Fundamental Characterizations of Diamond Disc, Pad, and Retaining Ring Wear in Chemical Mechanical Planarization Processes

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Outline

Introduction

Diamond disc wear characterization

- Active diamond characterization
- Aggressive diamond characterization
- Diamond wear characterization

Pad wear characterization

- Pad macro wear characterization
- Pad surface micro wear characterization

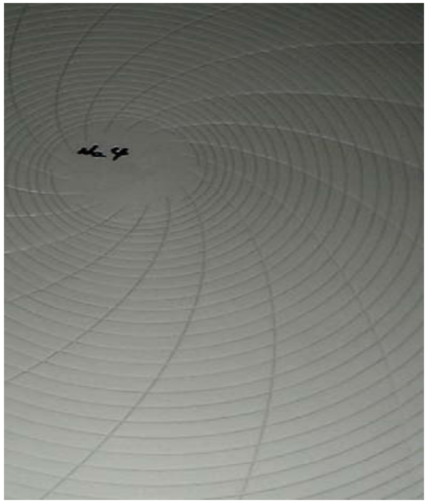
Retaining ring wear characterization

Summary

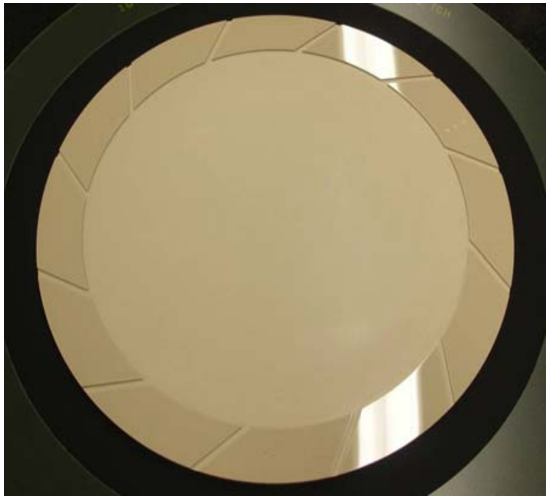
Introduction

Diamond disc

Pad



Retaining Ring



During pad conditioning, the interactions between the pad and diamond disc result in not only pad wear but also diamond disc wear.

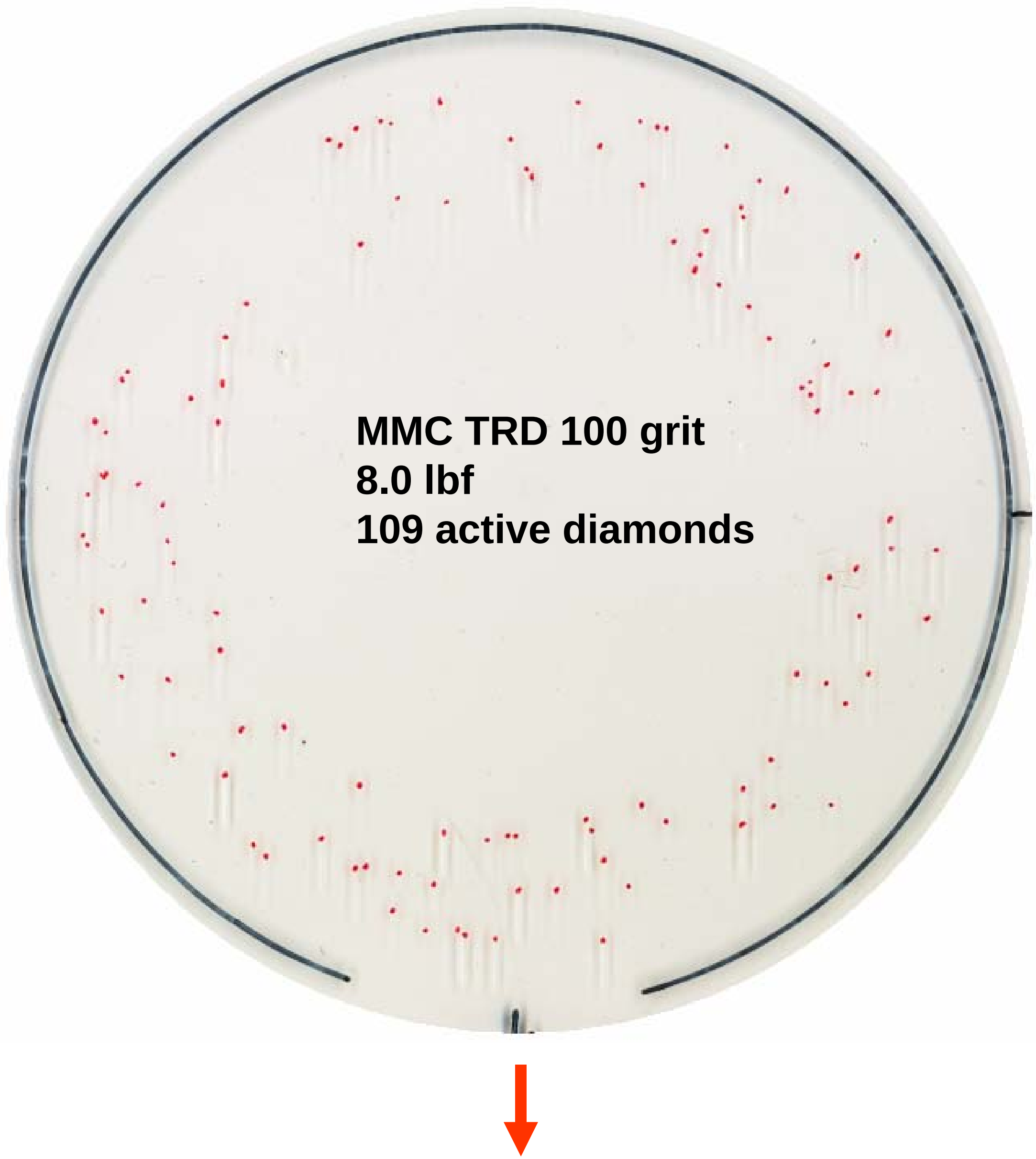
During wafer polishing, the interactions between the pad and retaining ring result in not only pad wear but also retaining ring wear.

Diamond Disc Wear Characterization

- Active diamond characterization
- Aggressive diamond characterization
- Diamond wear characterization

