# 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

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# 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 and Fujimi PL-7103 slurries**

- **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 APD-800 polisher at 25 and 50 ºC with Cabot Microelectronics Corporation iCue 600Y75 and Fujimi PL-7103 slurries**

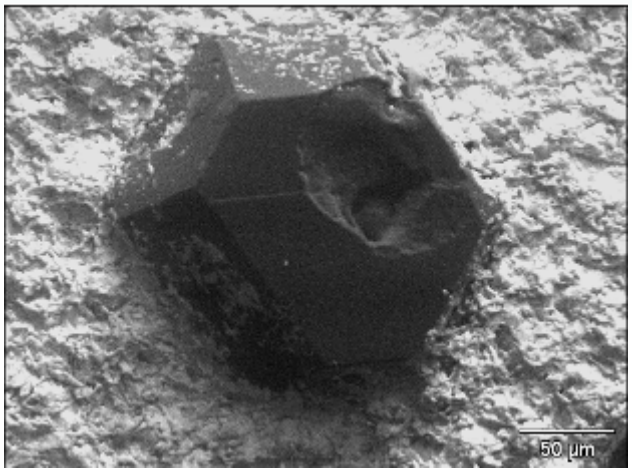
- **SEM analysis on diamond disc substrate and diamonds**
- **Interferometric analysis on individual aggressive diamonds**
- **Pad wear rate analysis**

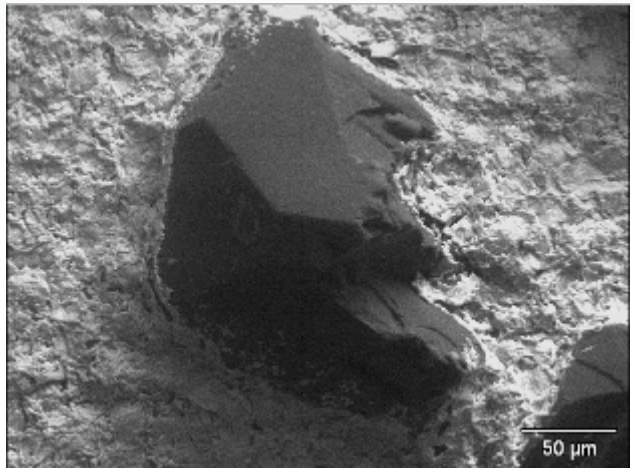
# Static Etch Test Results

# SEM Analysis

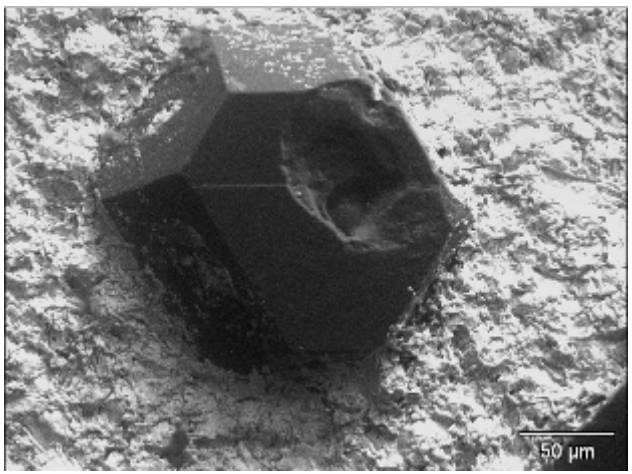
## D1 with CMC iCue 600Y75 Slurry at 25 ºC

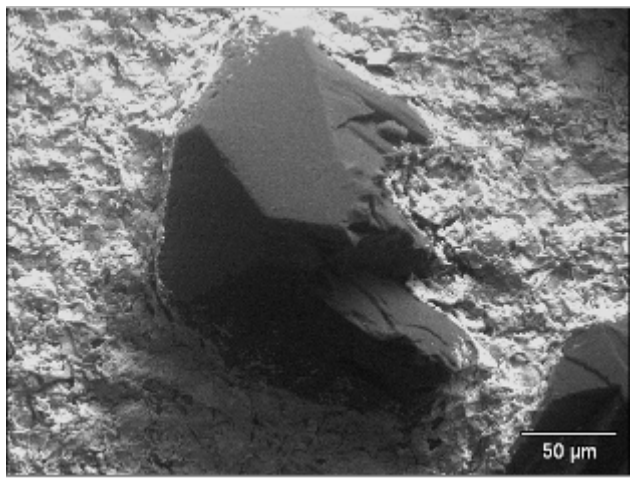
**Before Static Etch Test**




**After Static Etch Test**



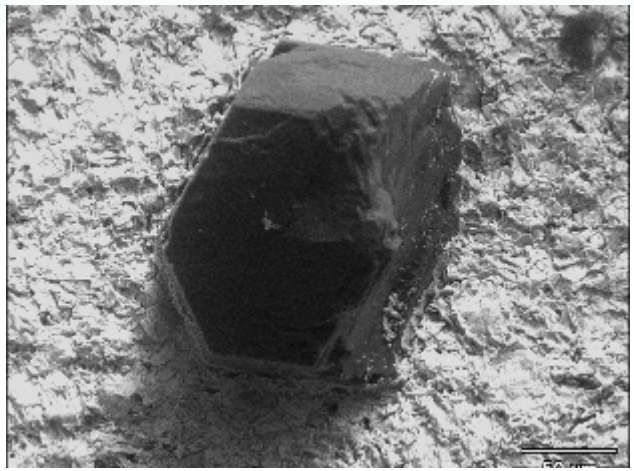



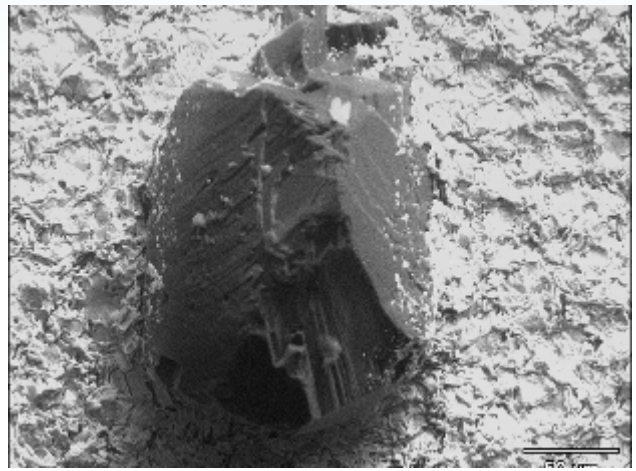

**There was no appreciable wear on the diamond disc substrate and diamonds.**

# SEM Analysis

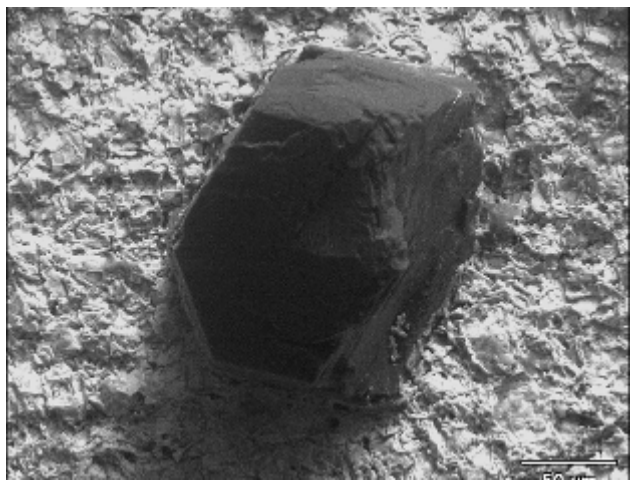
## D1 with CMC iCue 600Y75 Slurry at 50 ºC

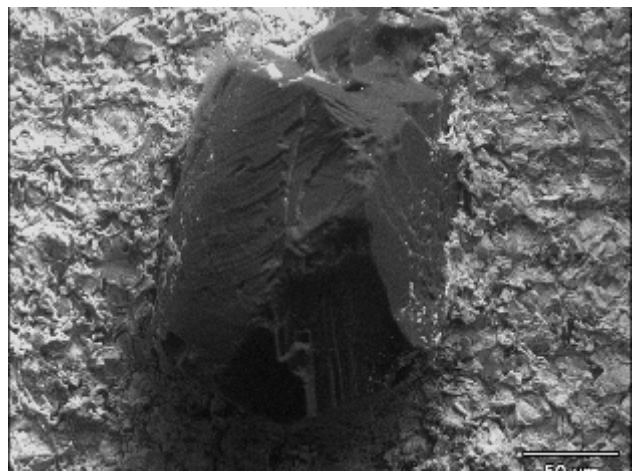
**Before Static Etch Test**





**After Static Etch Test**



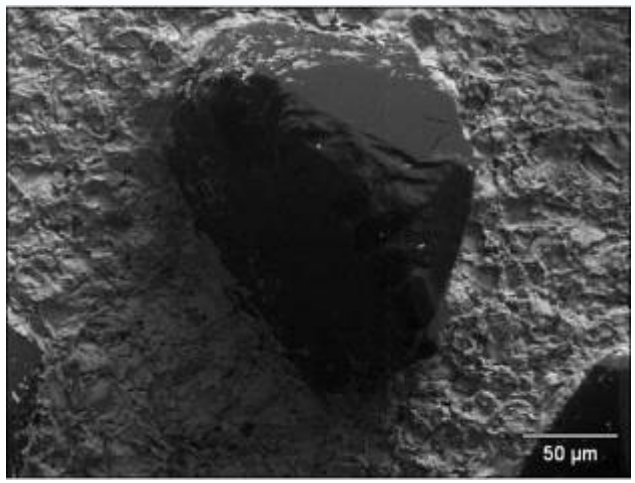


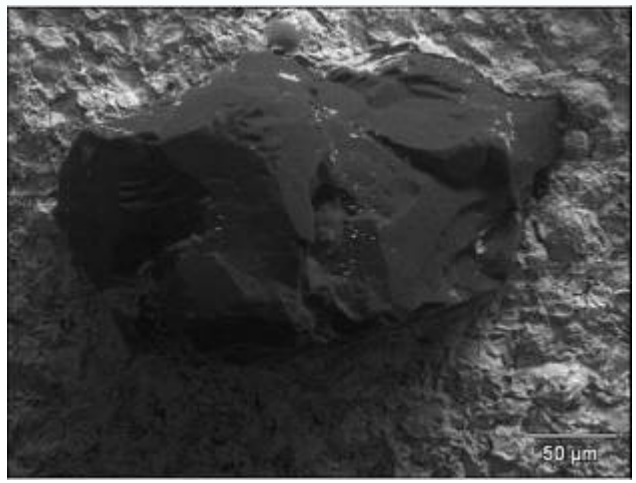
**There was no appreciable wear on the diamond disc substrate and diamonds.**

