Analyses of Diamond Disc Substrate Wear and Diamond Micro-Wear in Copper Chemical Mechanical Planarization Process

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Outline

1. Motivations

2. Objectives & approaches

3. Static etch test results
   - SEM analysis
   - ICPMS analysis
   - Interferometric analysis

4. Wear test results
   - SEM analysis
   - Interferometric analysis
   - Pad wear rate analysis

5. Summary

6. Current and Future Work

Motivations

There is strong evidence of diamond disc substrate loss and diamond micro-wear during extended copper CMP process.

It is not understood whether substrate loss in copper CMP process is due to chemical effects only or combined chemical and mechanical effects.

Although SEM images can show diamond micro-wear clearly, diamond micro-wear has not been successfully quantified.

Objectives & Approaches

Objectives: investigate diamond disc substrate wear and diamond micro-wear for three types of diamond discs during copper CMP process.

Approaches:

24-hour static etch test at 25 and 50 ºC with Cabot Microelectronics Corporation iCue 600Y75 slurry

- **SEM analysis on diamond disc substrate and diamonds**
- **ICPMS analysis on slurry**
- **Interferometric analysis on diamond disc substrate and diamonds**

24-hour wear test on Araca's APD-800 polisher at 25 ºC with Cabot Microelectronics Corporation iCue 600Y75 slurry

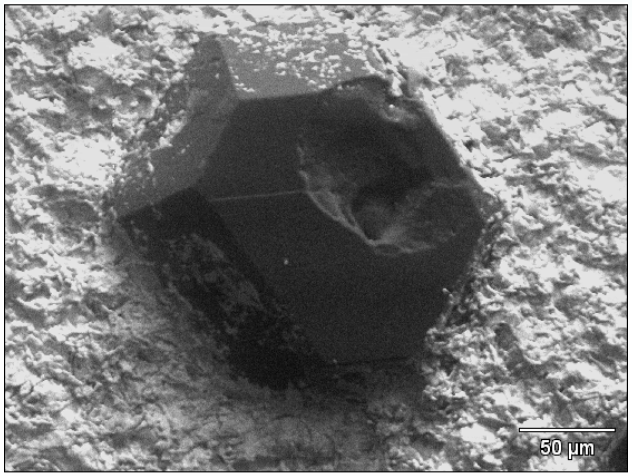
- **SEM analysis on diamond disc substrate and diamonds**
- **Interferometric analysis on individual aggressive diamonds**
- **Pad wear rate analysis**