Identify Active Diamonds - Short Draw Test

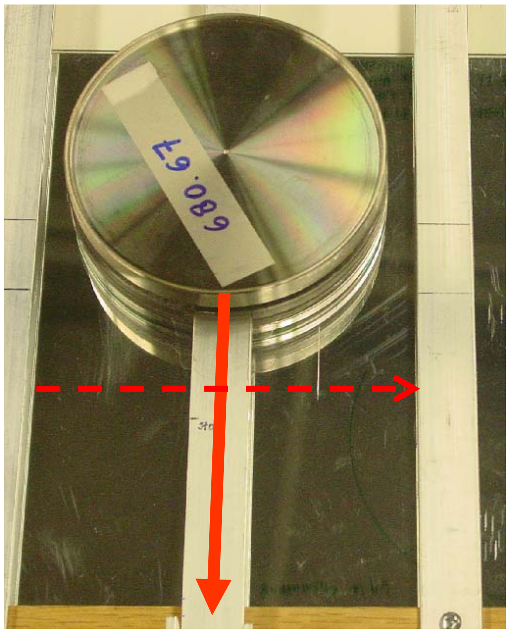
Patent Applied for US 11/528,825



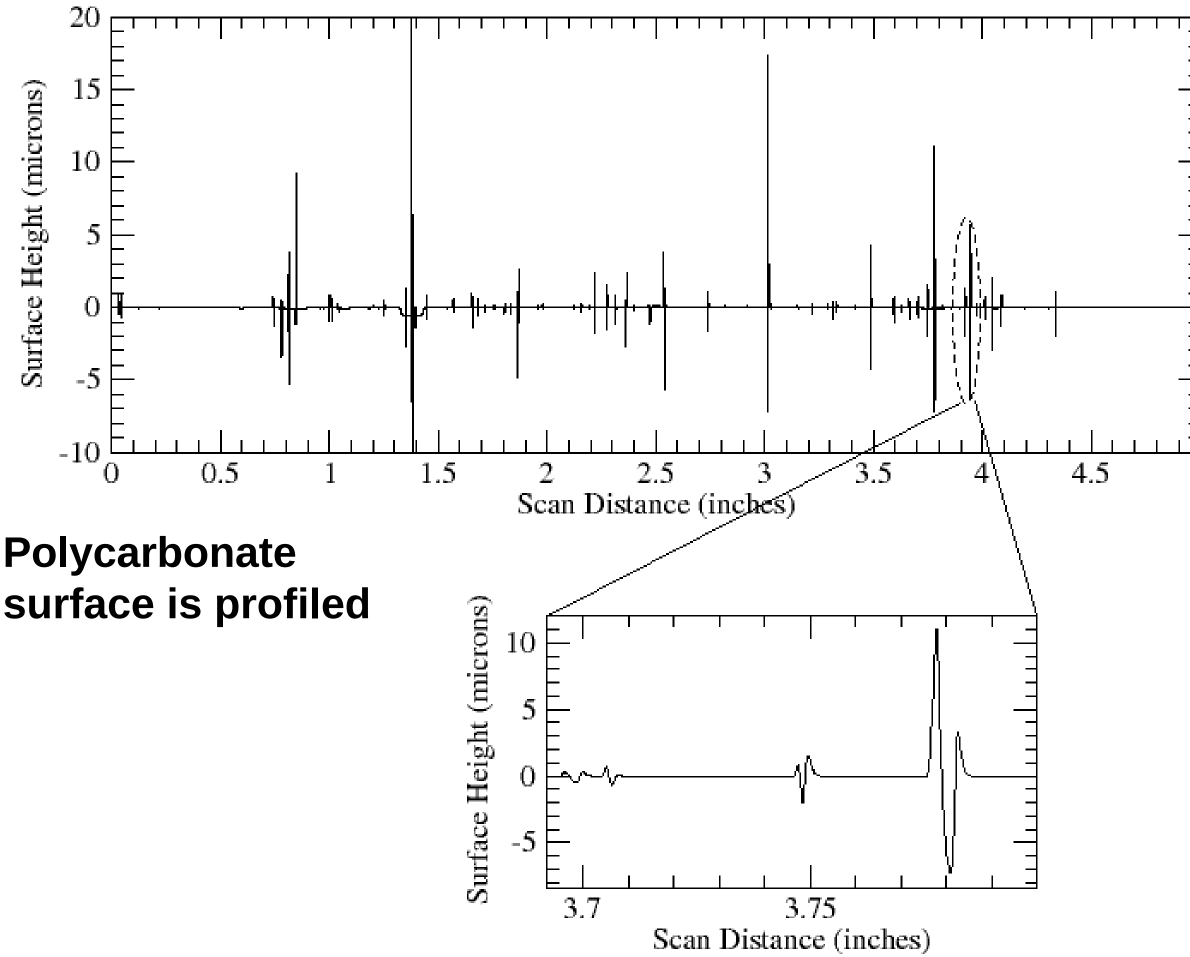
Conditioner is pulled only about ¼".

Scratch origins are marked.
- **Faint scratches**
- **Partial scratches**

Identify Aggressive Diamonds - Long Draw Test



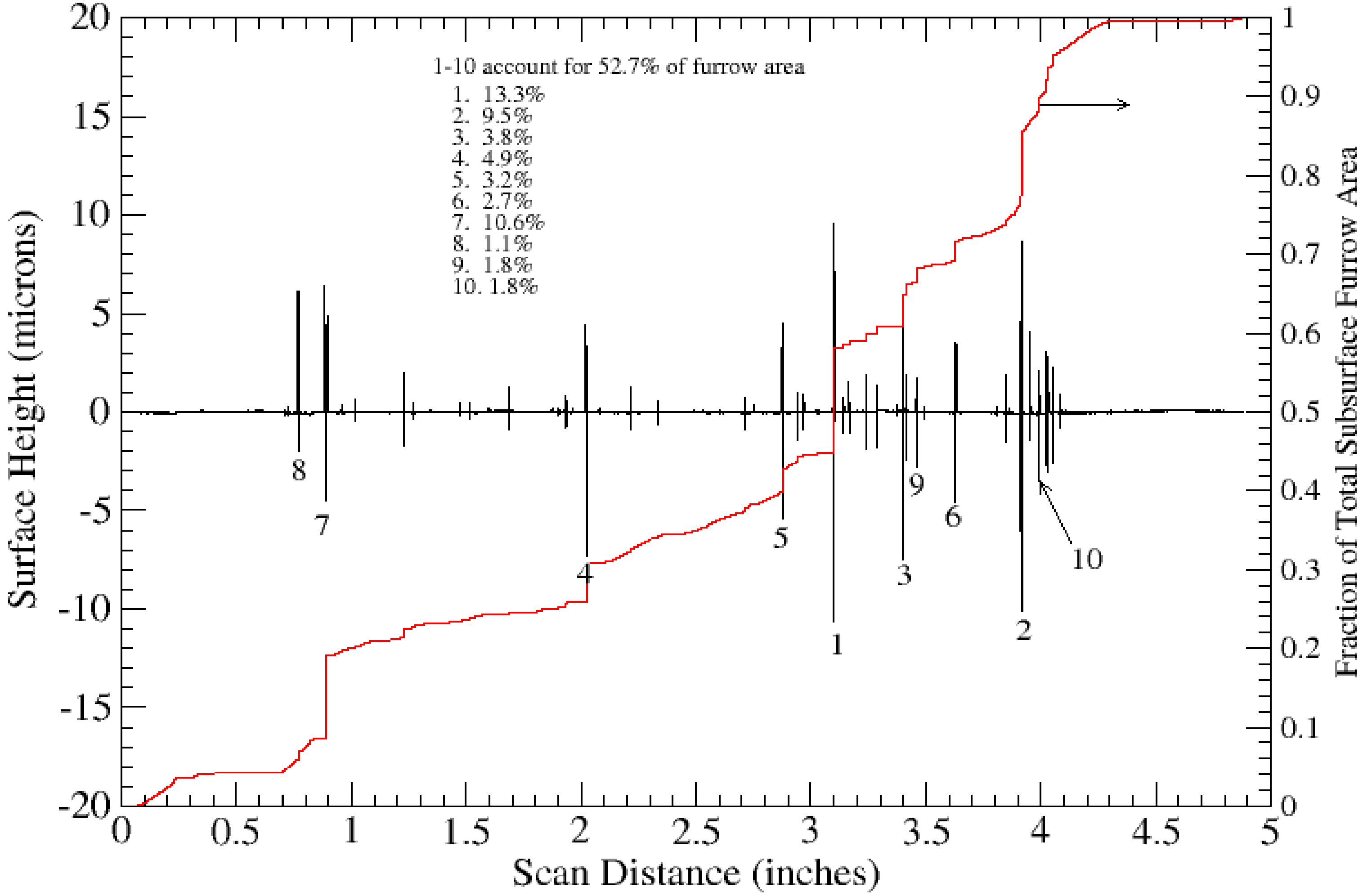
Conditioner is pulled more than one diameter.