# SEM Analysis

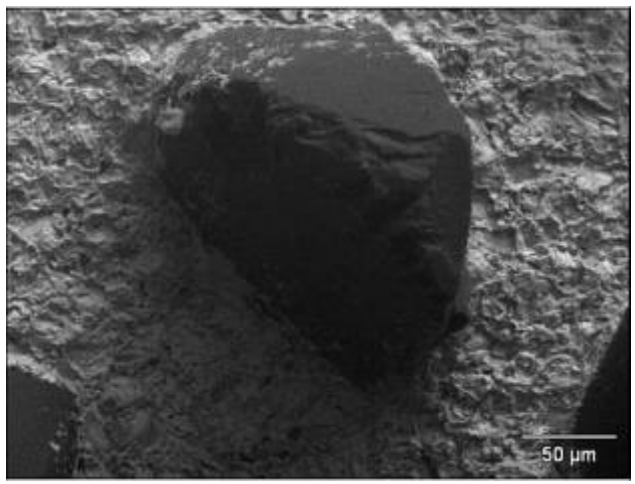
## D1 with Fujimi PL-7103 Slurry at 25 ºC

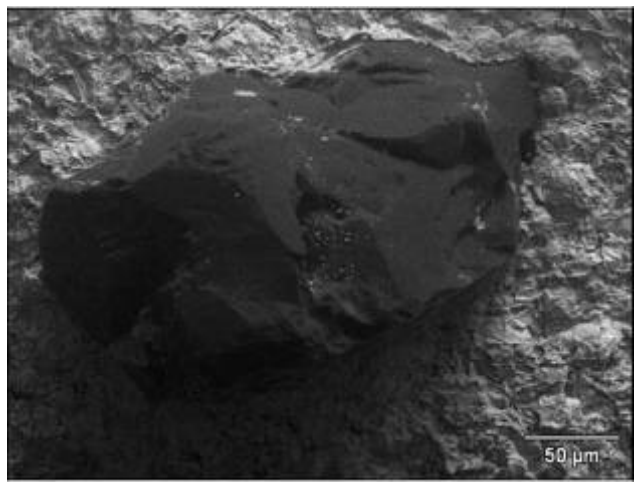
**Before Static Etch Test**




**After Static Etch Test**



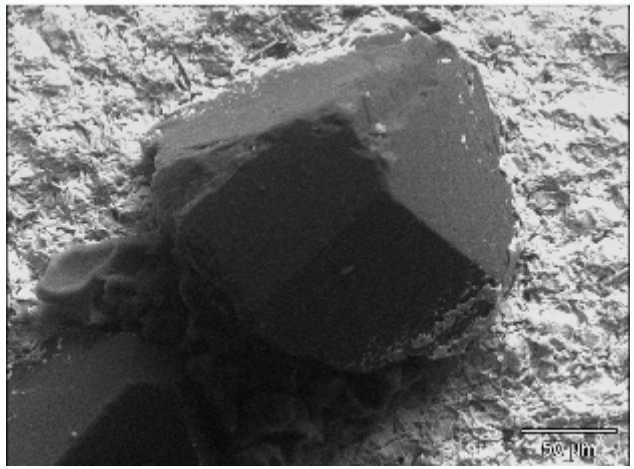



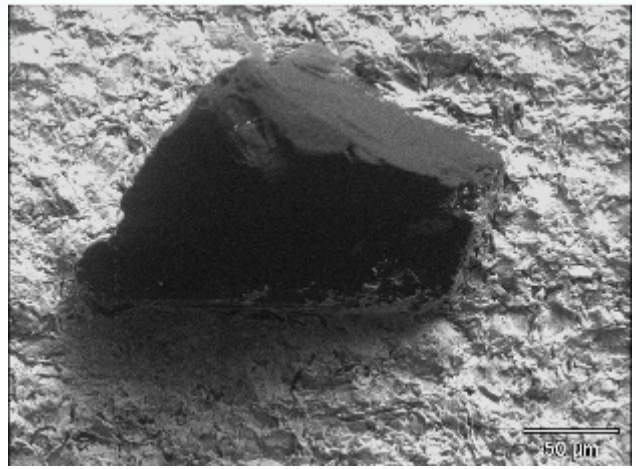

**There was no appreciable wear on the diamond disc substrate and diamonds.**

# SEM Analysis

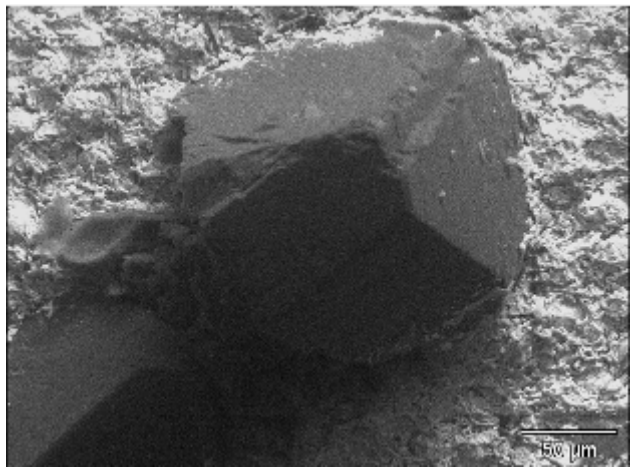
## D1 with Fujimi PL-7103 Slurry at 50 ºC

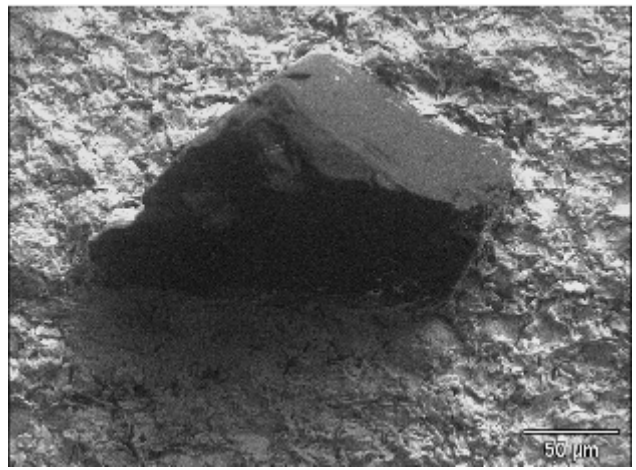
**Before Static Etch Test**




**After Static Etch Test**



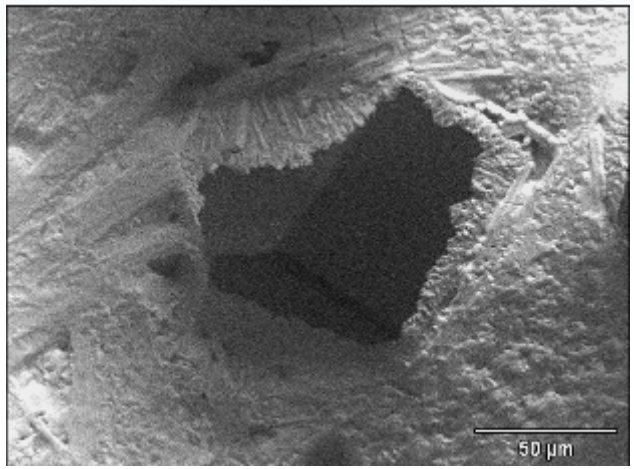



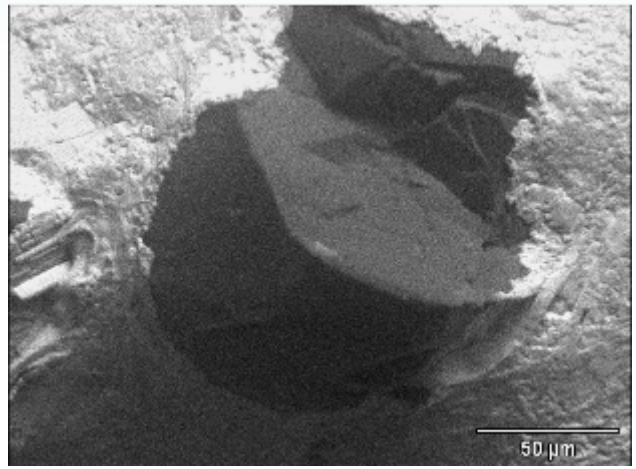

**There was no appreciable wear on the diamond disc substrate and diamonds.**

# SEM Analysis

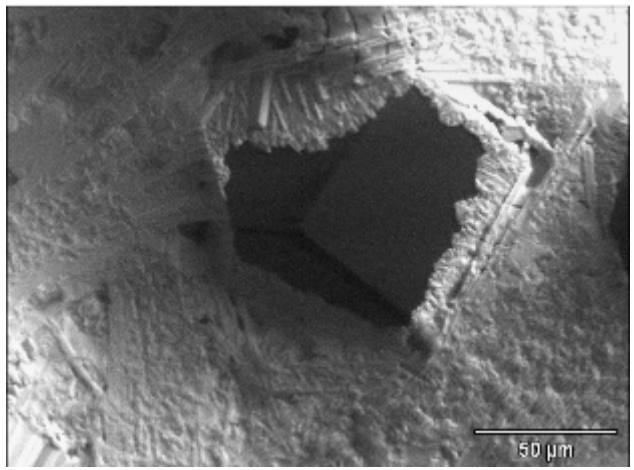
## D2 with CMC iCue 600Y75 Slurry at 25 ºC