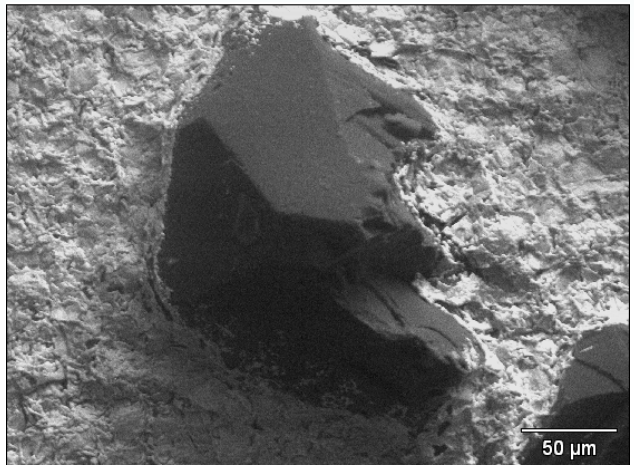
Static Etch Test Results

SEM Analysis

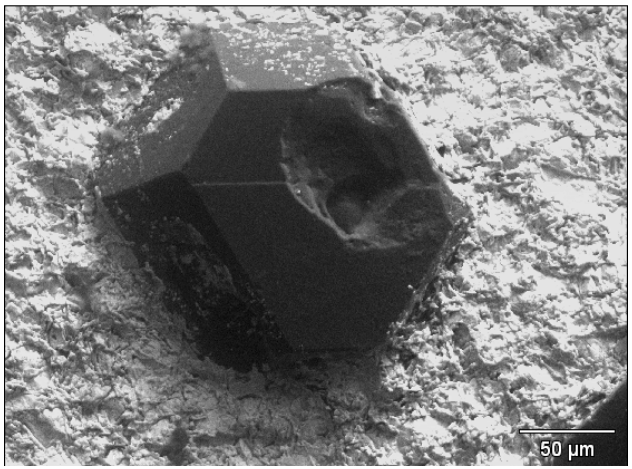
Disc D1 at 25 ºC

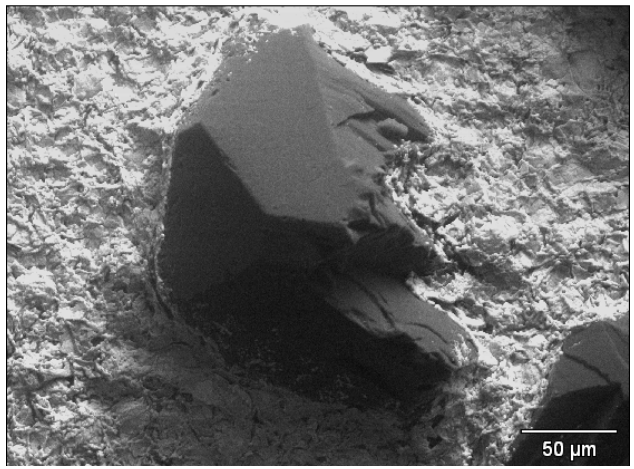
Before Static Etch Test





After Static Etch Test

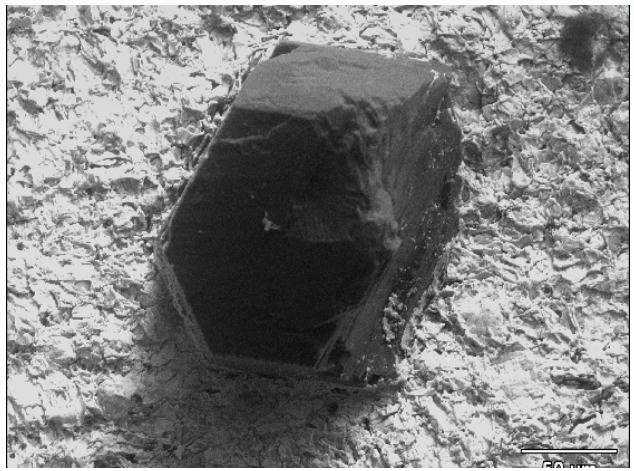


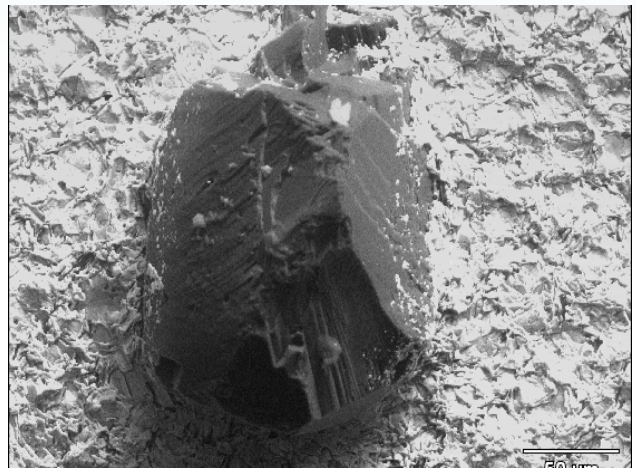


SEM Analysis

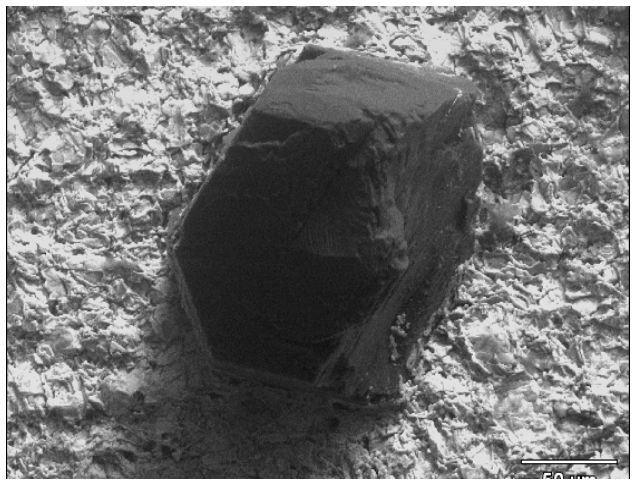
Disc D1 at 50 ºC

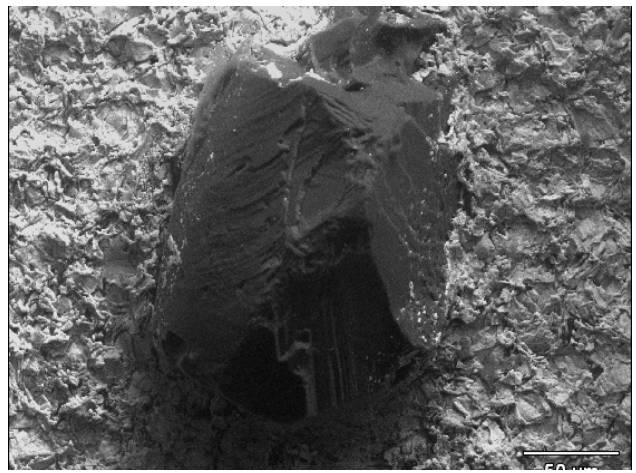
Before Static Etch Test





After Static Etch Test

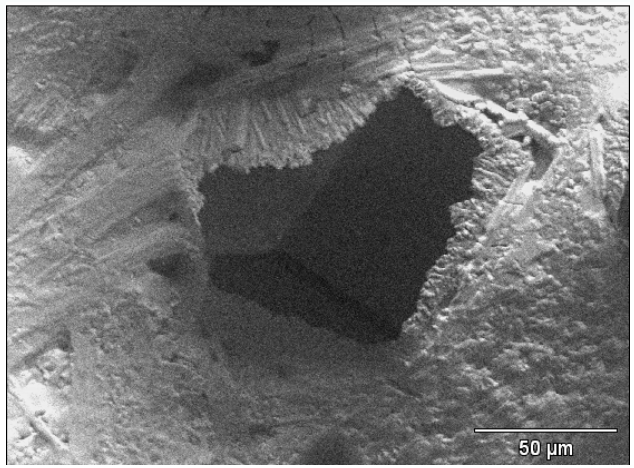


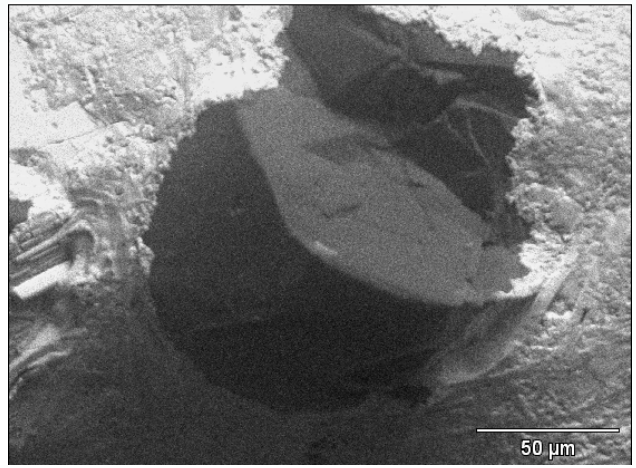


SEM Analysis

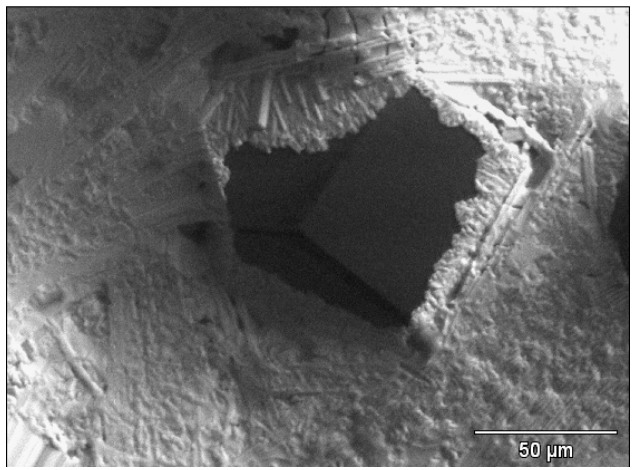