Polycarbonate surface is profiled

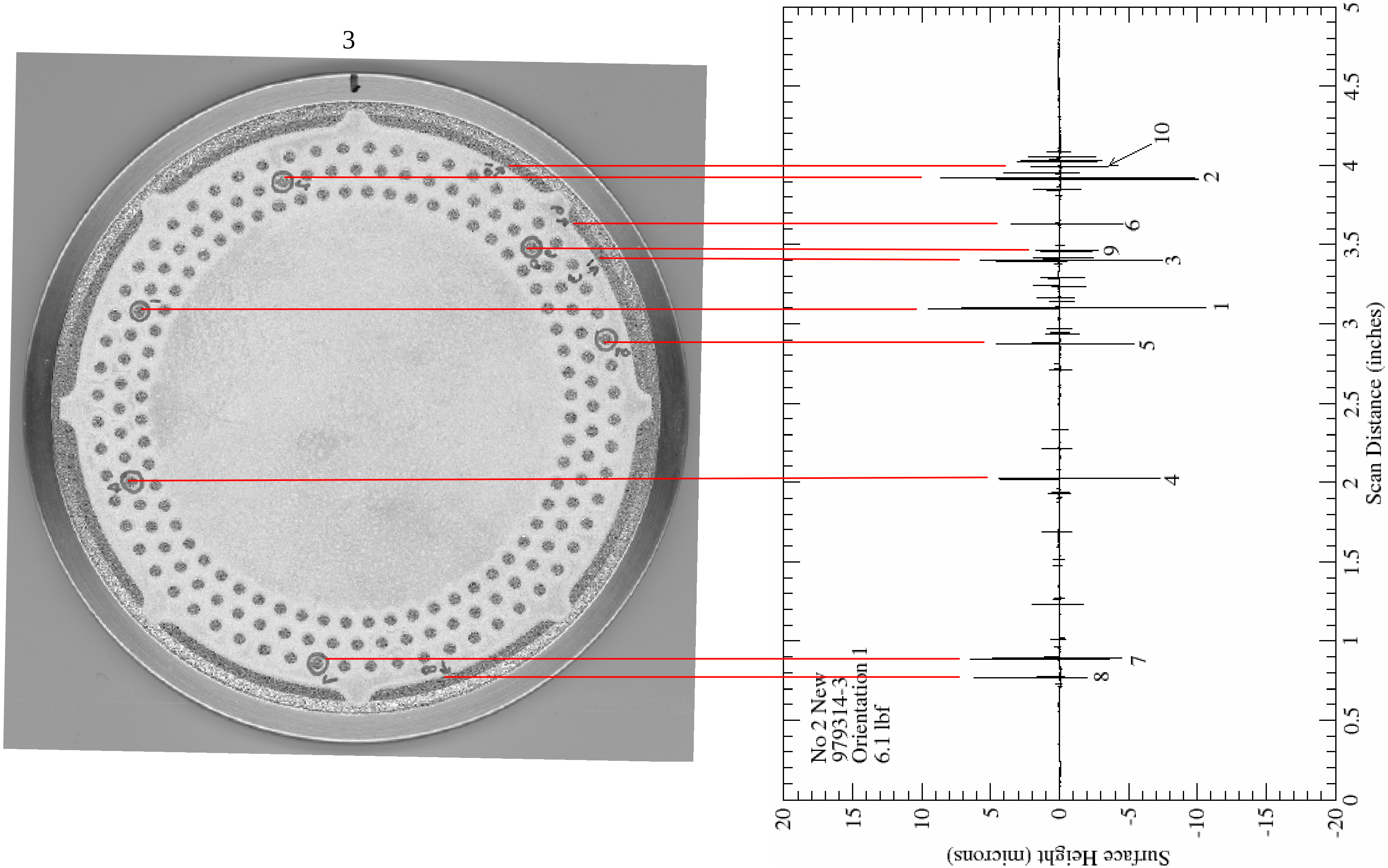
Sometimes color is used for contrast

Furrow Surface Area Analysis

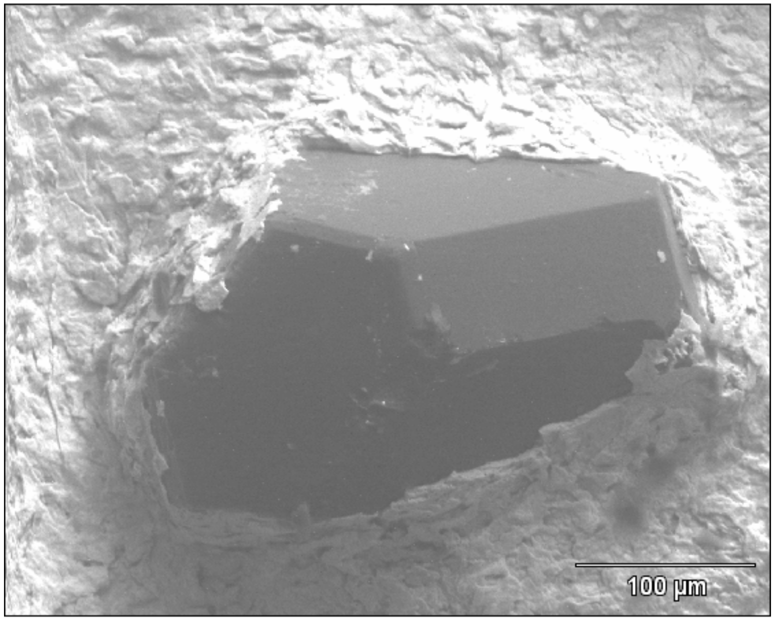


The ten most aggressive diamonds account for more than 50% of pad cut rate during conditioning.