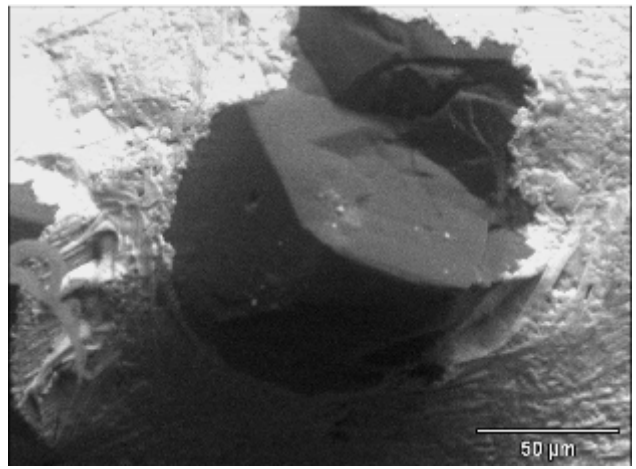
**Before Static Etch Test**




**After Static Etch Test**



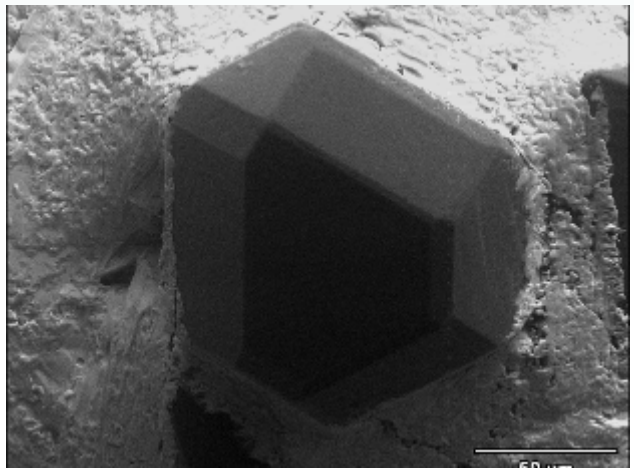



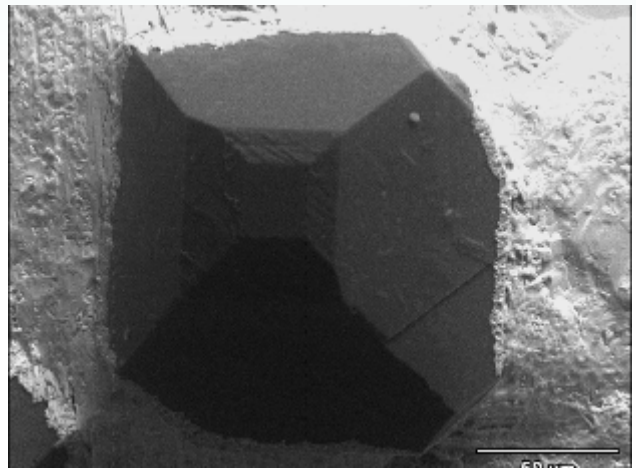

**There was no appreciable wear on the diamond disc substrate and diamonds.**

# SEM Analysis

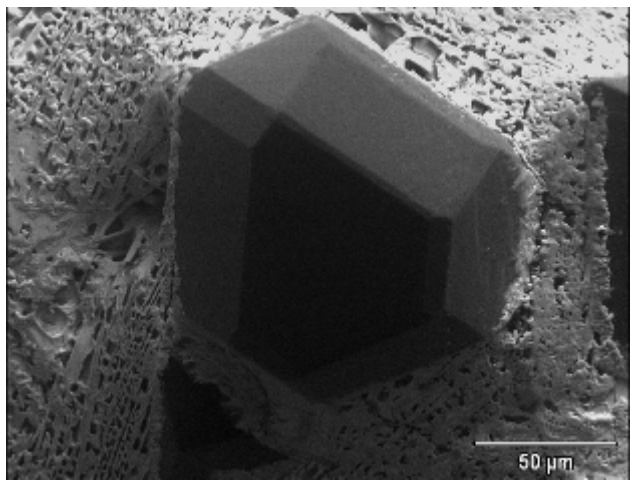
## D2 with CMC iCue 600Y75 Slurry at 50 ºC

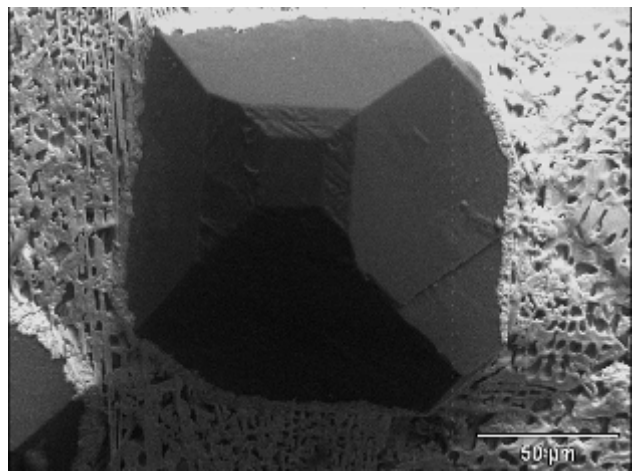
**Before Static Etch Test**





**After Static Etch Test**



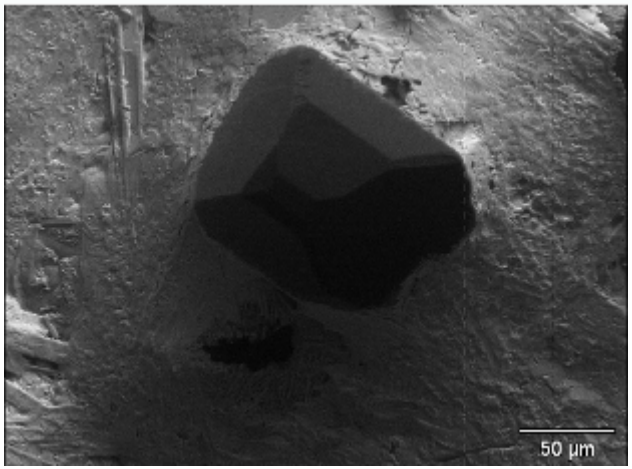



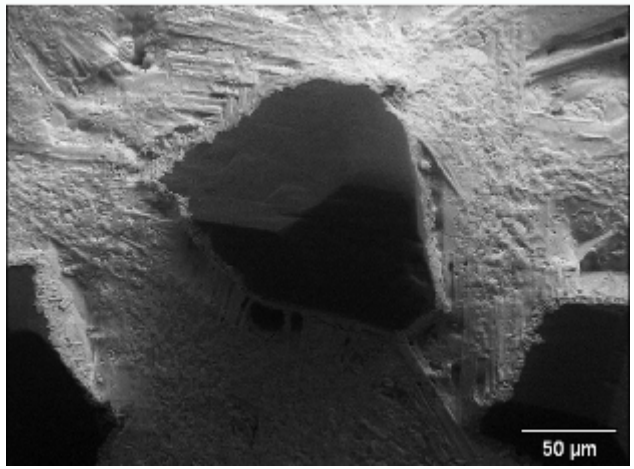

**There was apparent surface corrosion on the diamond disc substrate.**

# SEM Analysis

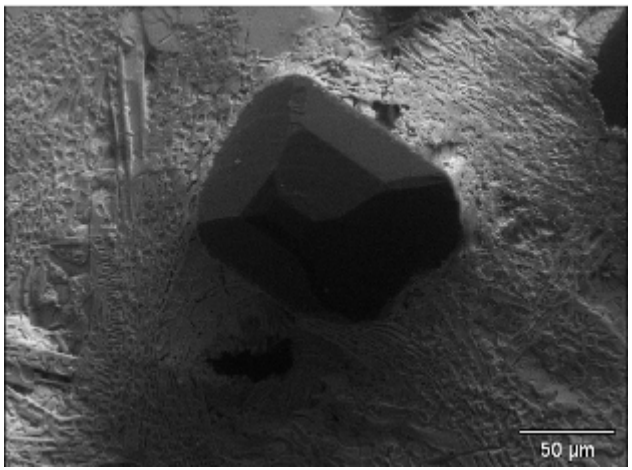
## D2 with Fijimi PL-7103 Slurry at 25 ºC

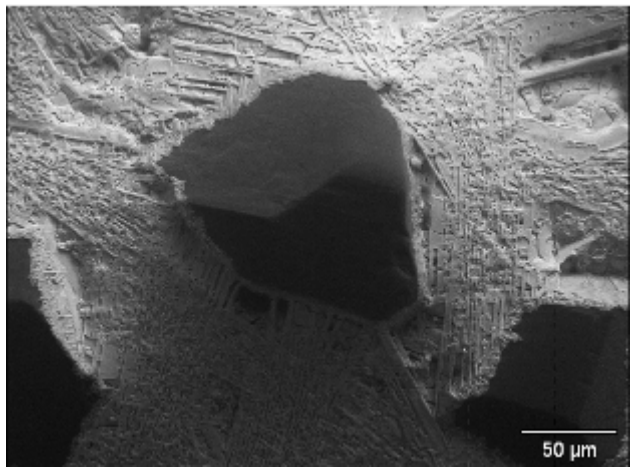
**Before Static Etch Test**




**After Static Etch Test**



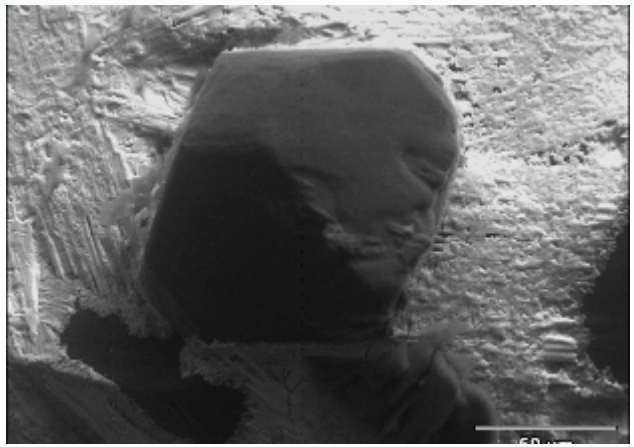



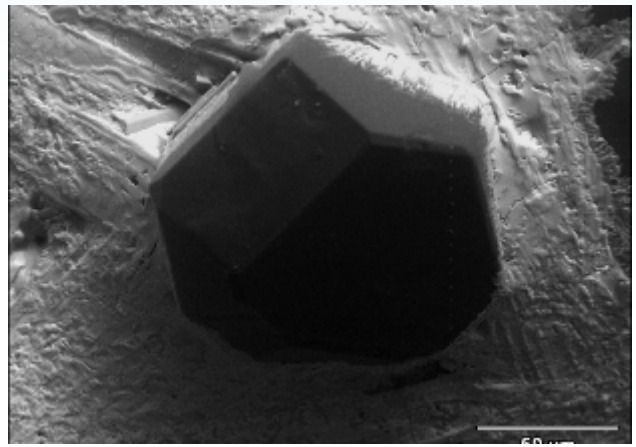

**There was apparent surface corrosion on the diamond disc substrate.**

# SEM Analysis

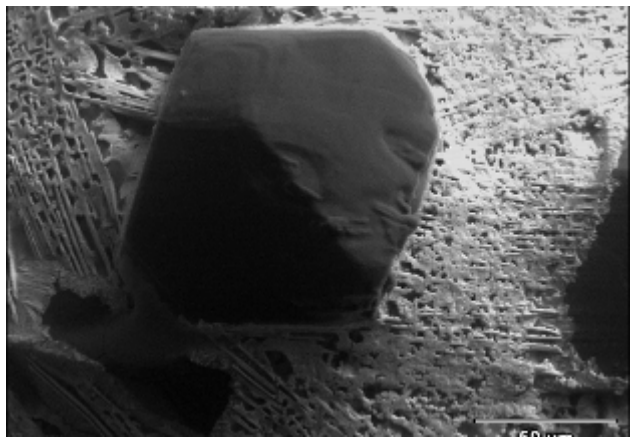
## D2 with Fijimi PL-7103 Slurry at 50 ºC