Disc D2 at 25 ºC

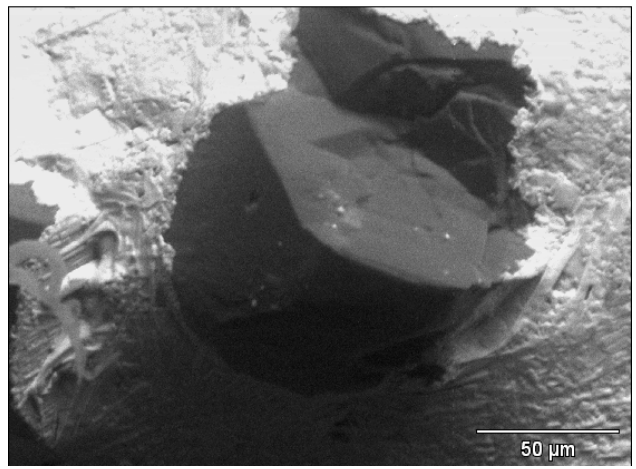
Before Static Etch Test





After Static Etch Test

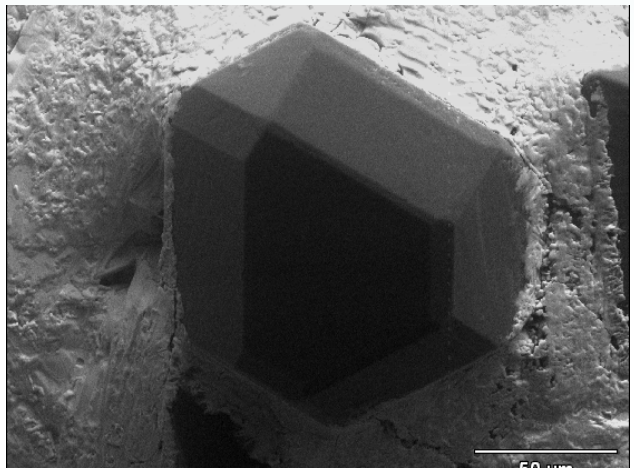


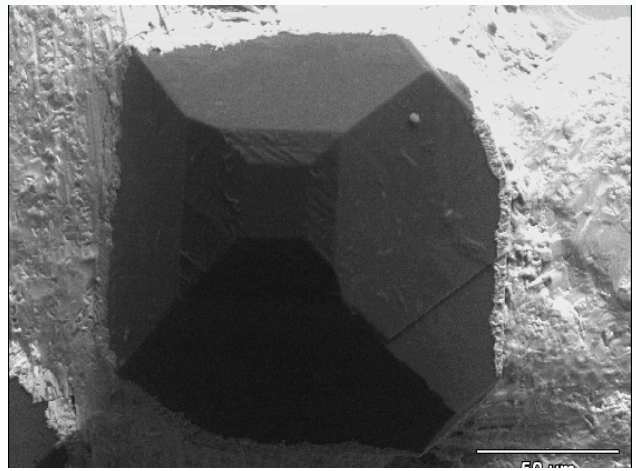


SEM Analysis

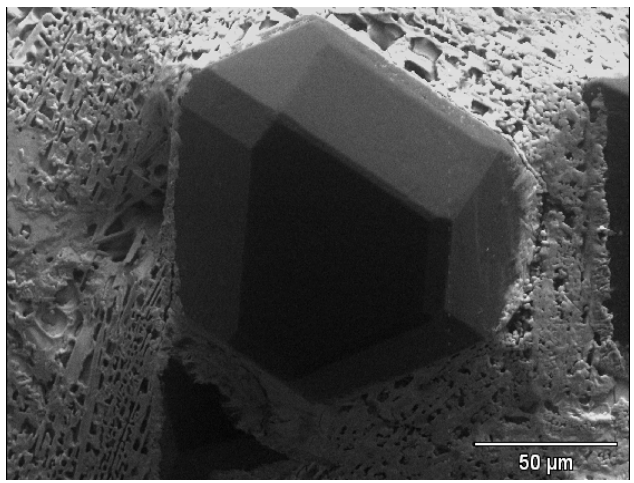
Disc D2 at 50 ºC

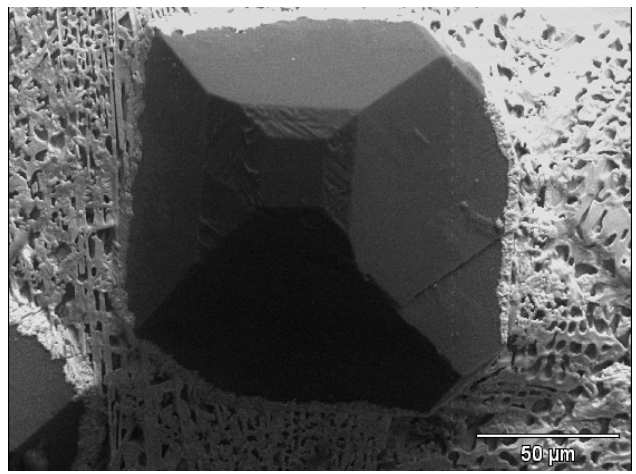
Before Static Etch Test





After Static Etch Test

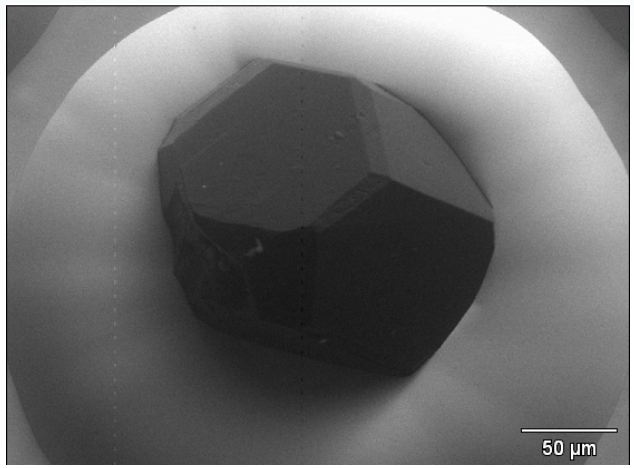


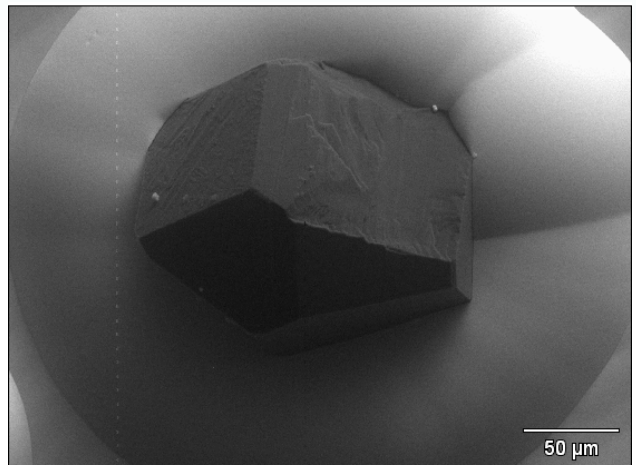


SEM Analysis

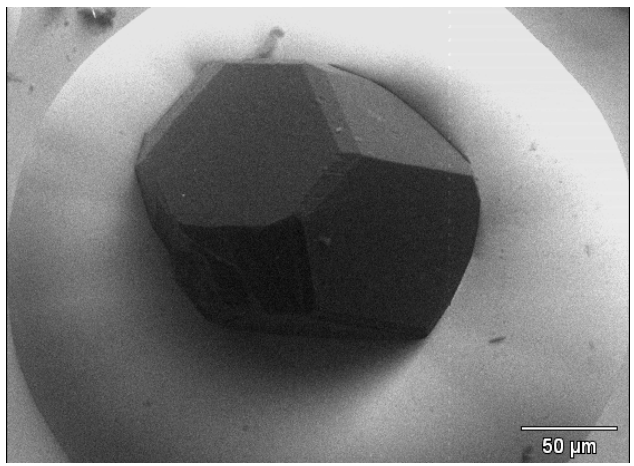
Disc D3 at 25 ºC

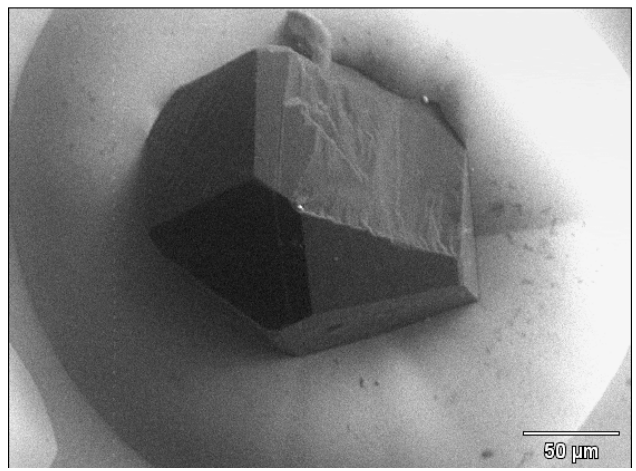
Before Static Etch Test