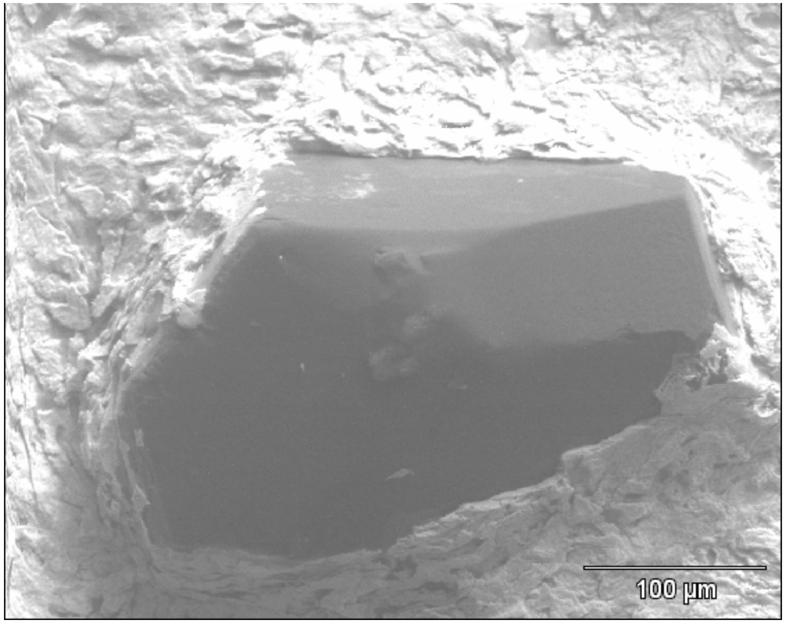
Locate Aggressive Diamonds



Diamond Wear



New aggressive diamond



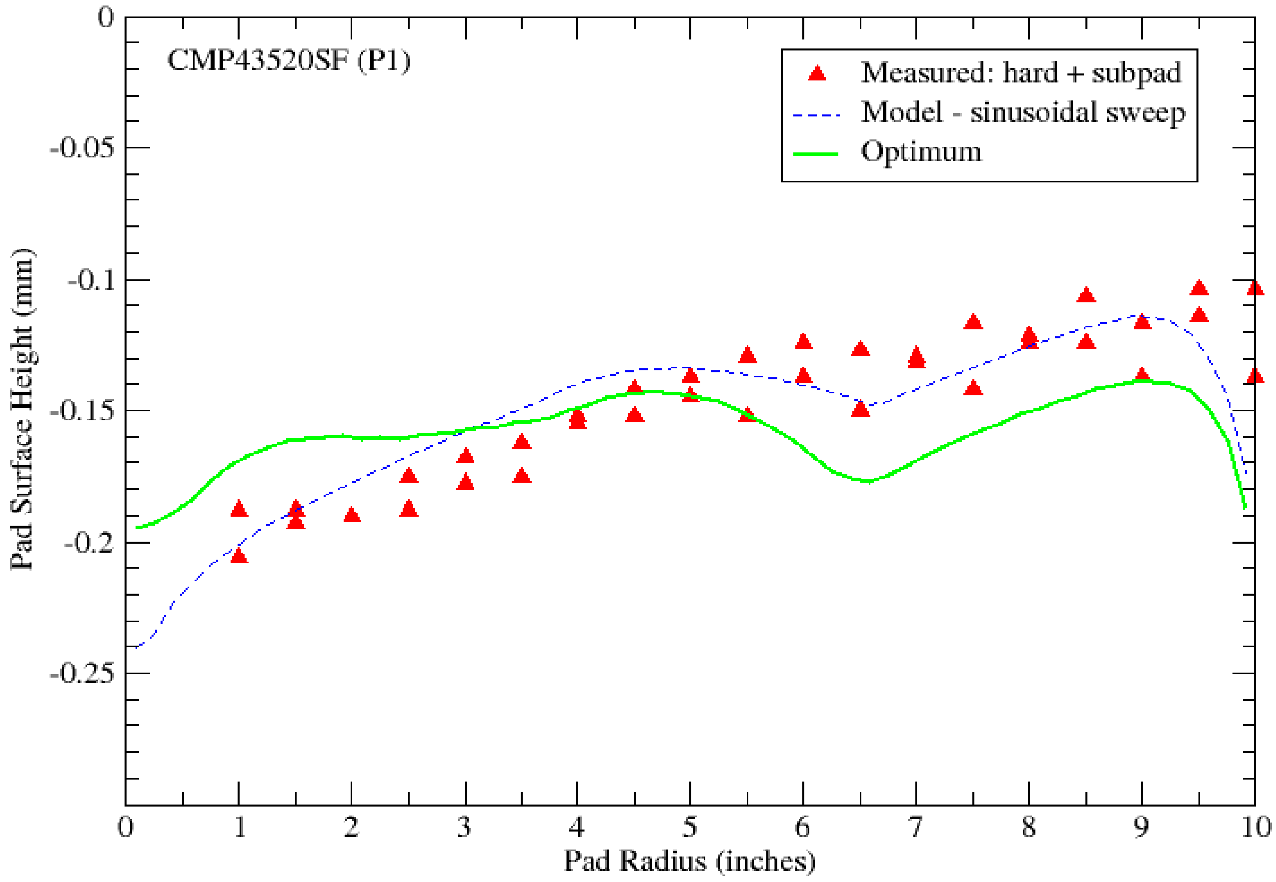
Same diamond after wear test

Normally there is no bulk wear on the diamond and micro wear occurs on the cutting edges of the diamond.

Pad Wear Characterization

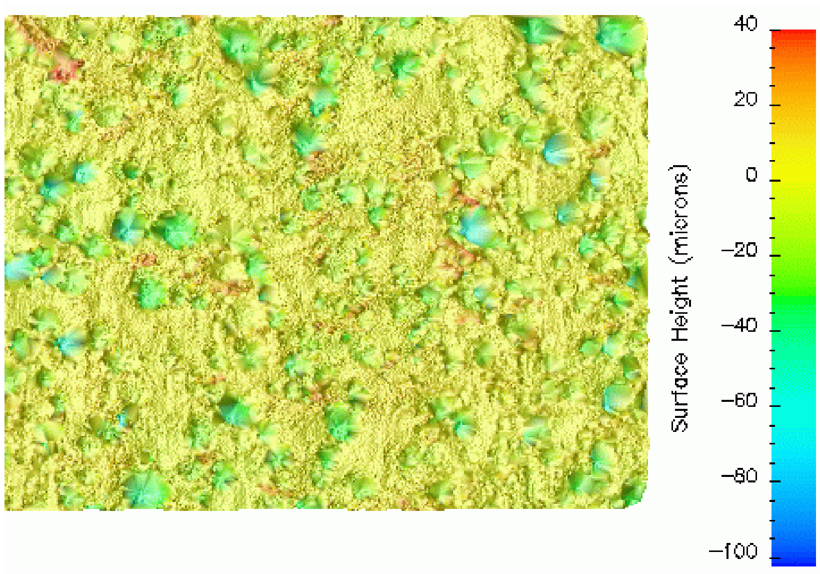
- Pad macro wear characterization
- Pad surface micro wear characterization

Pad Macro Wear Characterization

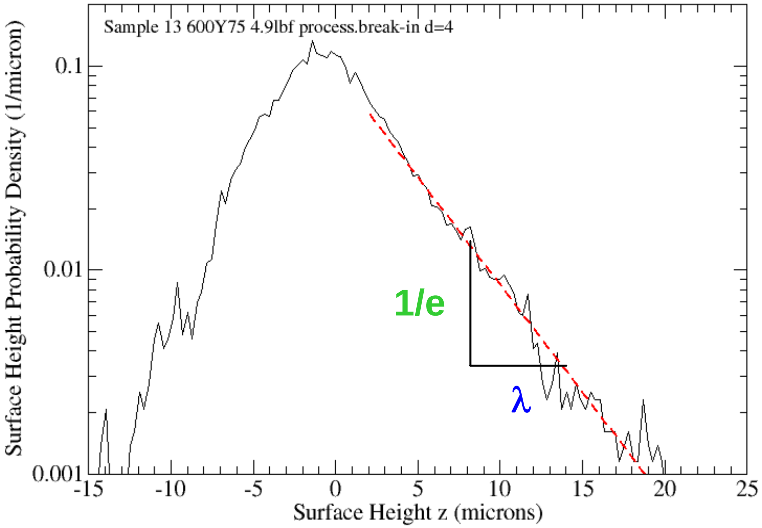


Optimization of the pad conditioning sweep schedule on a rotary polishing tool can significantly improve the pad macro wear uniformity.