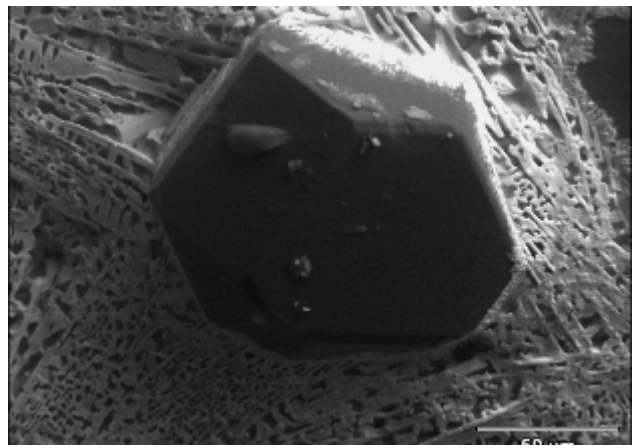
**Before Static Etch Test**





**After Static Etch Test**



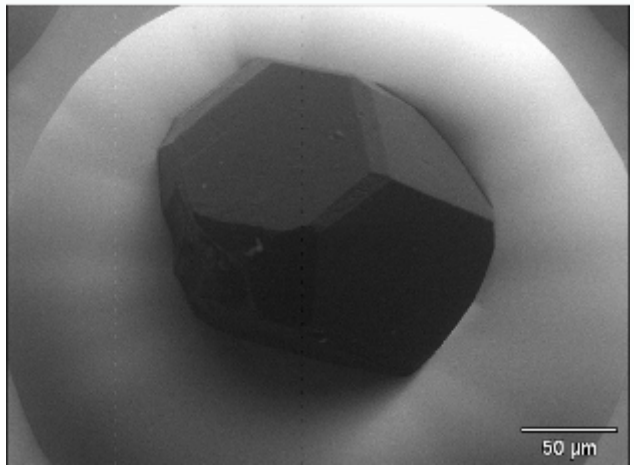


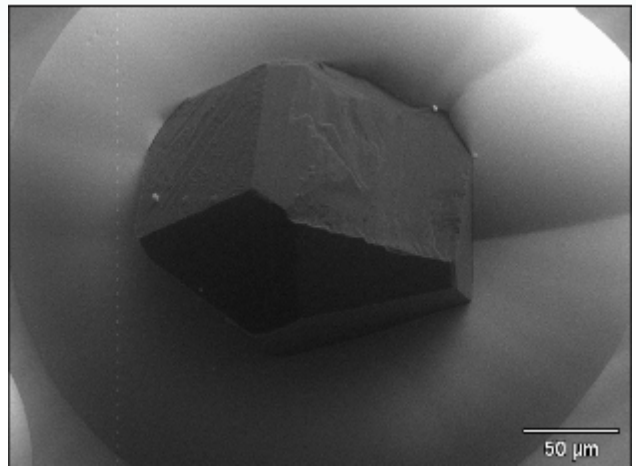
**There was apparent surface corrosion on the diamond disc substrate.**

# SEM Analysis

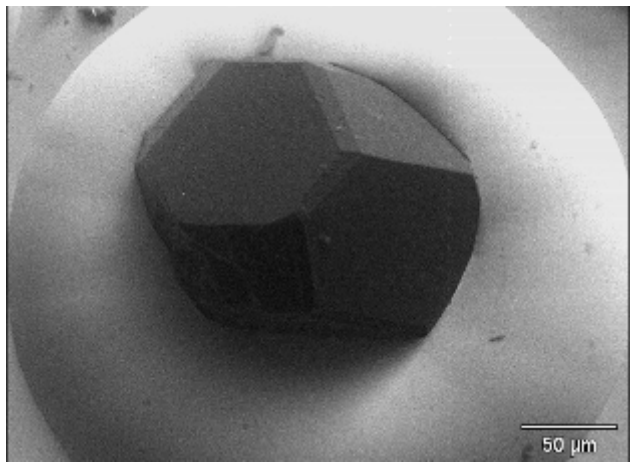
## D3 with CMC iCue 600Y75 Slurry at 25 ºC

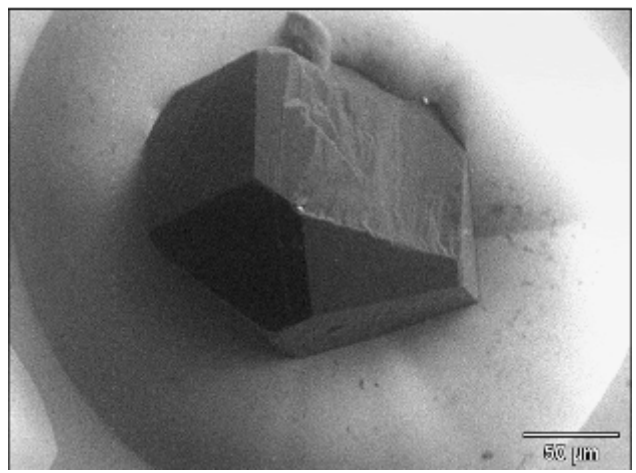
**Before Static Etch Test**




**After Static Etch Test**



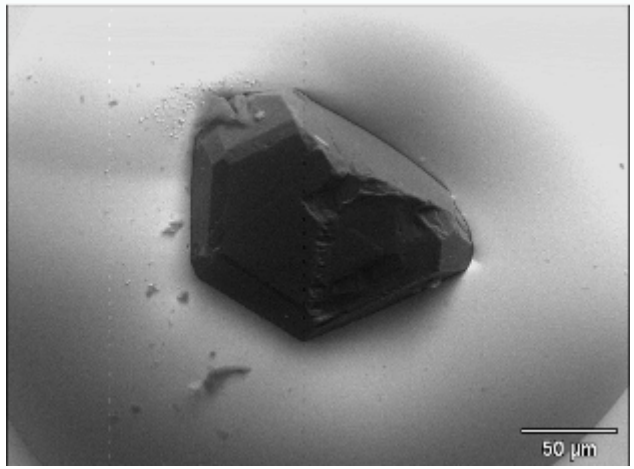



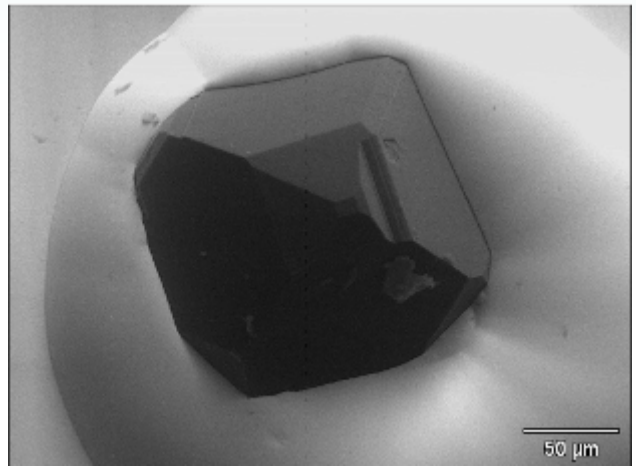

**There was no appreciable wear on the diamond disc substrate and diamonds.**

# SEM Analysis

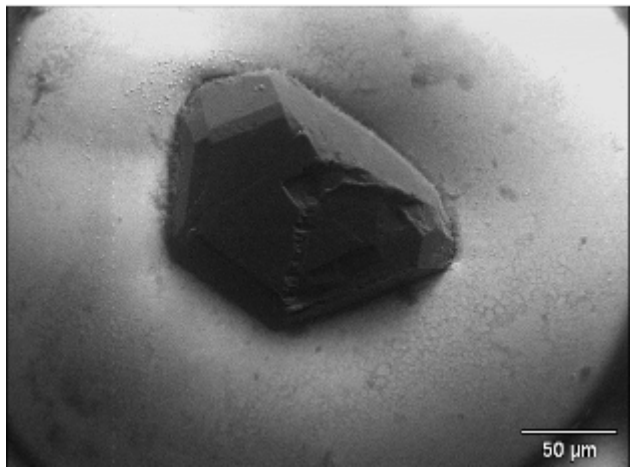
## D3 with CMC iCue 600Y75 Slurry at 50 ºC

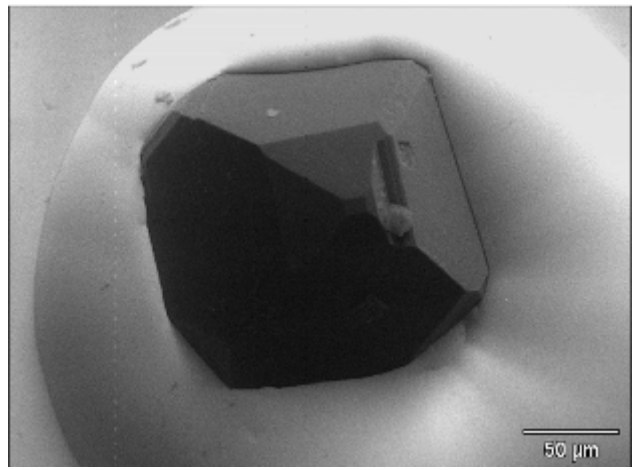
**Before Static Etch Test**




**After Static Etch Test**



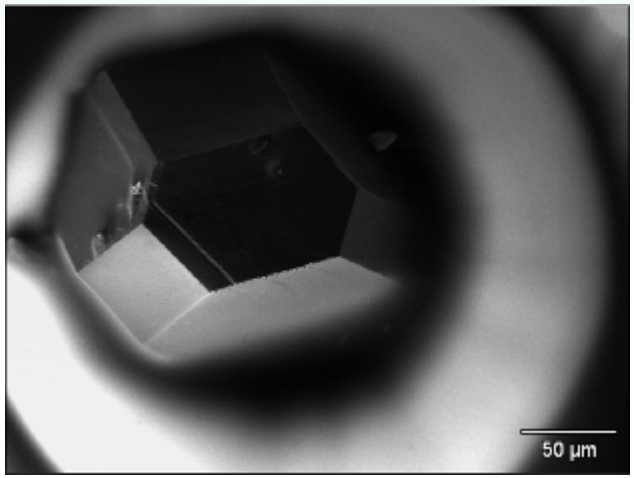



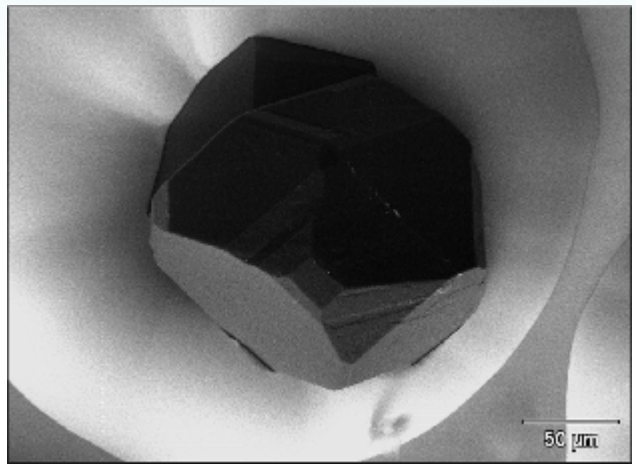

**There was no appreciable wear on the diamond disc substrate and diamonds.**

# SEM Analysis

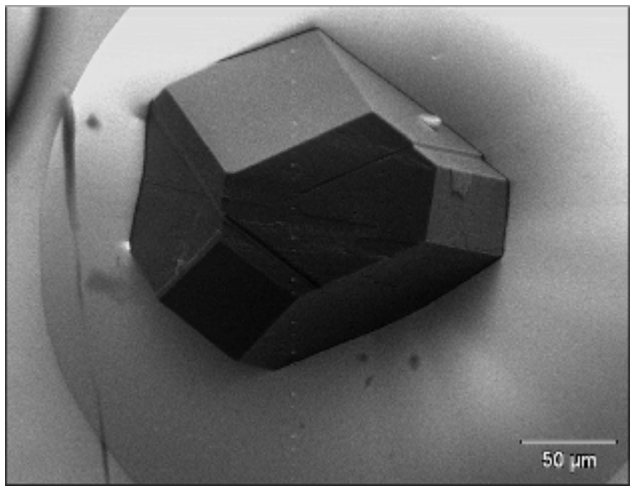
## D3 with Fujimi PL-7103 Slurry at 25 ºC

