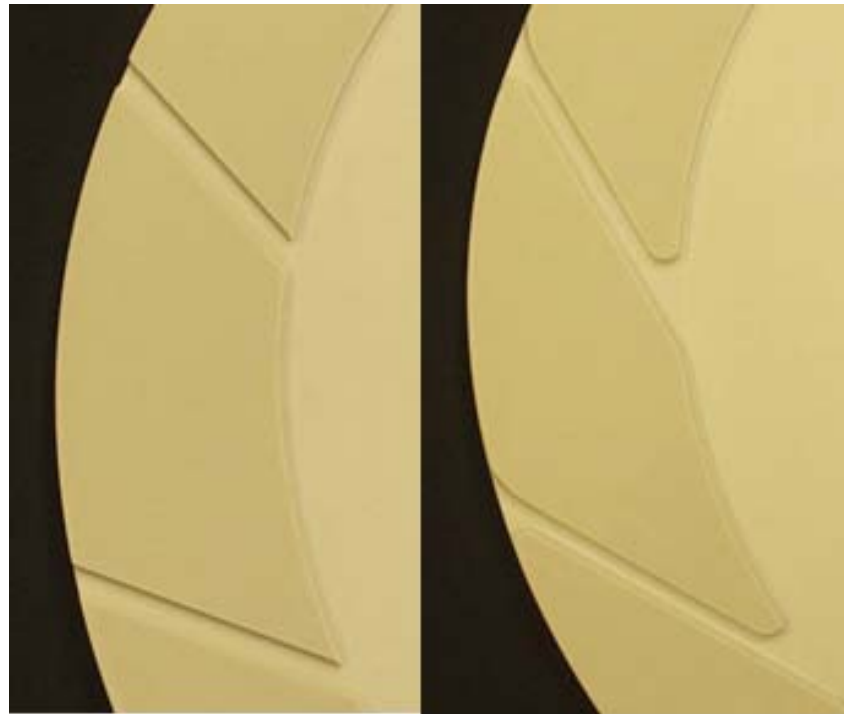
Laser Confocal Microscopy Examples of Pad Contacting Features at Low (top) and High (bottom) Pressures



$$\tau = \frac{V}{q}$$

Mean Residence Time Trend Analysis

- Effect of Retaining Ring Design
 - **Design – 1** is 10 – 20 percent more efficient in getting slurry in and out of the wafer – pad interface



Design – 1

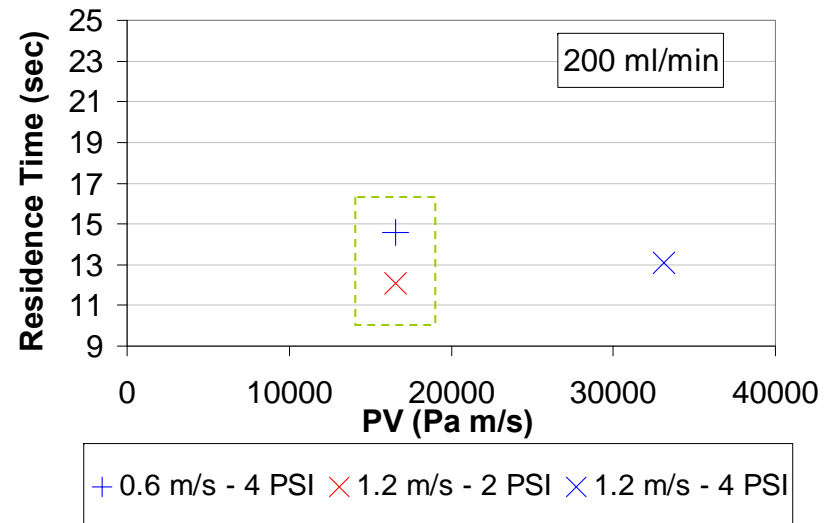
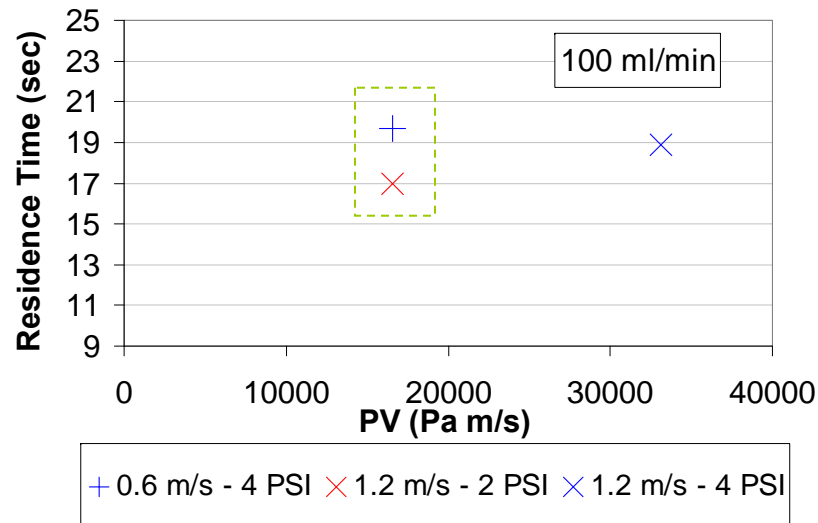
Design – 2

Preliminary MRT Results

- Effect of Retaining Ring Design
 - Design – 3 is just as efficient as Design – 1 in getting slurry in and out of the wafer – pad interface
 - Design – 3 does not have the 2-factor (i.e. $P \times V$) effect seen in Design – 1 and Design – 2

PEEK ... Type – 3

A new design ... please contact Entegris for details



Summary

- Our goal has been to **develop methods and perform experiments to determine how ring design and materials of construction affect:**
 - **Shear force (average and variance)**
 - **Wear rate**
 - **Temperature**
 - **Pad micro-texture**
 - **Slurry entrainment**