Pad Surface Interferometry Analysis



Pad surface interferometry image

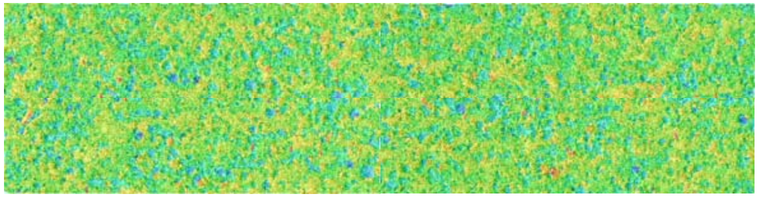


Pad surface abruptness extraction

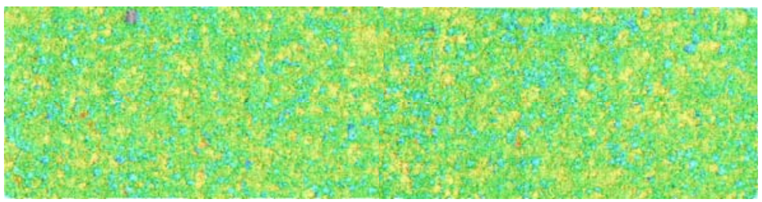
Profilometry analysis: surface roughness (top pad asperities to pad valleys), no consistent correlation with material removal rates.

Interferometry analysis: surface abruptness (top 20 - 30 μm pad asperities), closely correlated with material removal rates.

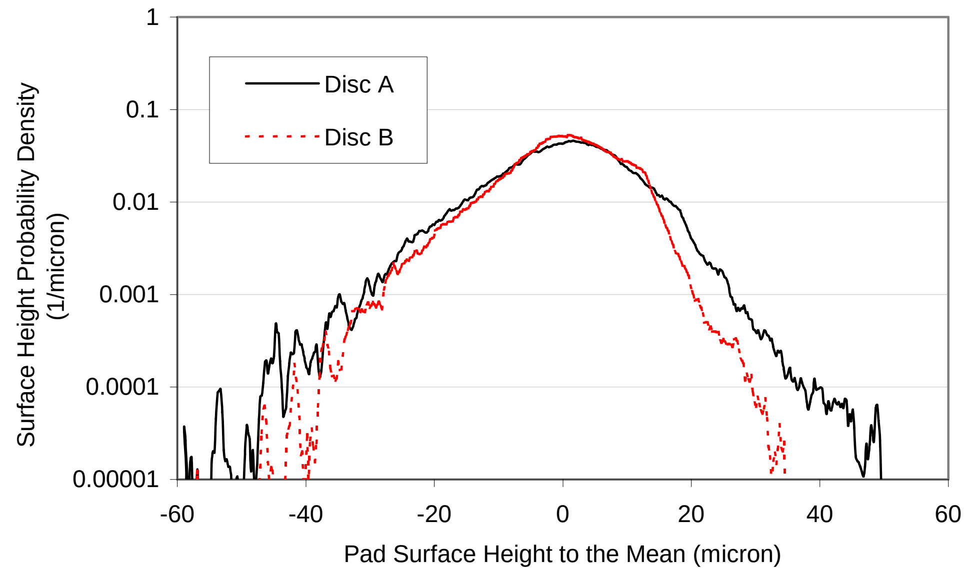
Effect of Pad Conditioning



Conditioned by Disc A



Conditioned by Disc B



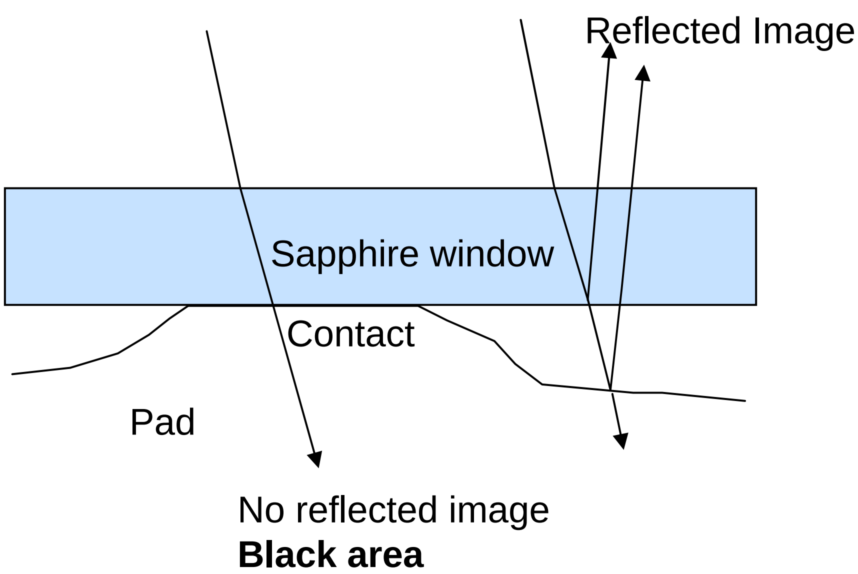
Disc aggressiveness	**A > B**
Coefficient of friction	**A > B**
Variance of shear force	**A > B**
Pad surface abruptness	**A > B**
ILD removal rate	**A > B**