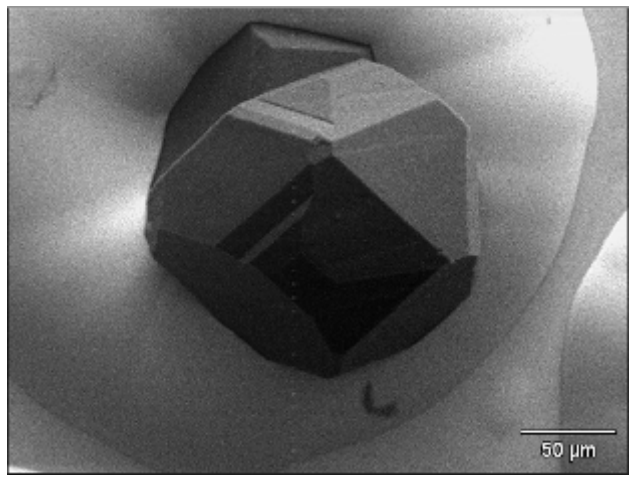
**Before Static Etch Test**




**After Static Etch Test**



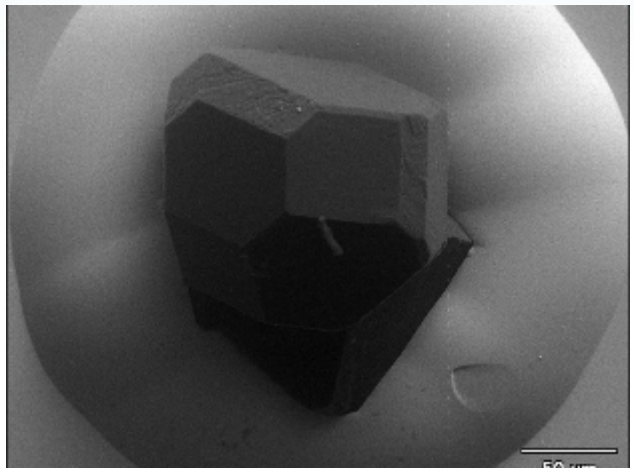



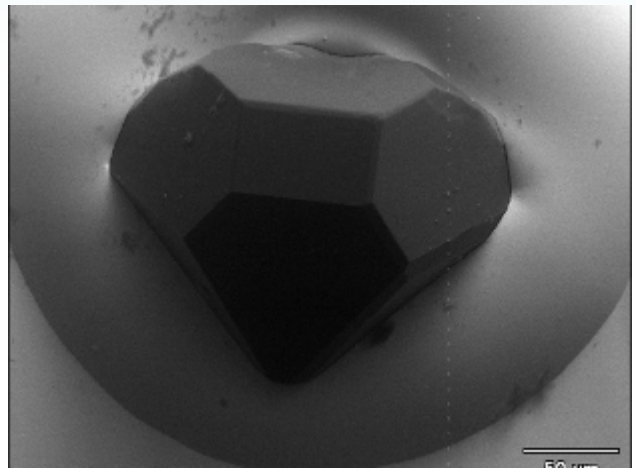

**There was no appreciable wear on the diamond disc substrate and diamonds.**

# SEM Analysis

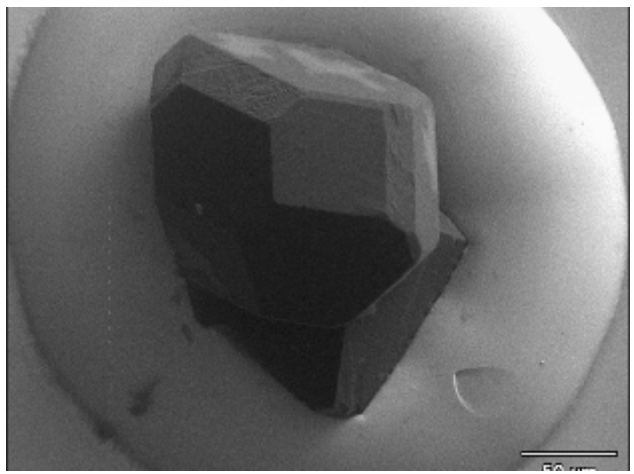
## D3 with Fujimi PL-7103 Slurry at 50 ºC

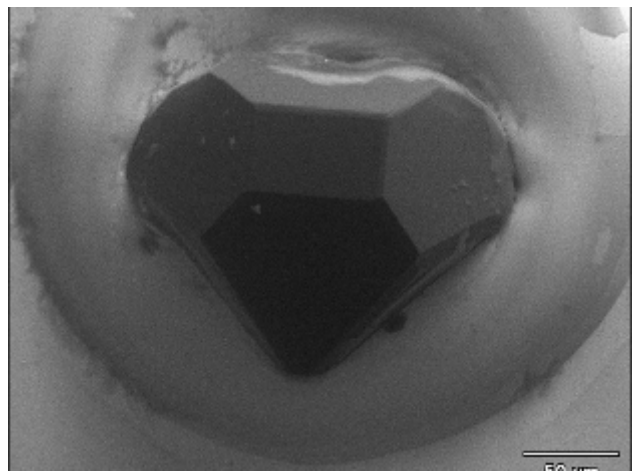
**Before Static Etch Test**





**After Static Etch Test**





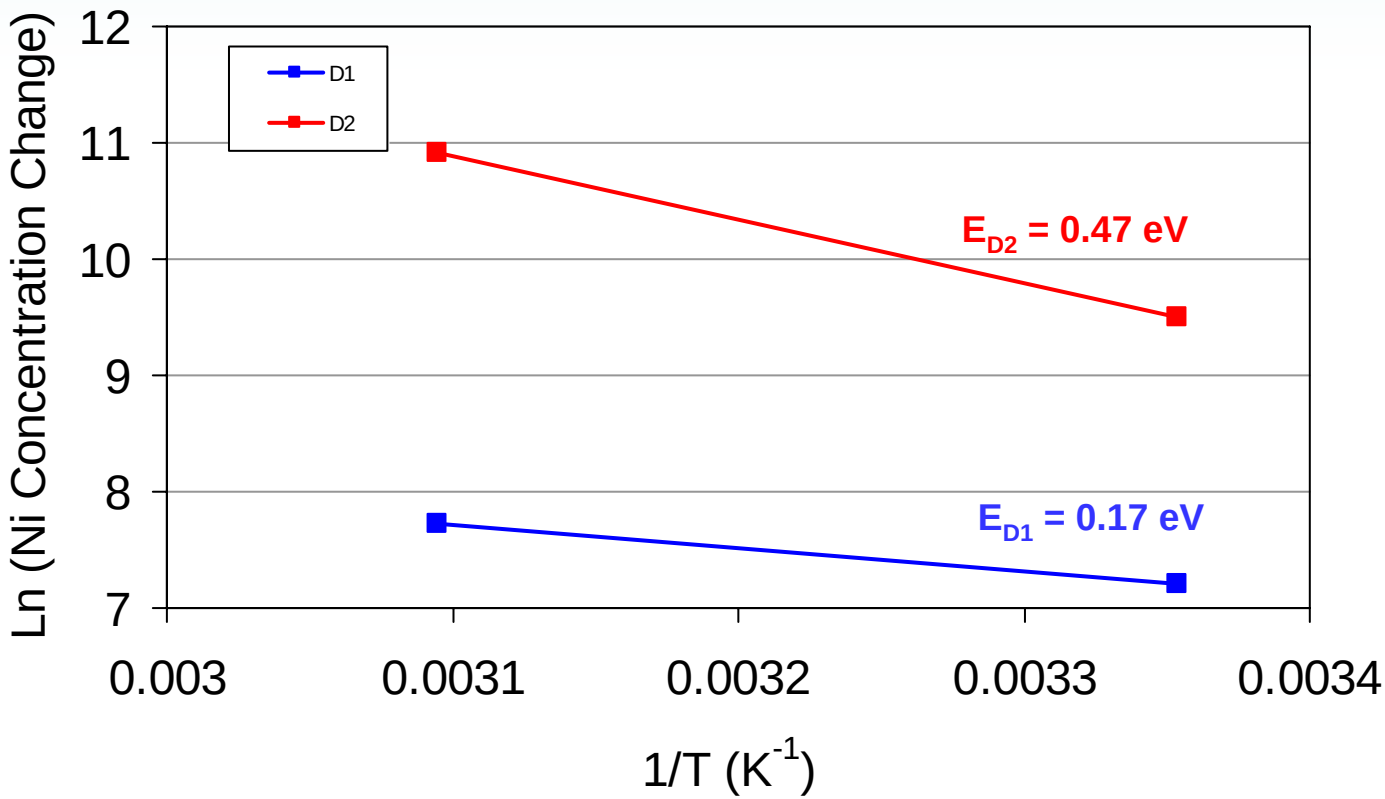
**There was no appreciable wear on the diamond disc substrate and diamonds.**

# ICPMS Analysis – Metal Concentration Changes

| Temperature | Metal | D1 (mg/L) | | D2 (mg/L) | | D3 (mg/L) | |
|---|---|---|---|---|---|---|---|
| | | Fujimi PL-7103 | CMC iCue 600Y75 | Fujimi PL-7103 | CMC iCue 600Y75 | Fujimi PL-7103 | CMC iCue 600Y75 |
| 25 °C | Ni | 1.35 | 1.33 | 13.26 | 1.89 | 0 | 0 |
| | Fe | 0.03 | 0 | 0.44 | 0.22 | 0 | 0 |
| | Cr | 0.10 | 0.07 | 0.40 | 0.45 | 0.02 | 0.06 |
| 50 °C | Ni | 2.28 | 4.25 | 54.81 | 42.85 | 0.06 | 0.05 |
| | Fe | 0 | 0.07 | 0.62 | 1.72 | 0 | 0.04 |
| | Cr | 0.04 | 0.13 | 2.35 | 2.33 | 0.02 | 0.10 |