After Static Etch Test

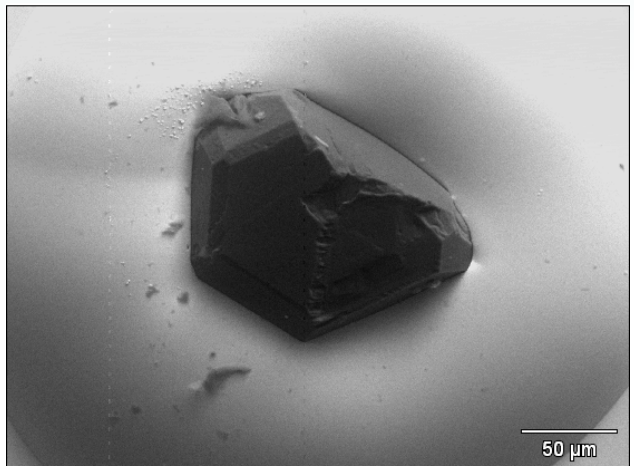


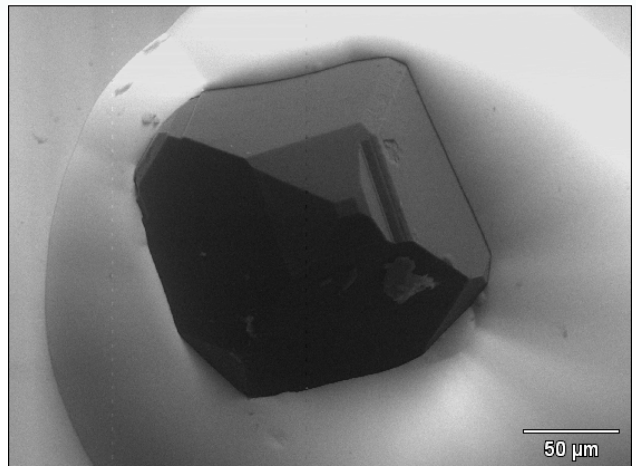


SEM Analysis

Disc D3 at 50 ºC

Before Static Etch Test





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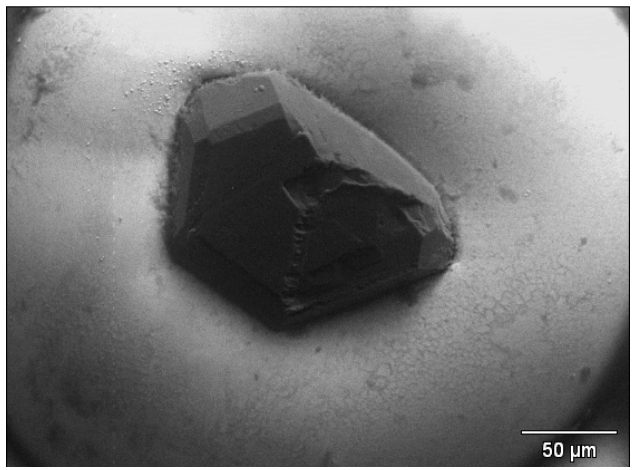
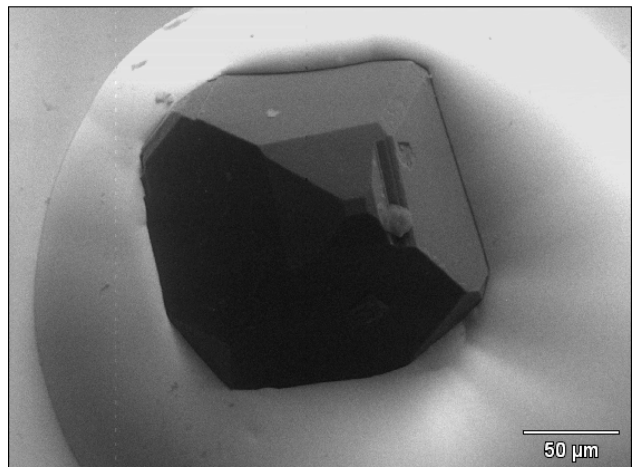
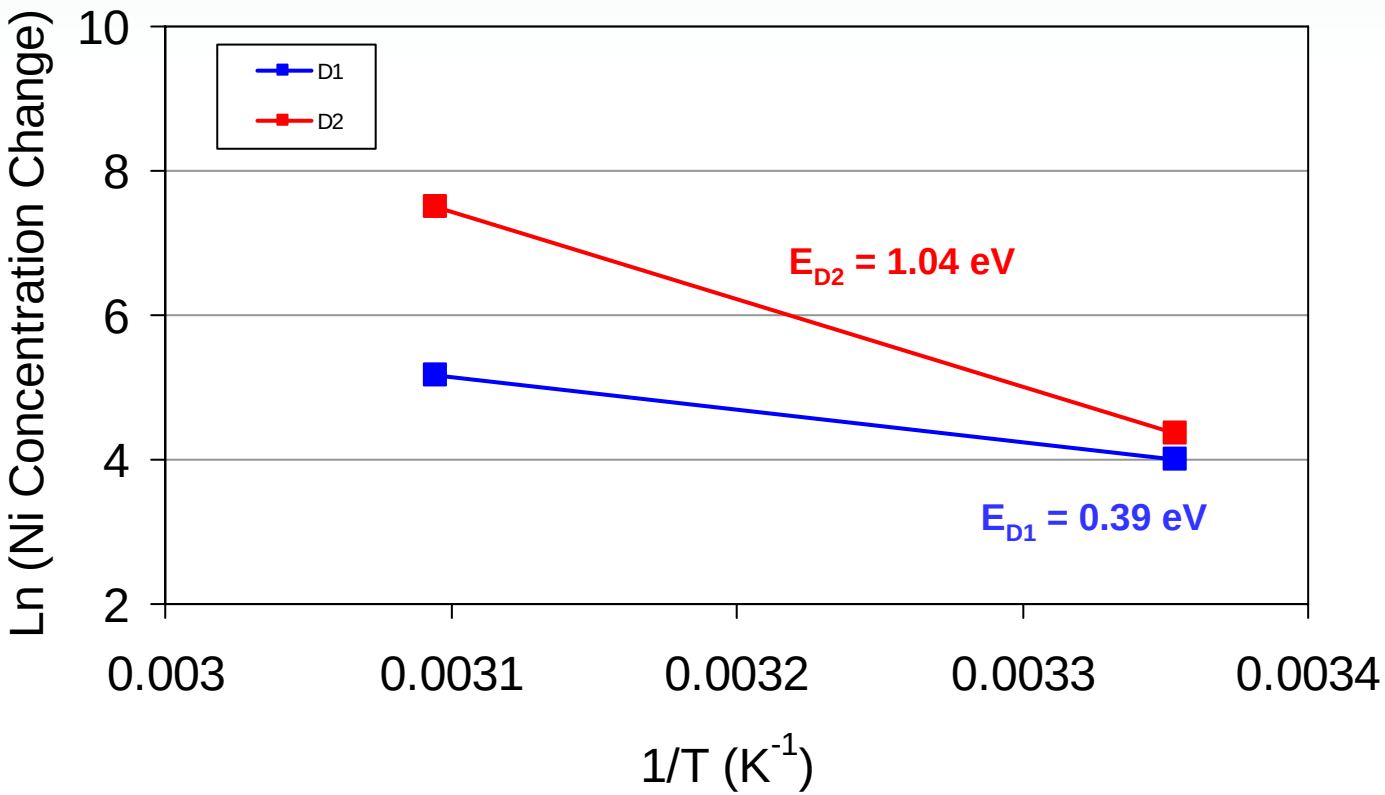




ICPMS Analysis – Metal Concentration Changes

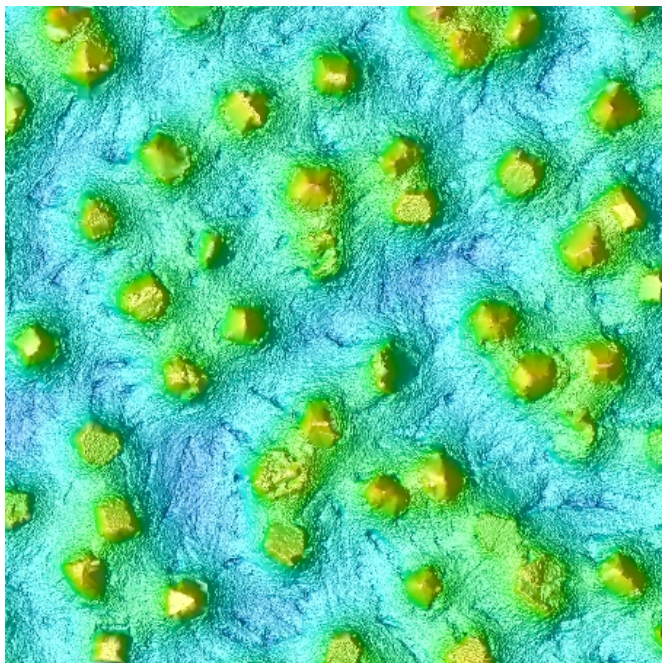
Temperature	Metal	D1 (mg/L)	D2 (mg/L)	D3 (mg/L)
25 ºC	Ni	1.33	1.89	0
	Fe	0	0.22	0
	Cr	0.07	0.45	0.06
50 ºC	Ni	4.25	42.85	0.05
	Fe	0.07	1.72	0.04
	Cr	0.13	2.33	0.10