Pad Surface Contact Area Measurement

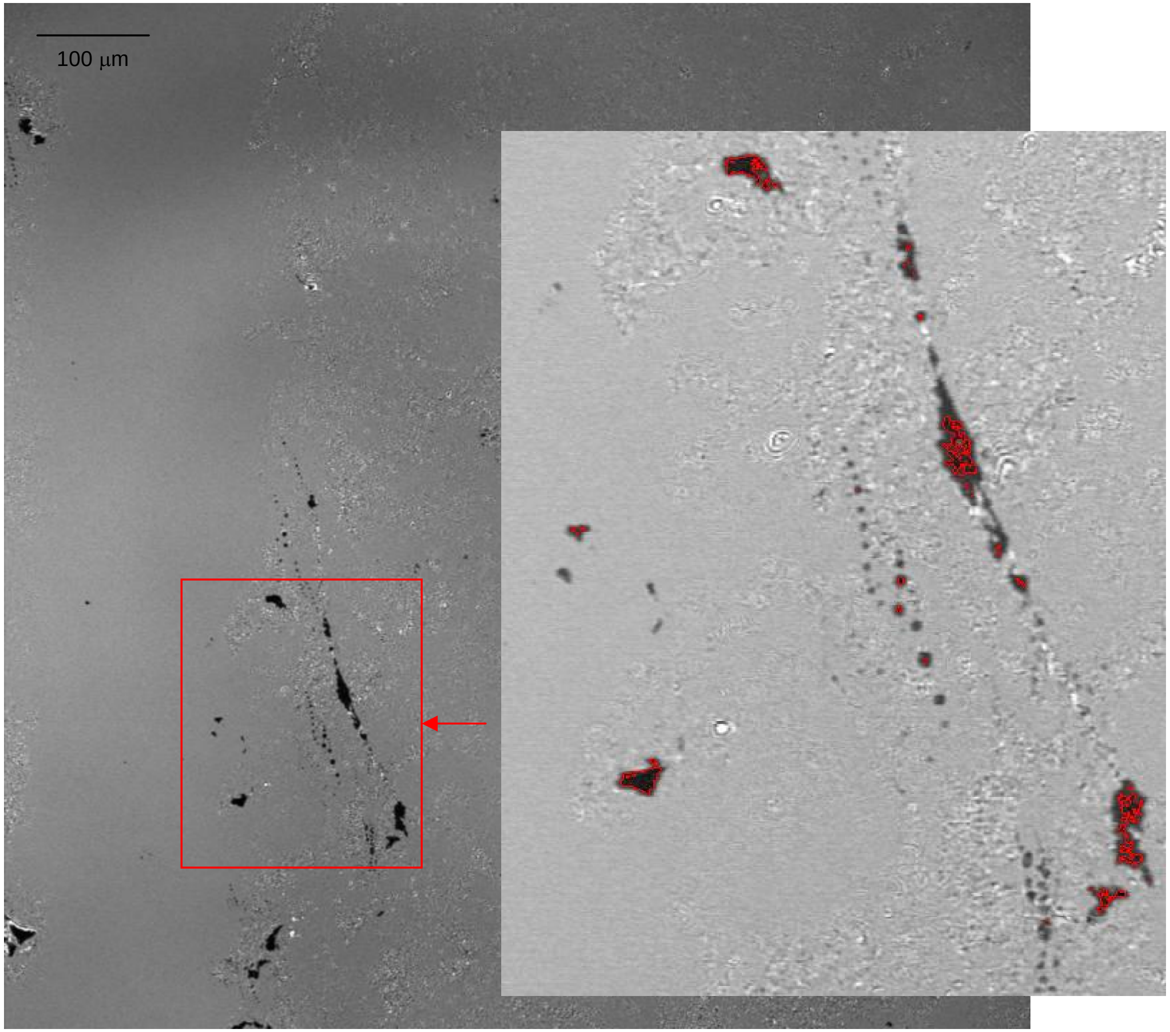
Laser Confocal Microscopy

Zeiss LSM 510 Meta NLO
Plan-Neoflaur 10x/0.3 objective
488 nm wavelength laser

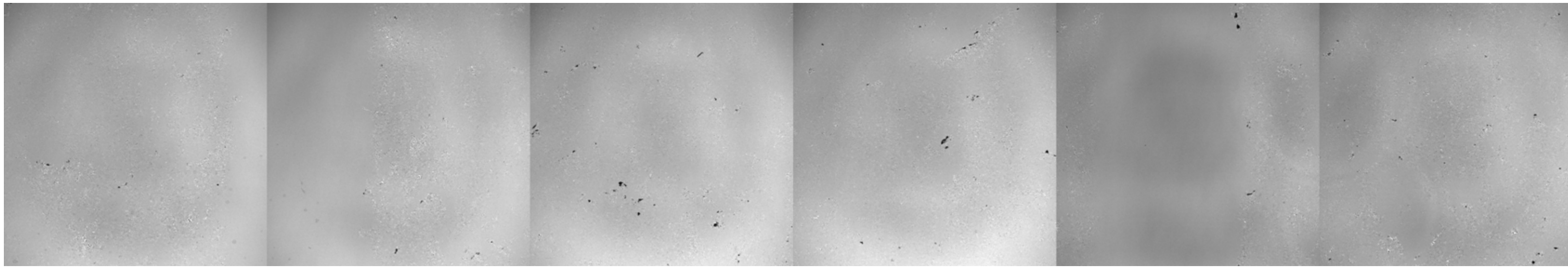
Sample holder with sapphire window and load cell