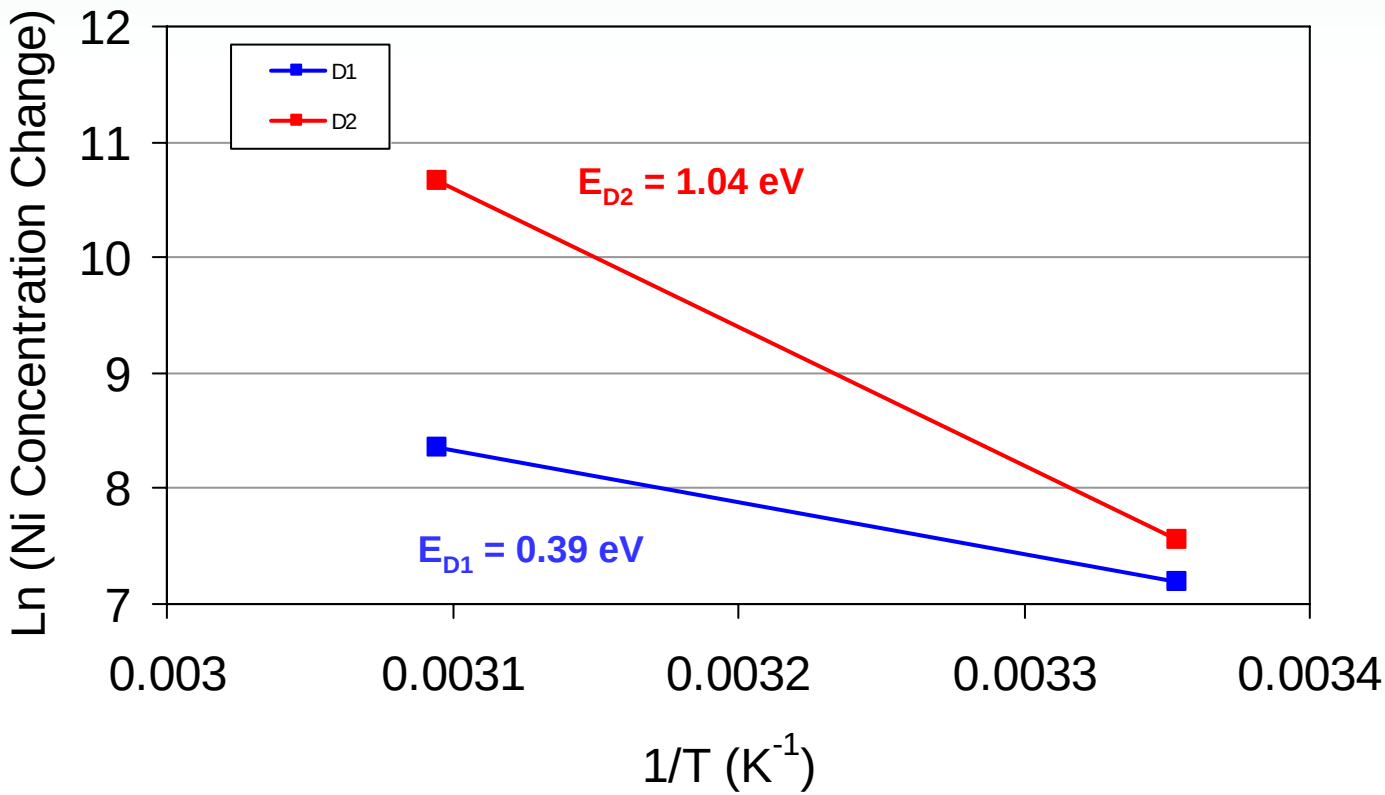
# Activation Energy of Ni Corrosion

## Fujimi PL-7103 Slurry



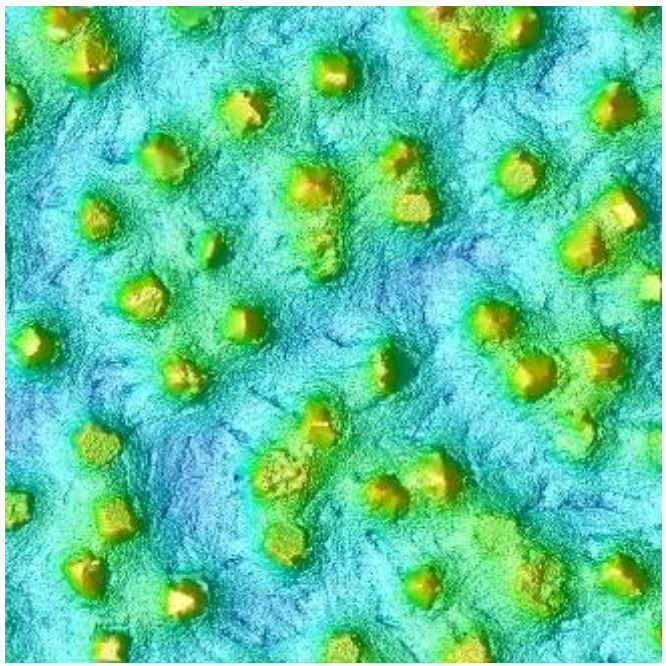
# Activation Energy of Ni Corrosion

## CMC iCue 600Y75 Slurry

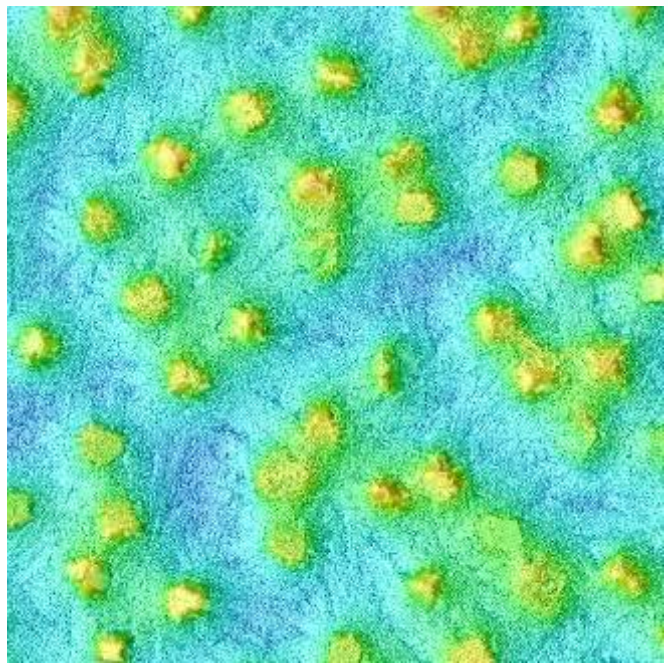


# Interferometric Analysis – 2 x 2 $mm^2$

## D2 with CMC iCue 600Y75 Slurry at 50 ºC

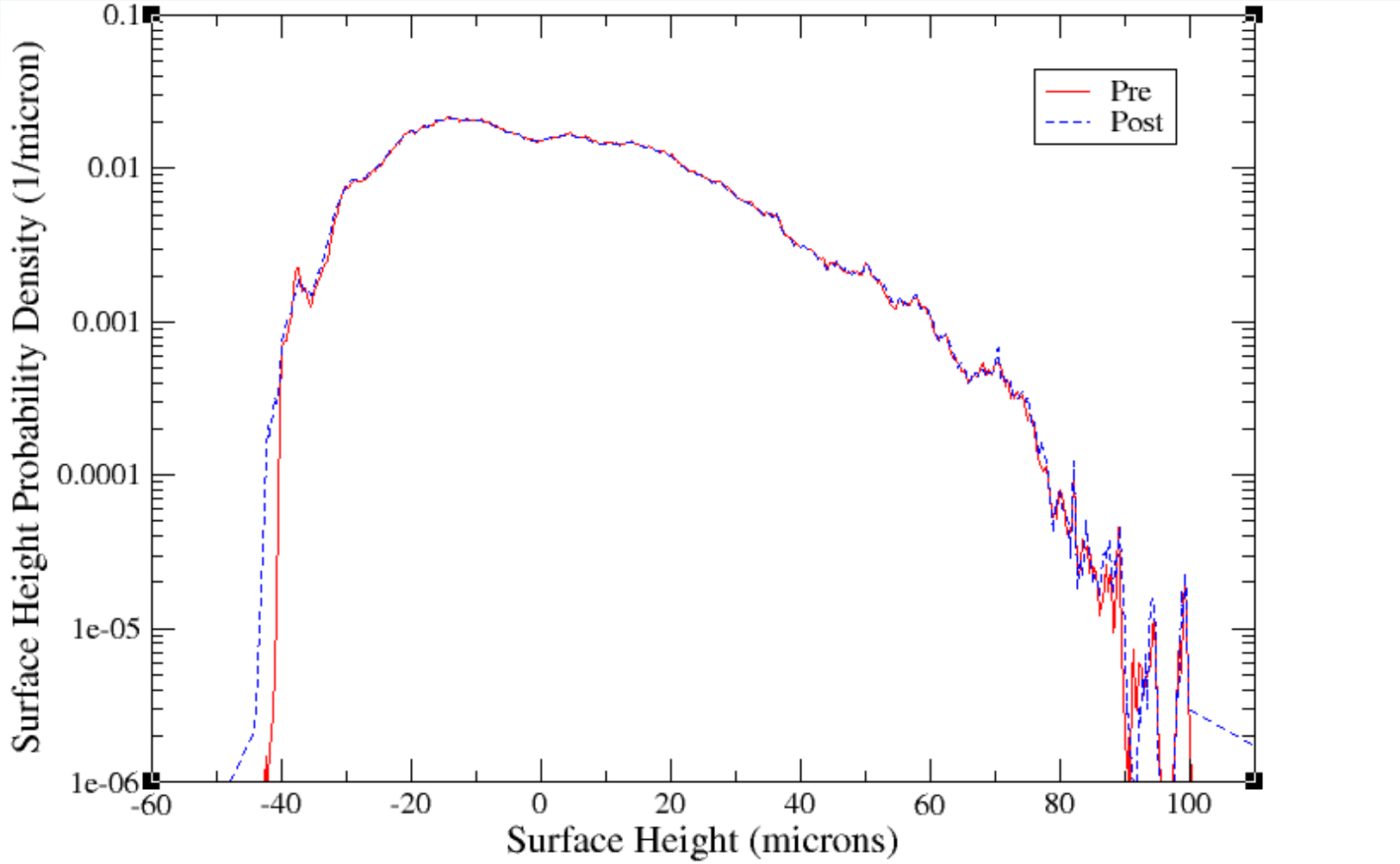


Before Static Etch Test

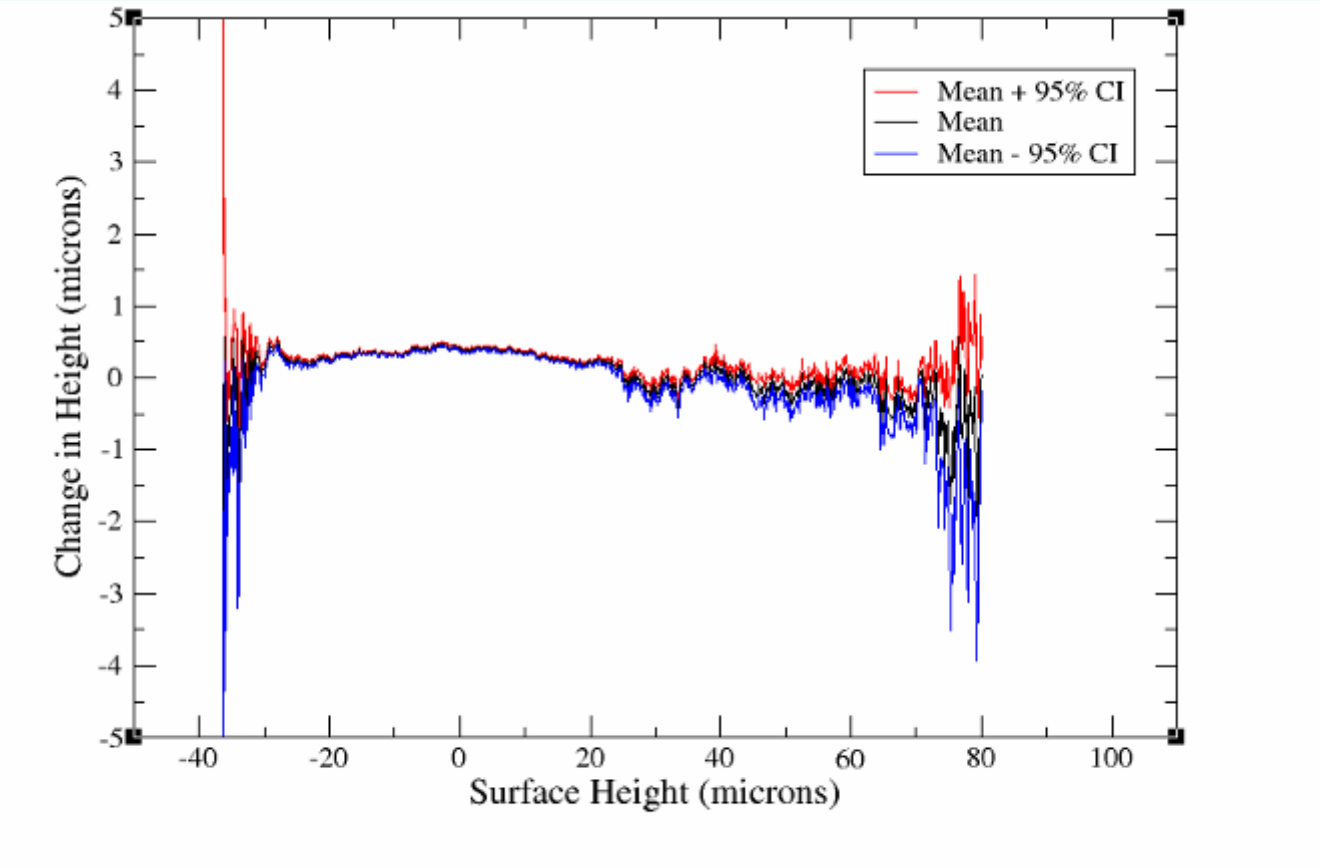



After Static Etch Test

# Diamond Disc Surface Height PDFs



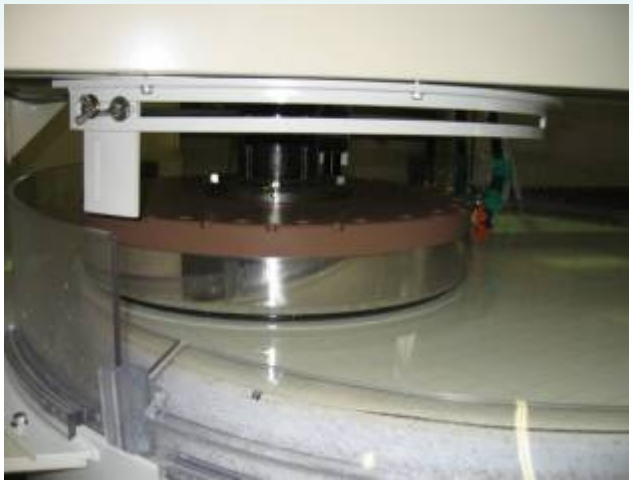
# Change in Diamond Disc Surface Height

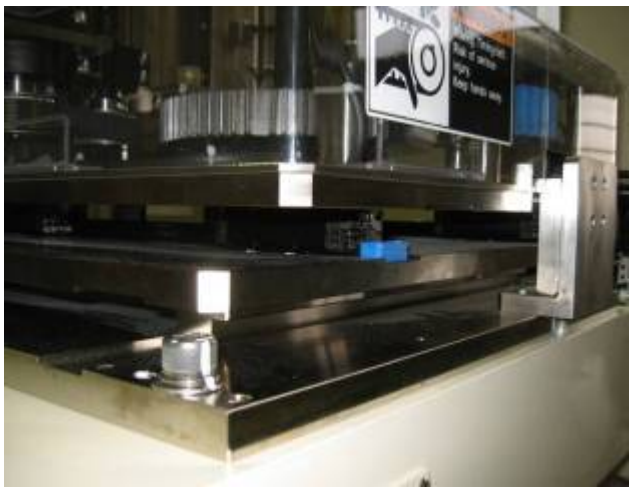



**The interferometric analysis did not quantify diamond disc substrate wear accurately.**

# Wear Test Results

# Araca APD – 800 Polisher & Tribometer





# Experimental Conditions

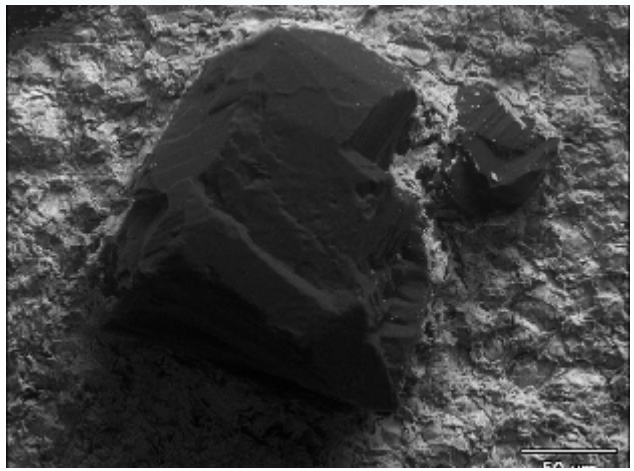
- **Pad**