Activation Energy of Ni Corrosion

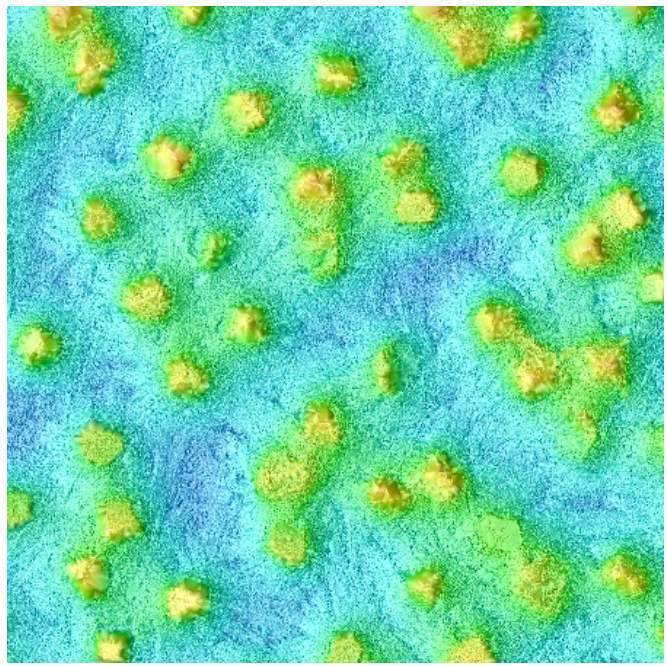


Interferometric Analysis – 2 x 2 mm²

Disc D2 at 50 ºC

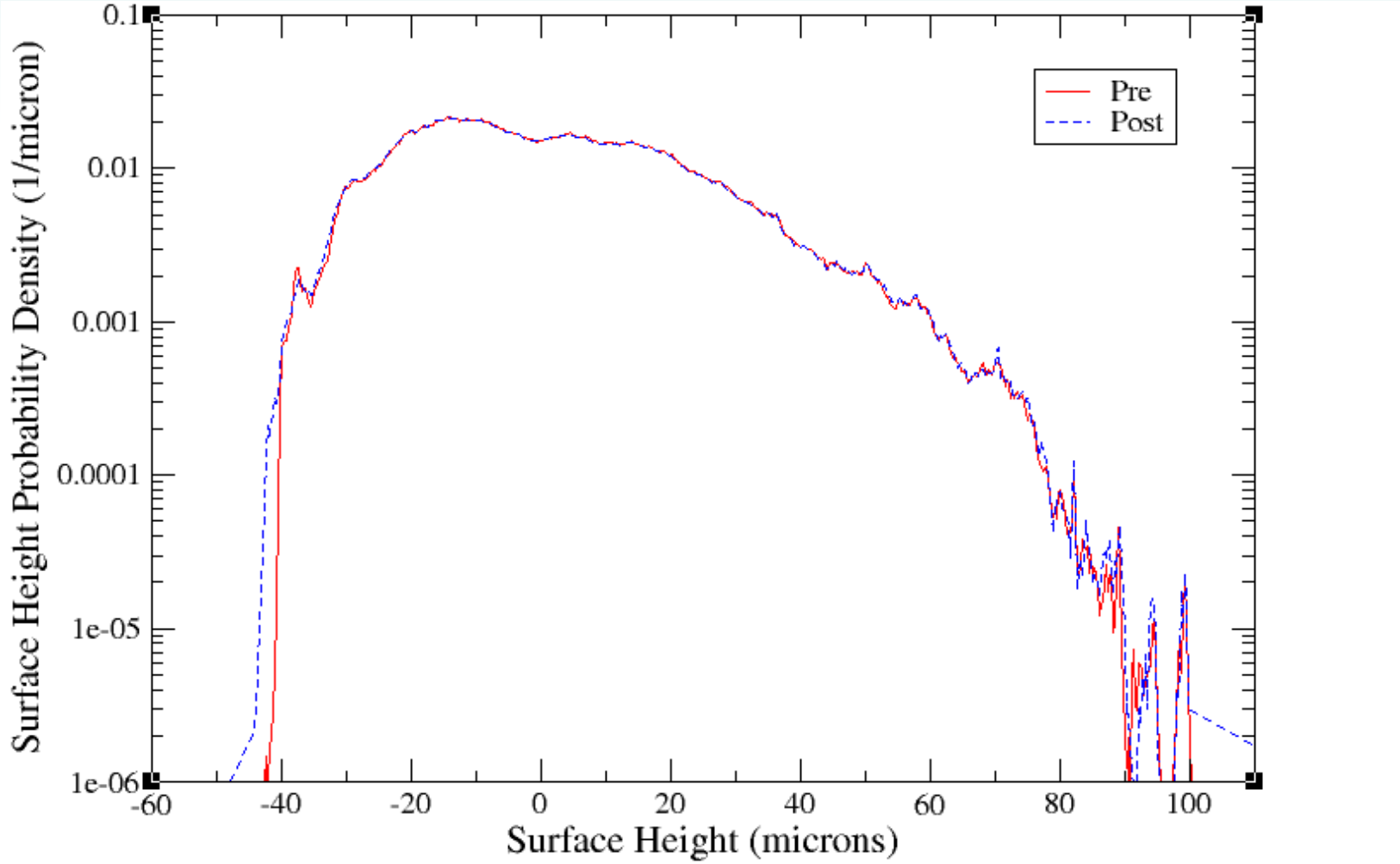


Before Static Etch Test

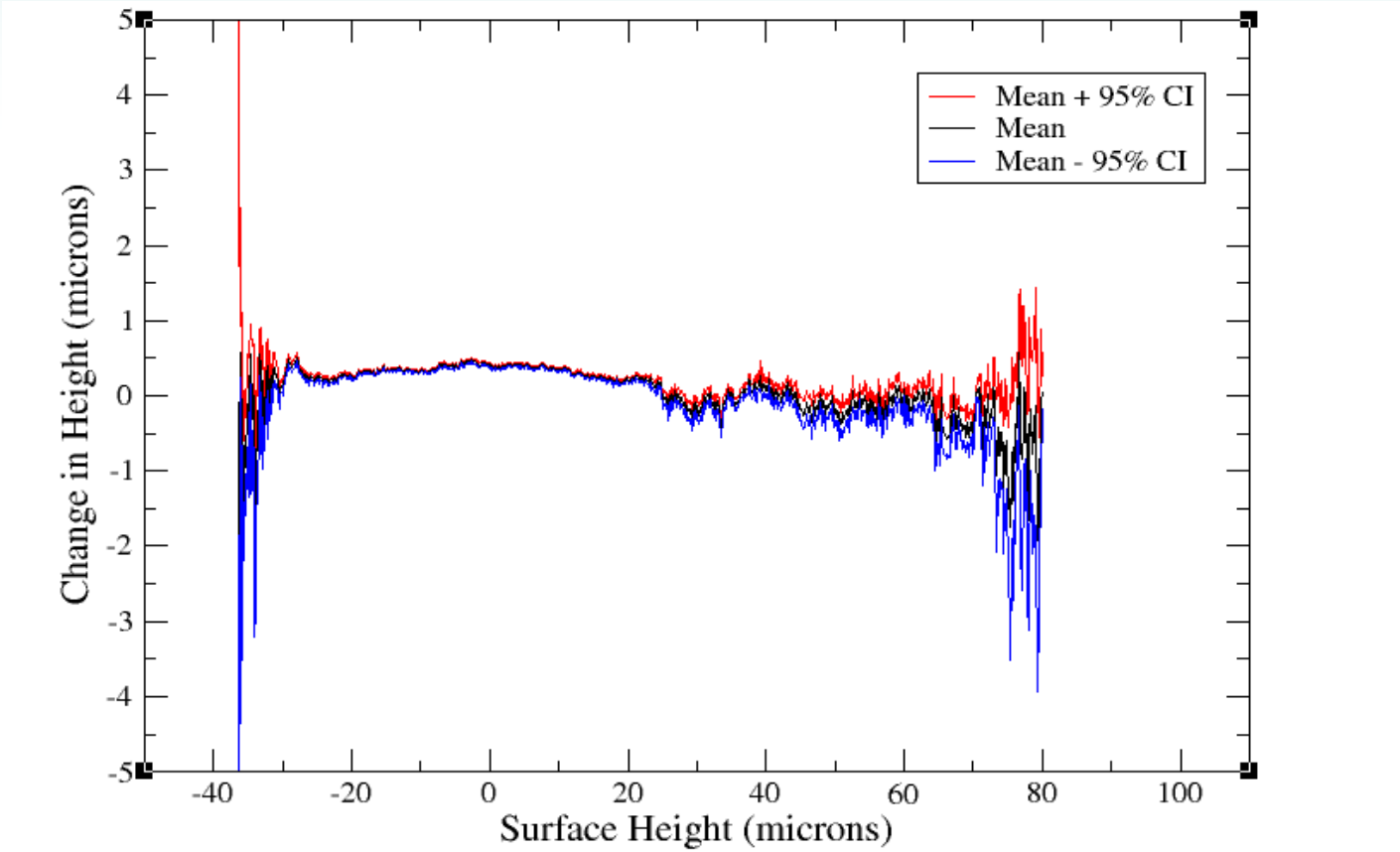


After Static Etch Test

Diamond Disc Surface Height PDFs

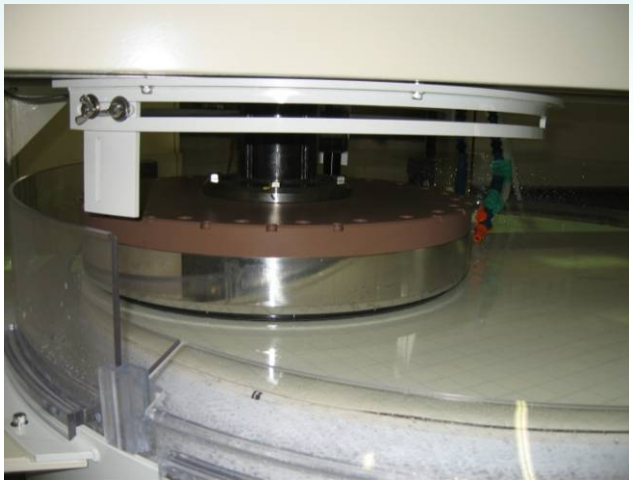


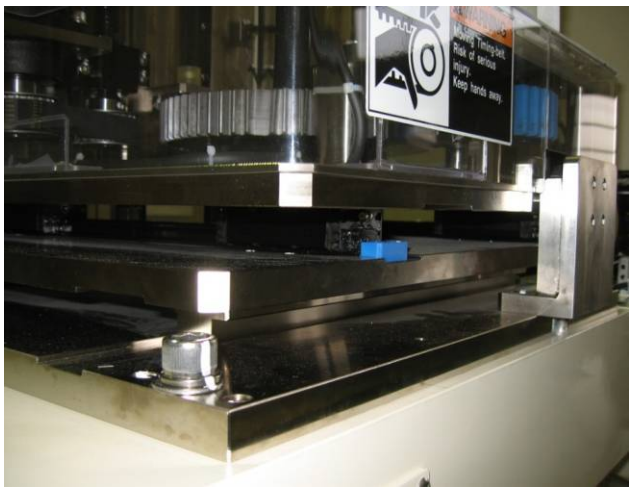
Change in Diamond Disc Surface Height



Wear Test Results

Araca APD – 800 Polisher & Tribometer





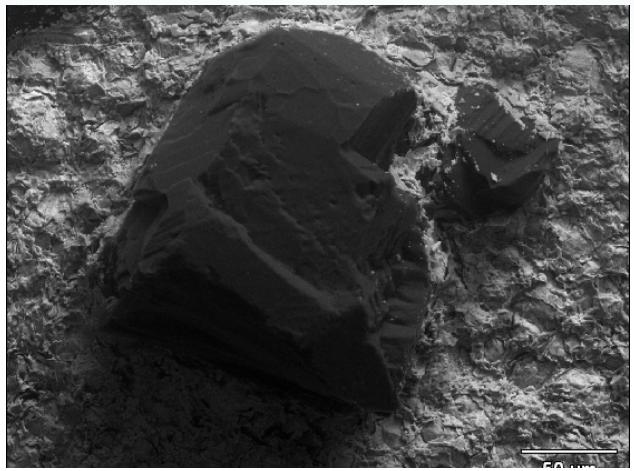
Experimental Conditions

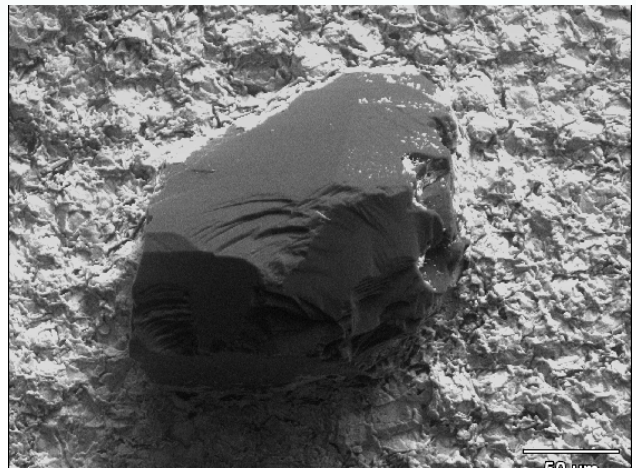
- **Pad**
  - 30-inch IC1000 A6 pad with Suba IV sub-pad
- **Slurry**
  - 10 volume parts of Cabot Microelectronics Corporation iCue 600Y75 slurry + 1.1 volume parts of 30% ultra pure H_2O_2
  - Flow rate = 250 ml/min
- **Pad Conditioning**
  - Diamond disc rotational rate = 95 RPM
  - Diamond disc sweeping rate = 10 times/min
  - Platen rotational rate = 42 RPM
  - Platen temperature = 25 ºC
  - Conditioning down force = 10 lb_f
  - Conditioning time = 24 hours