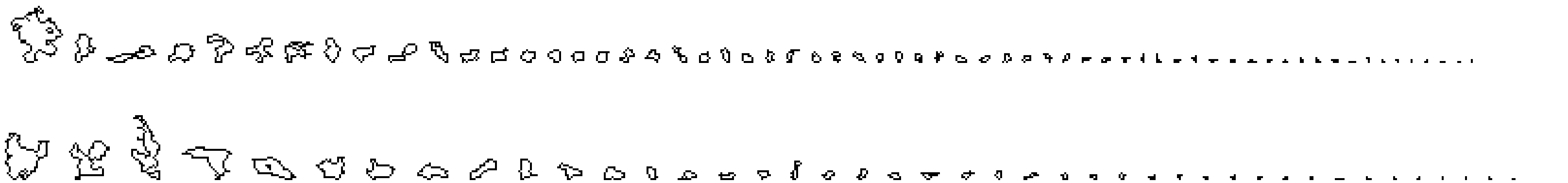


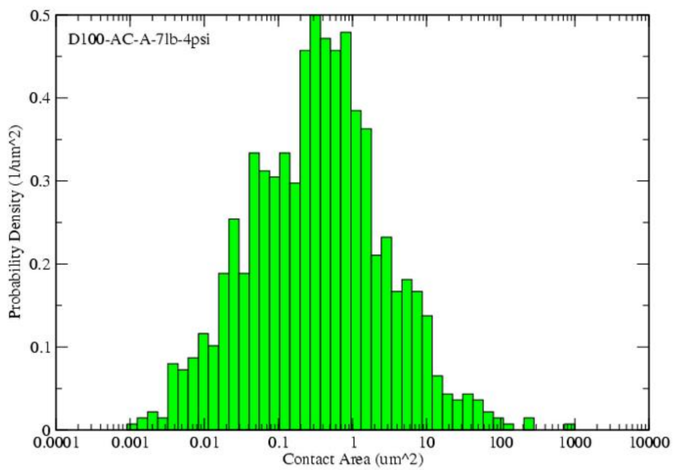
Pad Surface Contact Area Image



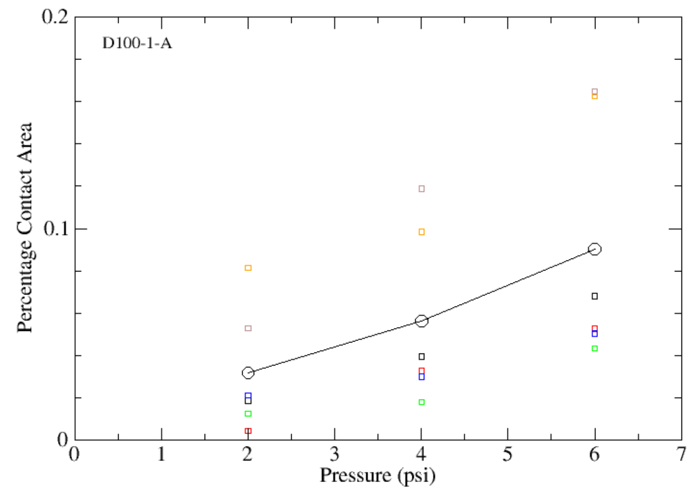
Pad Surface Contact Area Analysis





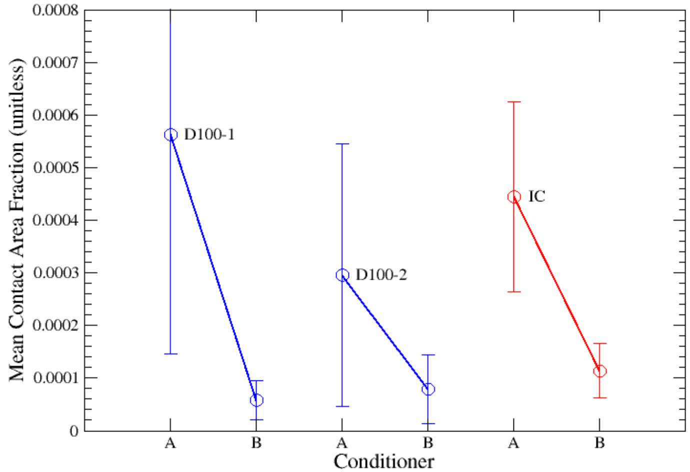


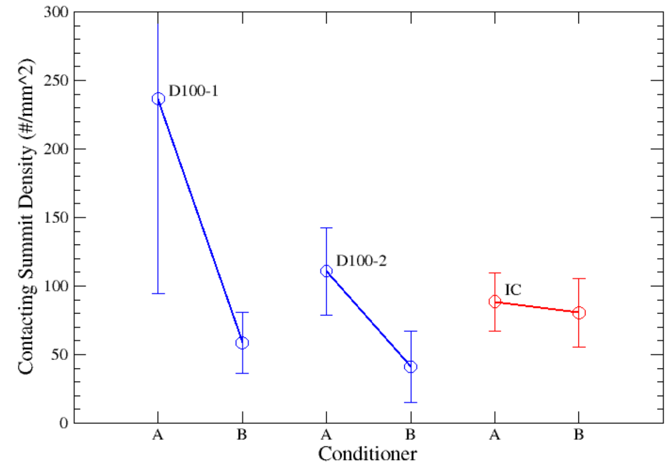
Pad contact area histogram

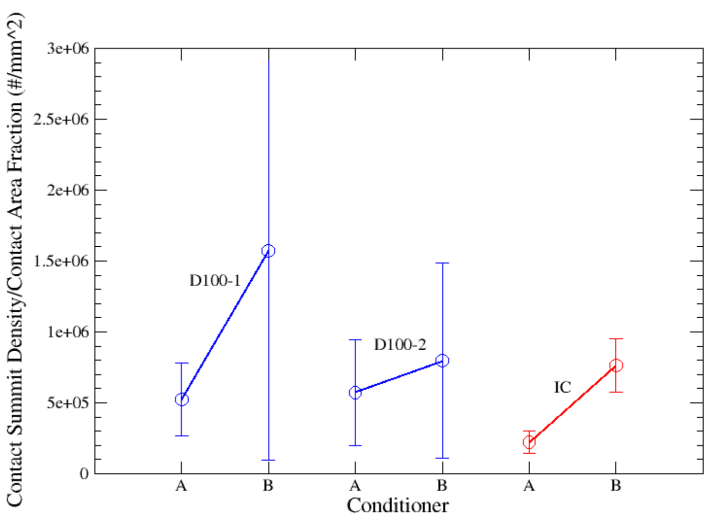


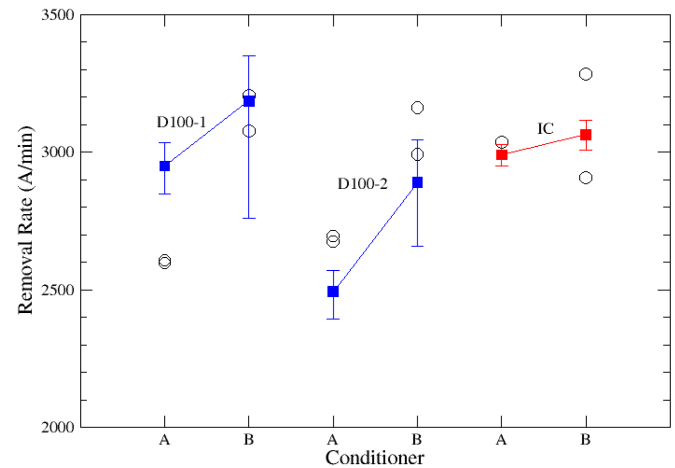
Pad contact area vs. Pressure

Effect of Pad Conditioning









The ratio of the contacting summit density to the contact area fraction is more important than either measured separately since the ratio determines the mean real contact pressure.

Retaining Ring Wear Characterization

Conventional methods:

- **Micrometry**
  Long wear time
  May introduce gross measurement error

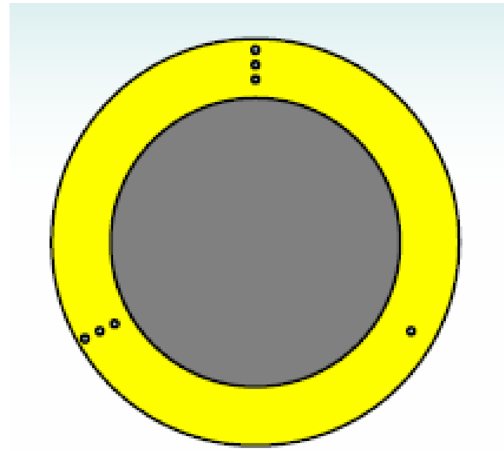
- **Weight Loss**
  Long wear time
  May introduce gross measurement error
  Cannot provide local wear rate

Advanced method:

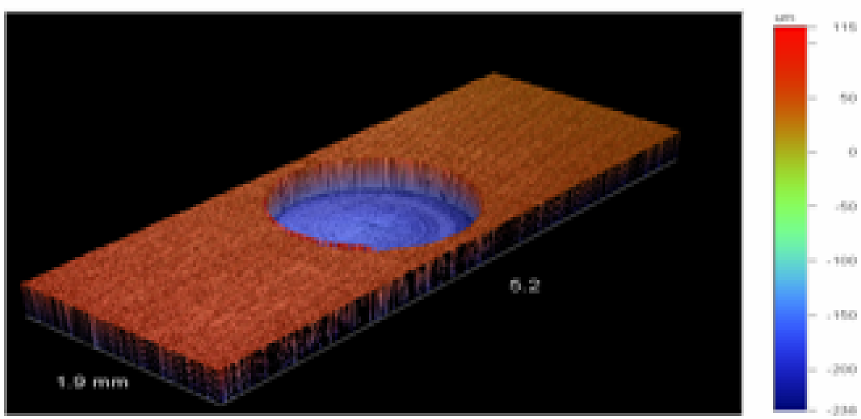
- **Interferometry**
  Short wear time
  Provide accurate local wear rate

Retaining Ring Design and Wear Characterization

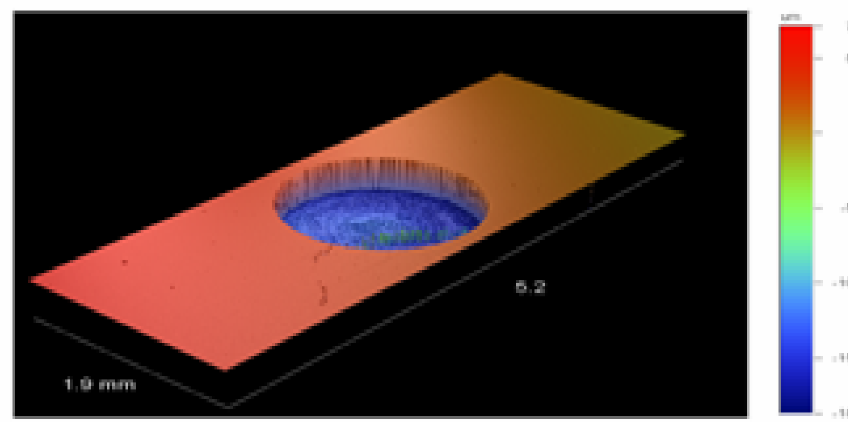
Design – 1   Design – 2



Several shallow trenches (1.5 mm in diameter and 0.2 mm in depth) were precision-machined into the land areas of each ring.