  - 30-inch IC1000 A6 pad with Suba IV sub-pad
- **Slurry**
  - 2 volume parts of Fujimi PL-7103 slurry + 8 volume parts of DI $H_2O$ + 0.33 volume parts of 30% ultra pure $H_2O_2$
  - 10 volume parts of Cabot Microelectronics Corporation iCue 600Y75 slurry + 1.1 volume parts of 30% ultra pure $H_2O_2$
  - 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

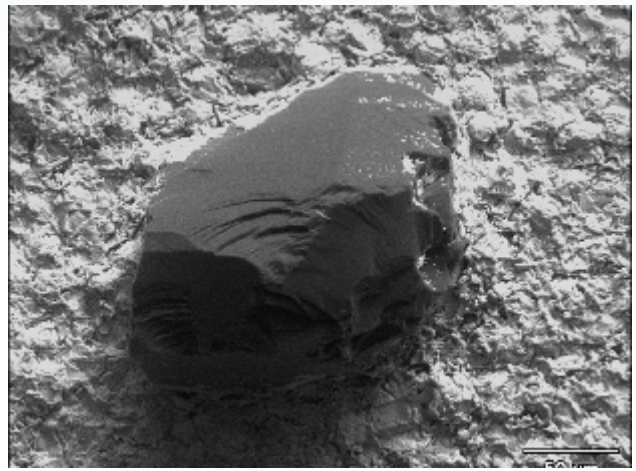
**No wafer polishing was performed during the wear test.**

# SEM Analysis – Aggressive Diamonds

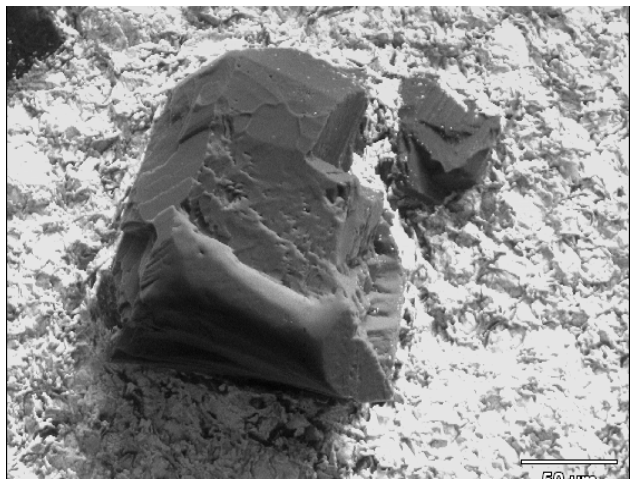
## D1 with CMC iCue 600Y75 Slurry at 25 ºC

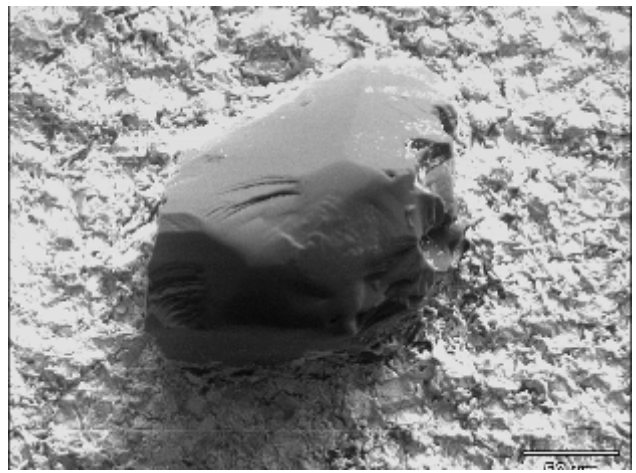
**Before Wear Test**





**After Wear Test**



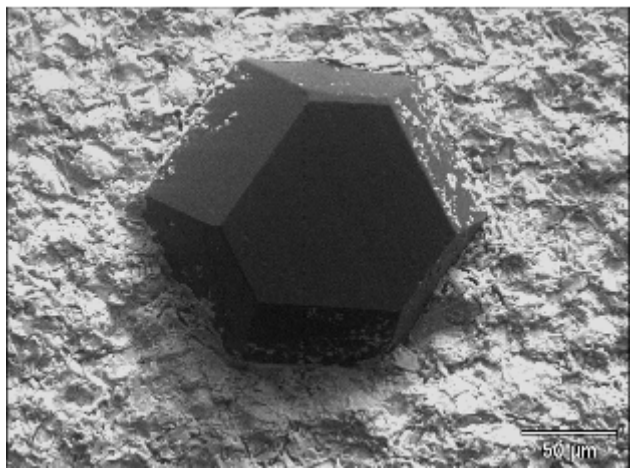


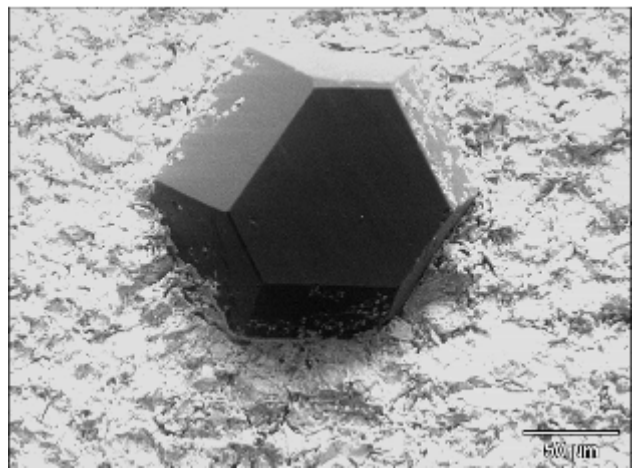
**There was micro wear on the cutting edges of aggressive diamonds.**
**There was no appreciable wear on the diamond disc substrate.**