SEM Analysis – Aggressive Diamonds

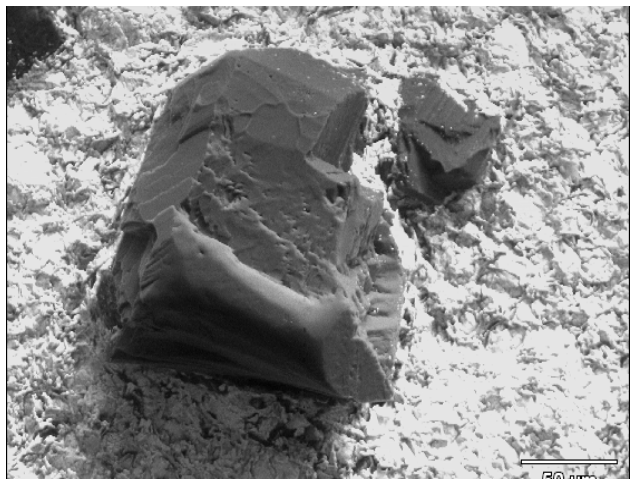
Disc D1

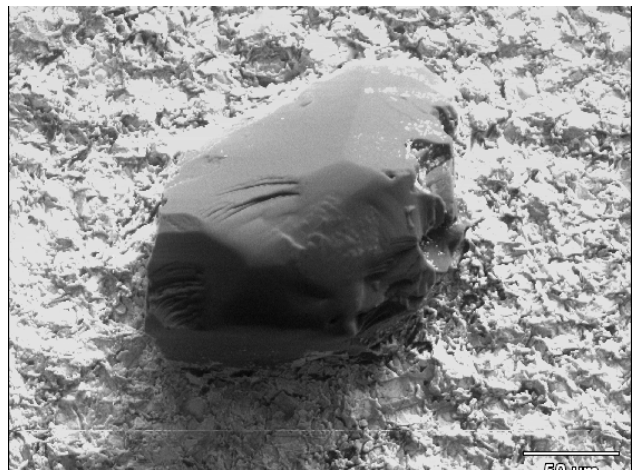
Before Wear Test





After Wear Test

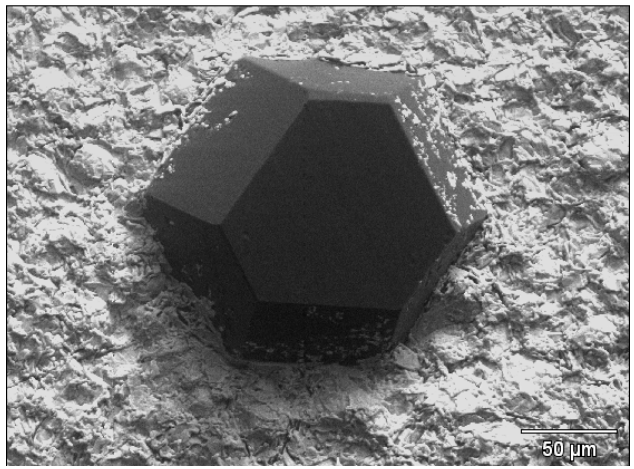


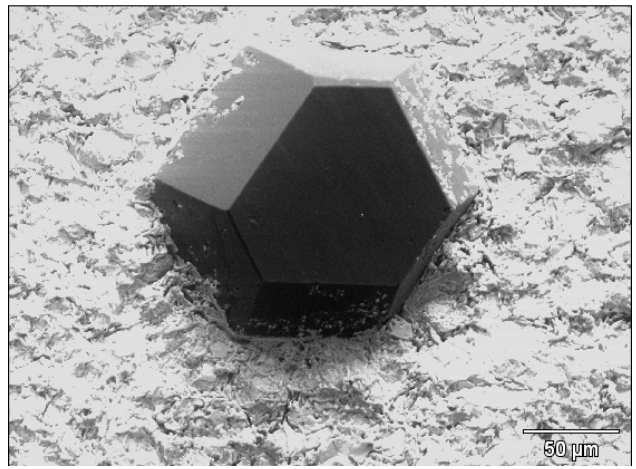


SEM Analysis – Inactive Diamond

Disc D1

Before Wear Test



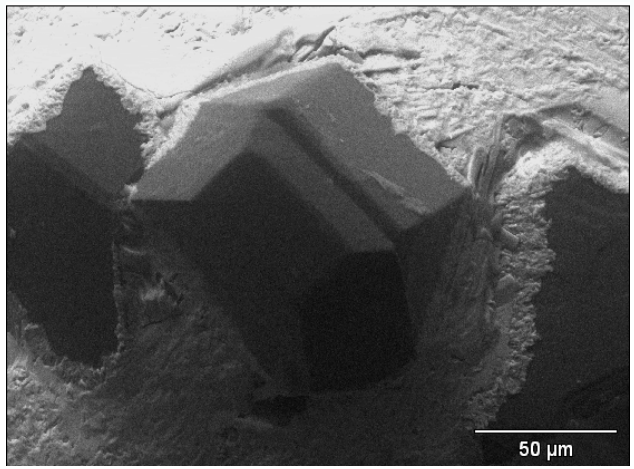


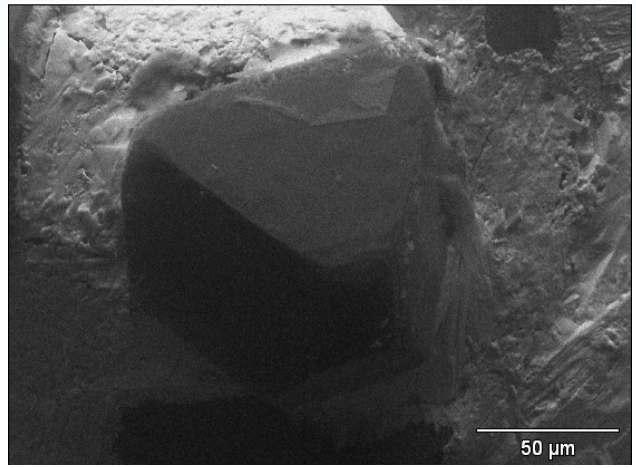
After Wear Test

SEM Analysis – Aggressive Diamonds

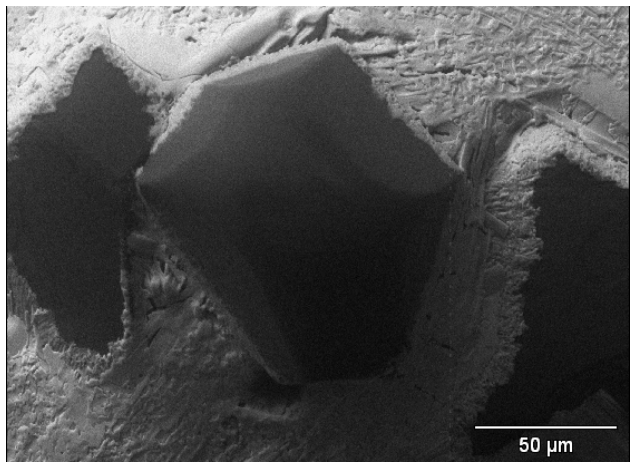
Disc D2

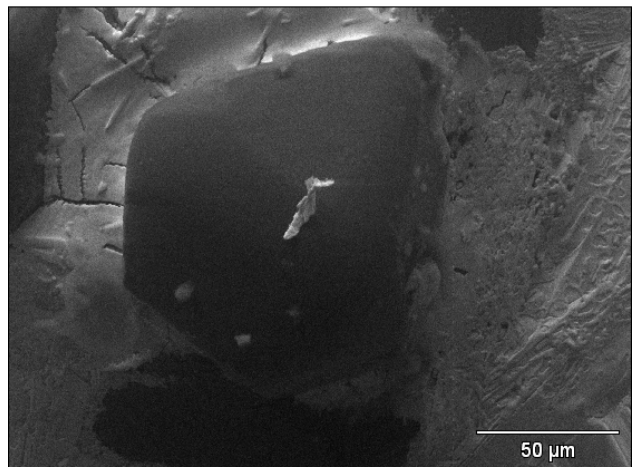
Before Wear Test





After Wear Test

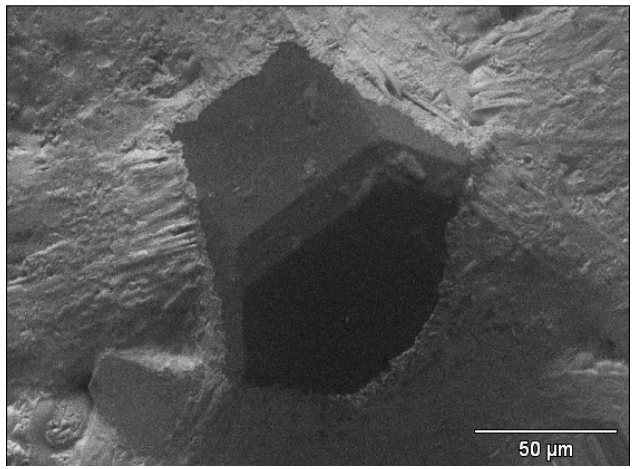


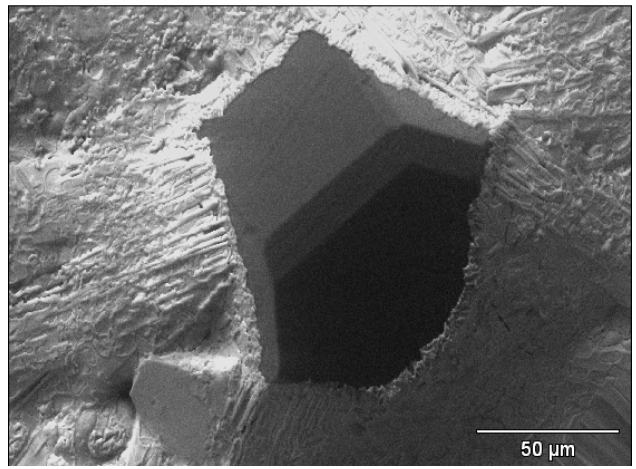


SEM Analysis – Inactive Diamond

Disc D2

Before Wear Test



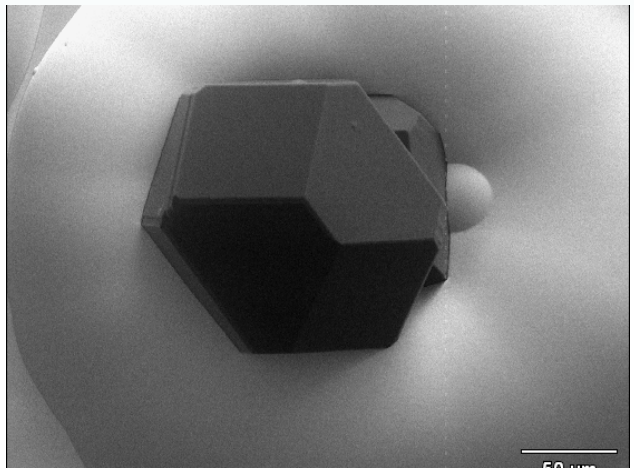


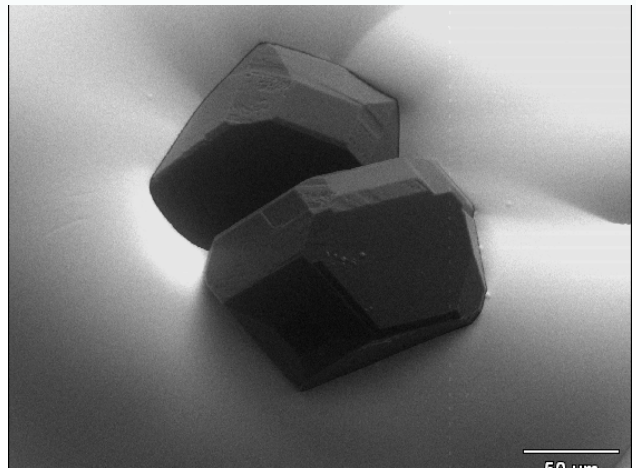
After Wear Test

SEM Analysis – Aggressive Diamonds

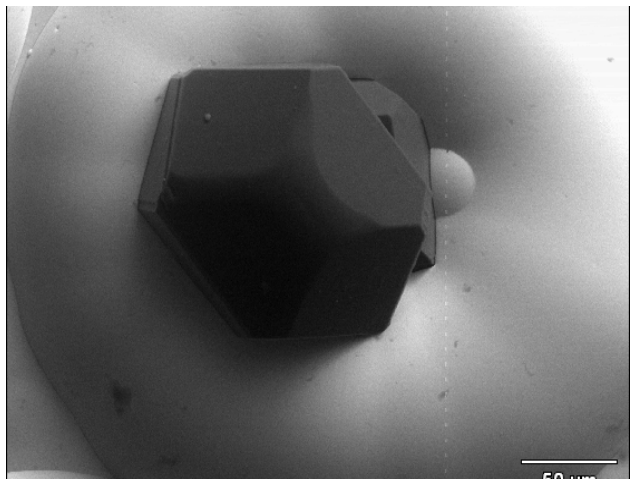
Disc D3

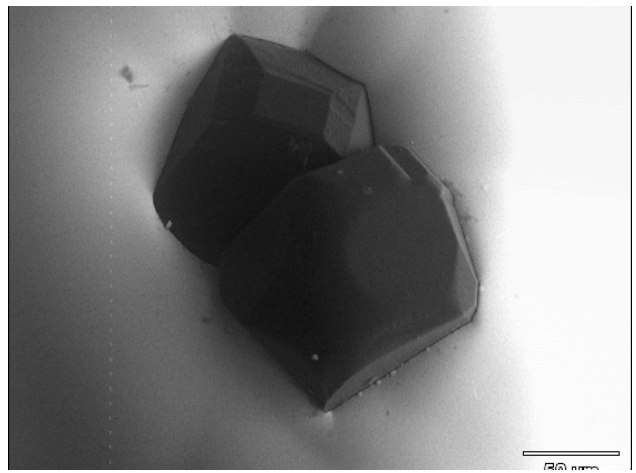
Before Wear Test





After Wear Test

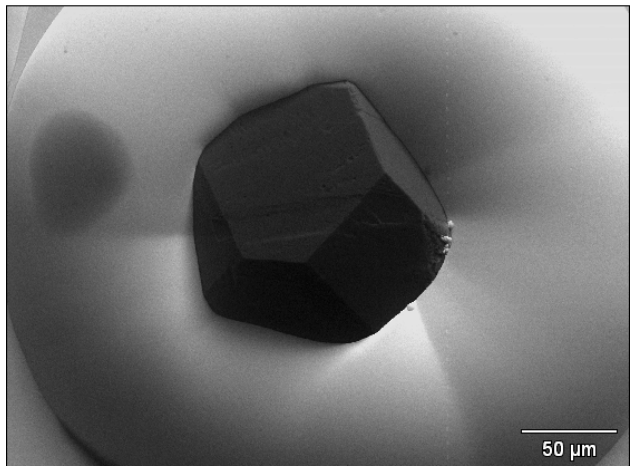


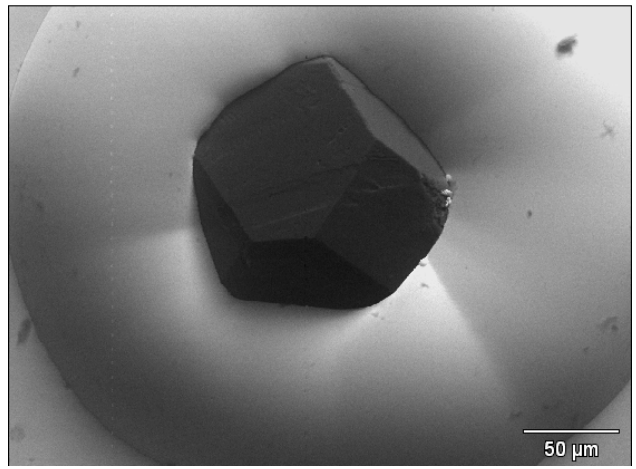


SEM Analysis – Inactive Diamond

Disc D3

Before Wear Test

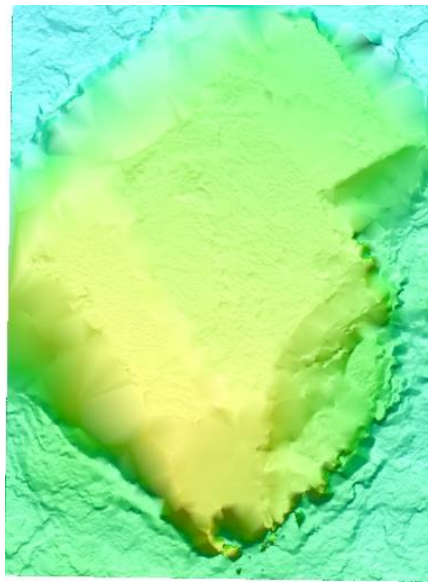


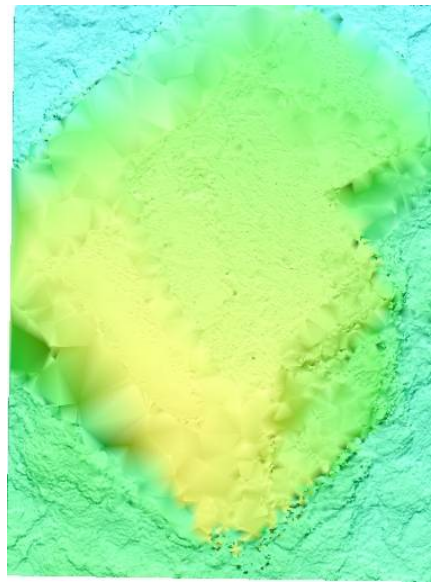


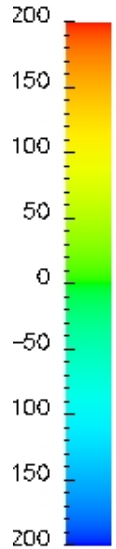
After Wear Test

Interferometric Analysis – Aggressive Diamond

Disc D1



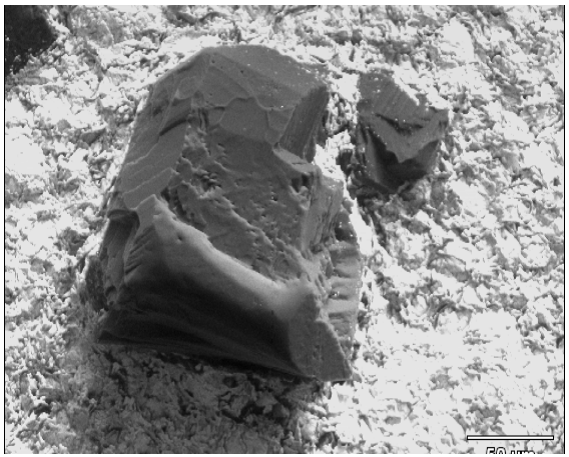




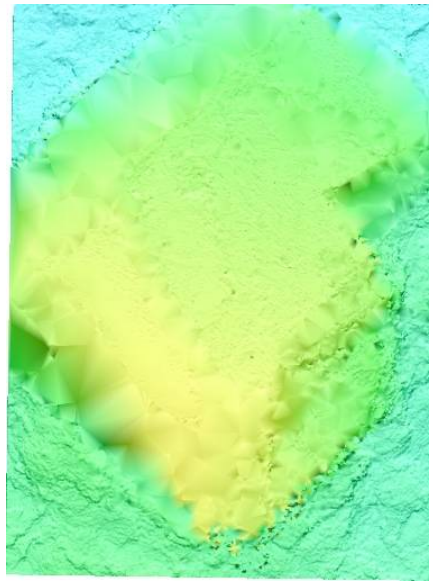
Before Wear Test