Trench interferometry image before wear test



Trench interferometry image after 4-hour wear test

Retaining Ring Wear Rate

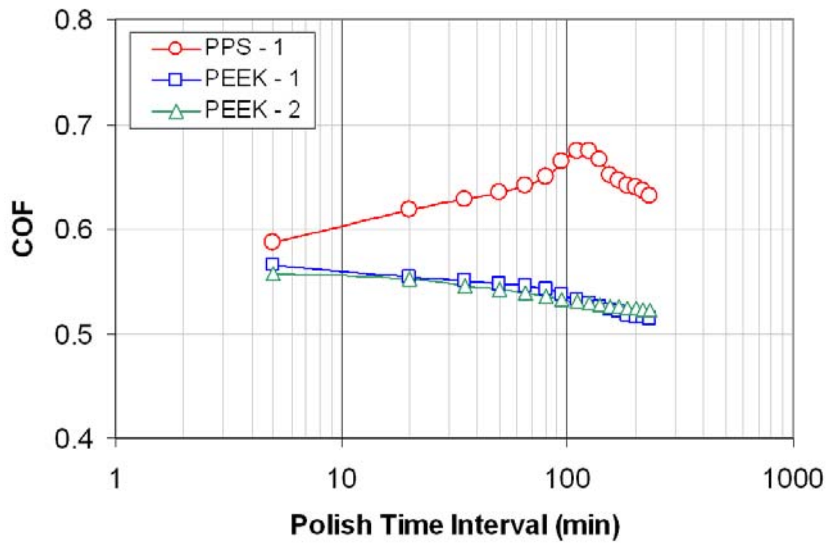
Pre and post interferometry results from the micro-machined trenches indicate the following wear rates:

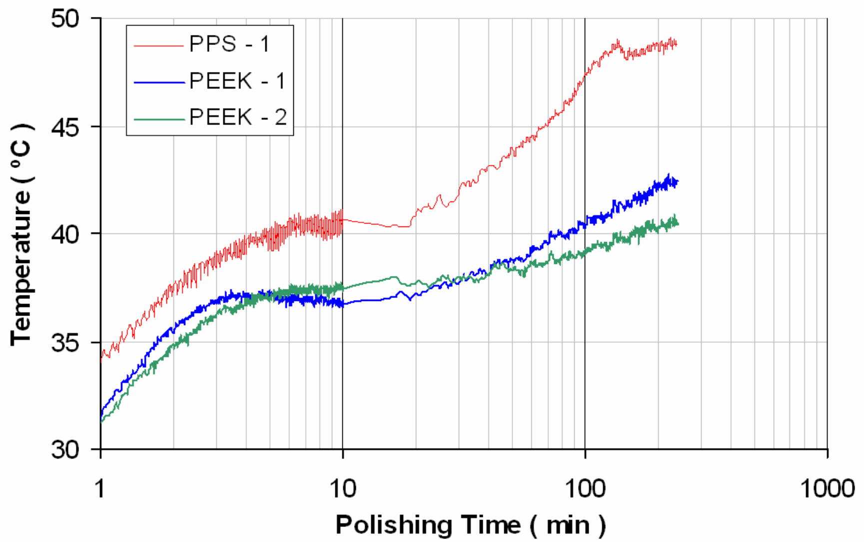
PPS - 1 ring: 28.2 µm/hour
PEEK - 1 ring: 24.0 µm/hour
PEEK - 2 ring: 23.5 µm/hour

This indicates that the retaining ring material, not design, is the main factor influencing the wear rate.

Micrometry results (taken from areas adjacent to the micro-machined trenches) indicate a difference of ± 13 percent compared to interferometry results.

COF and Pad Temperature

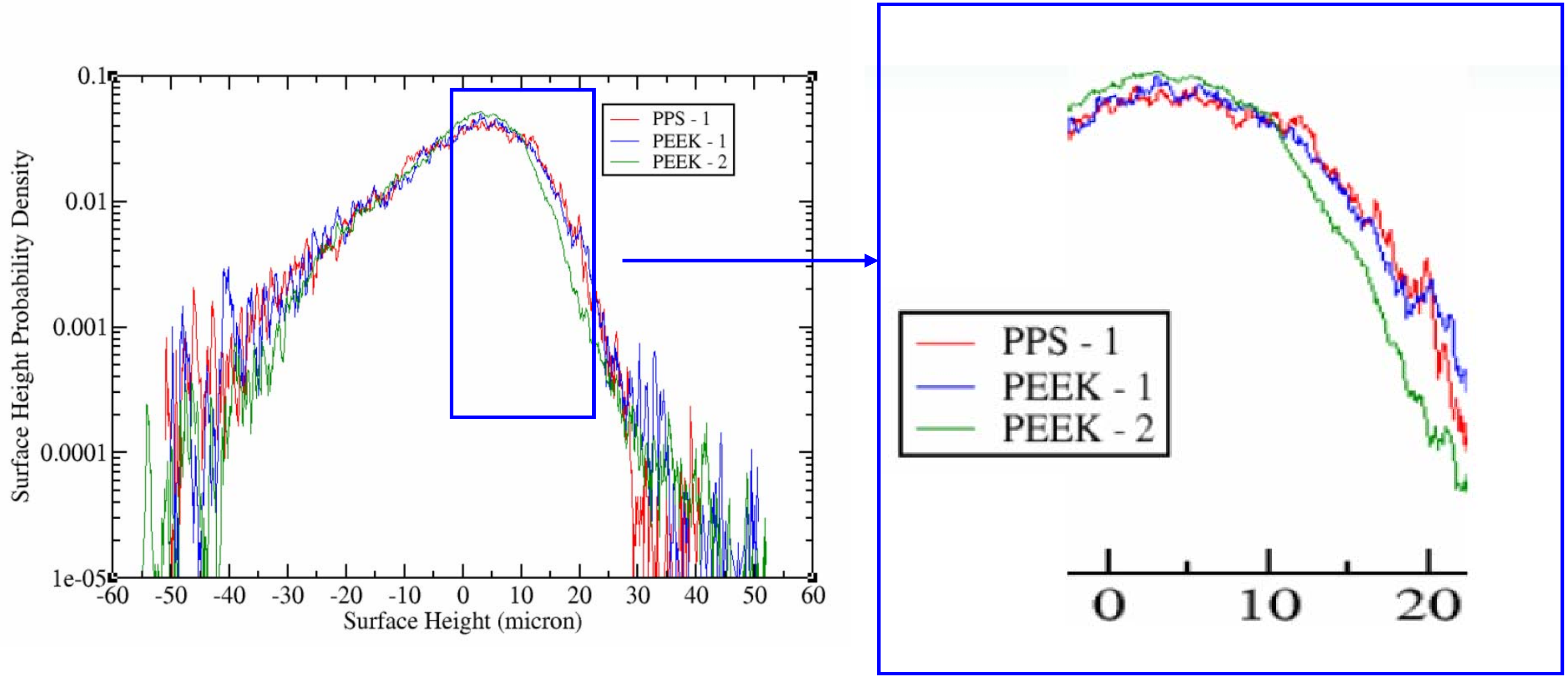




The PEEK rings achieve better lubricity and COF stability than the PPS ring.

Higher temperatures associated with the PPS ring can cause higher material removal rates, thus indicating that thermal effects need to be taken into account when qualifying rings made of new materials.

Pad Surface Interferometry Analysis



The PEEK – 2 ring achieves a narrower pad surface height distribution than the PPS – 1 and PEEK – 1 rings, suggesting that the slot design and or the edge rounding plays significant roles in shaping the pad micro texture.

Summary

The method for active and aggressive diamond characterization is introduced. Normally there is no bulk wear on diamonds and wear mainly occurs on the cutting edges of the active diamonds.

An optimized conditioning sweep schedule can generate a much more uniform pad thickness profile.

For pad surface micro wear characterization, confocal microscopy analysis is used to analyze pad surface contact area. Interferometry analysis is used to establish pad surface height probability density functions and extract pad surface abruptness.

Interferometry analysis is used to characterize retaining ring wear, which not only allows retaining rings to be subjected to significantly shorter than usual wear time, but also provides more accurate estimate of local wear rates than conventional micrometry or weight loss measurements.