After Wear Test

SEM vs. Inteferometer vs. Confocal Microscope



SEM Image



Interferometric Image

Confocal Microscopic Image

Average Pad Cut Rate

D1 (µm/hour)	D2 (µm/hour)	D3 (µm/hour)
3.03	2.32	0.93

Summary – Static Etch Tests

SEM analysis indicated that there was no appreciable wear on the diamond disc substrate and diamonds for all three discs with Cabot Microelectronics Corporation iCue 600Y75 slurry at 25 ºC.

SEM analysis indicated that there was no appreciable wear on the diamond disc substrate and diamonds for Discs D1 and D3 with Cabot Microelectronics Corporation iCue 600Y75 slurry at 50 ºC.

SEM analysis indicated that there was no appreciable wear on diamonds but there was apparent surface corrosion on the diamond disc substrate for Disc D2 with Cabot Microelectronics Corporation iCue 600Y75 slurry at 50 ºC.

ICPMS analysis indicated that the Ni concentration in the Cabot Microelectronics Corporation iCue 600Y75 slurry increased appreciably for Discs D1 and D2 after the static etch test at 25 ºC. At 50 ºC, the Ni concentration in the slurry increased dramatically for Disc D2 after the static etch test, resulting in an extremely high activation energy for Ni corrosion. In comparison, the Ni concentration in the slurry did not increase for Disc D3 at 25 and 50 ºC.

White light interferometer did not provide as detailed and accurate diamond disc images as SEM. As a result, the interferometric analysis did not quantify diamond disc substrate wear accurately.

Summary – Wear Tests

SEM analysis indicated that there was micro-wear on the cutting edges of aggressive diamonds and no micro-wear on the inactive diamonds for all three discs with Cabot Microelectronics Corporation iCue 600Y75 slurry at 25 ºC.

SEM analysis indicated there was no appreciable wear on the diamond disc substrate for Discs D1 and D3 with Cabot Microelectronics Corporation iCue 600Y75 slurry at 25 ºC. In comparison, there were surface corrosion and micro cracks formed on the diamond disc substrate for Disc D2 after the wear test.

As the white light interferometer did not capture the cutting edges of individual diamonds and the boundaries between embedded diamonds and disc substrate, the interferometric analysis did not quantify diamond micro-wear accurately.

Disc D1 generated the highest pad wear rate and Disc D3 generated the lowest pad wear rate.

Current and Future Work

Perform 24-hour wear tests on Araca APD-800 polisher with Cabot Microelectronics Corporation iCue 600Y75 slurry at 50 ºC.

Perform 24-hour static etch tests with Fujimi PL-7103 slurry at 25 and 50 ºC.

Perform 24-hour wear tests on Araca APD-800 polisher with Fujimi PL-7103 slurry at 25 and 50 ºC.

Investigate the feasibility of using laser confocal microscopy to quantify diamond disc substrate wear and diamond micro-wear.

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