# SEM Analysis – Inactive Diamond

## D1 with CMC iCue 600Y75 Slurry at 25 ºC

**Before Wear Test**



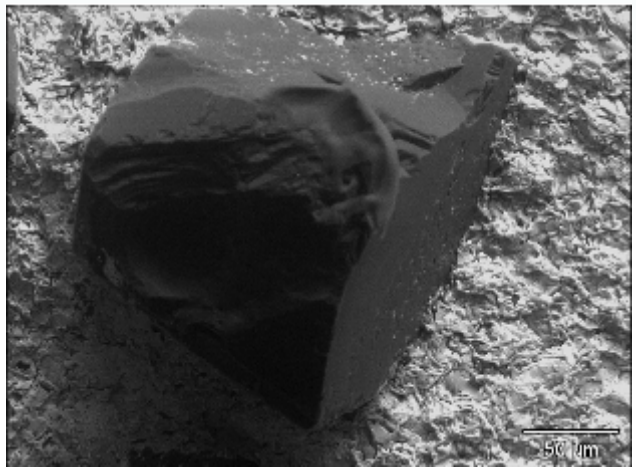

**After Wear Test**

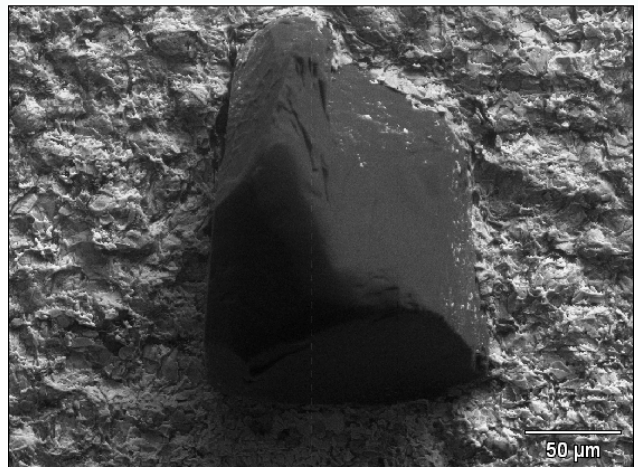
**There was no appreciable wear on the inactive diamond and diamond disc substrate.**

# SEM Analysis – Aggressive Diamonds

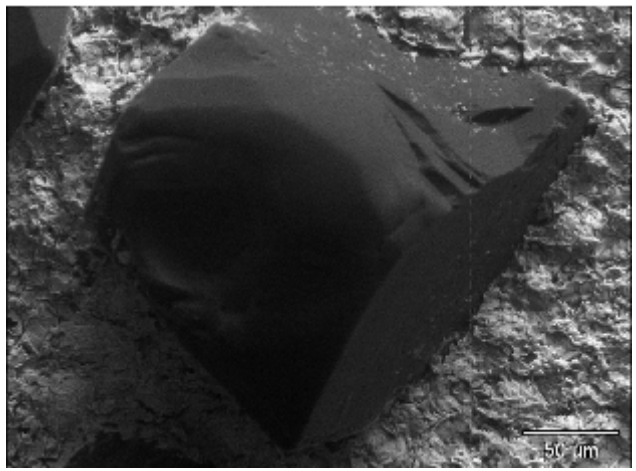
## D1 with CMC iCue 600Y75 Slurry at 50 ºC

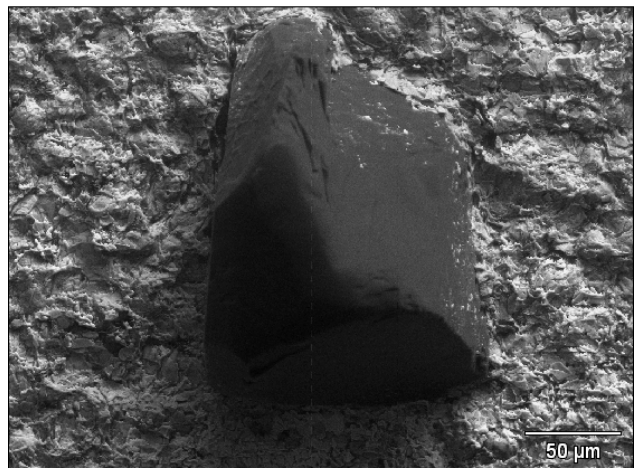
**Before Wear Test**




**After Wear Test**



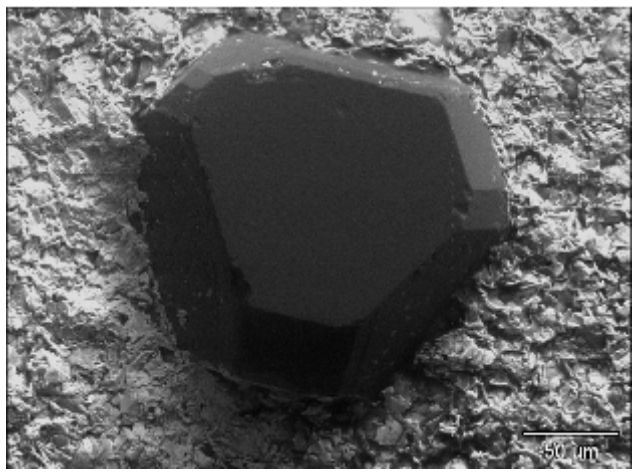



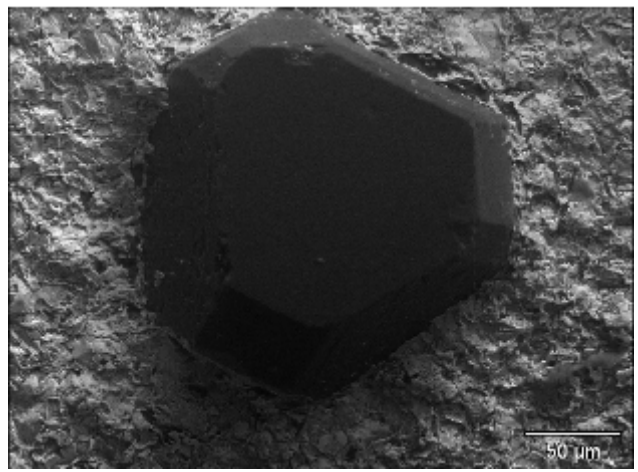

**There was micro wear on the cutting edges of aggressive diamonds.**
**There was no appreciable wear on the diamond disc substrate.**

# SEM Analysis – Inactive Diamond

## D1 with CMC iCue 600Y75 Slurry at 50 ºC

**Before Wear Test**



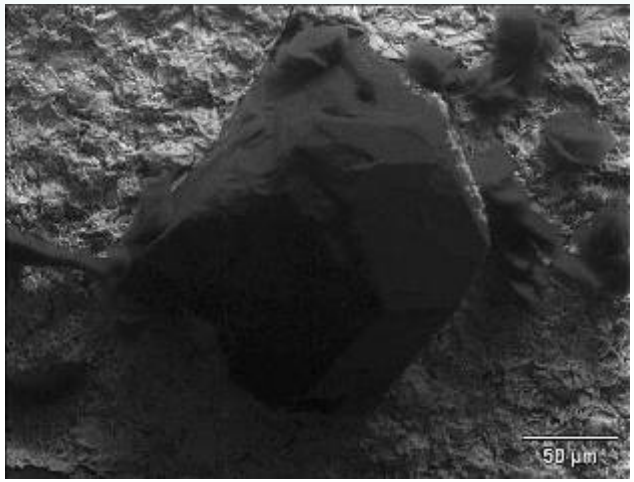

**After Wear Test**

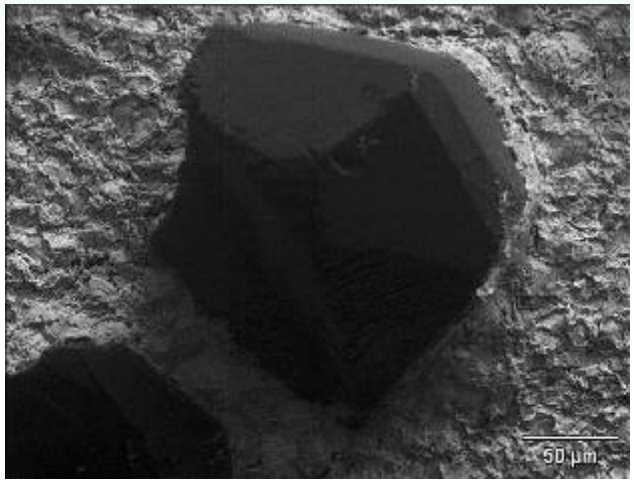
**There was no appreciable wear on the inactive diamond and diamond disc substrate.**

# SEM Analysis – Aggressive Diamonds

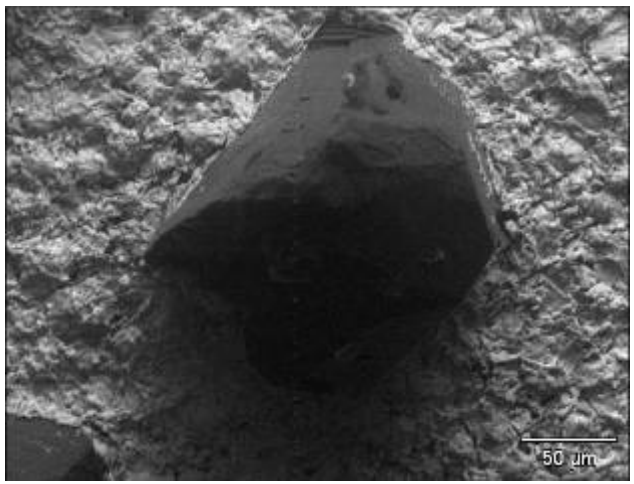
## D1 with Fujimi PL-7103 Slurry at 25 ºC

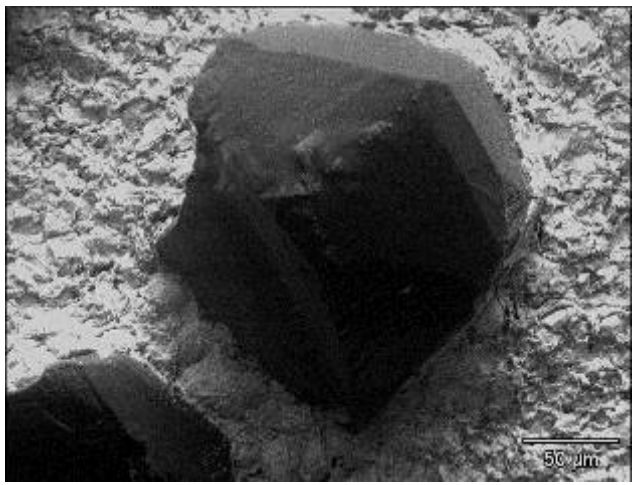
**Before Wear Test**




**After Wear Test**



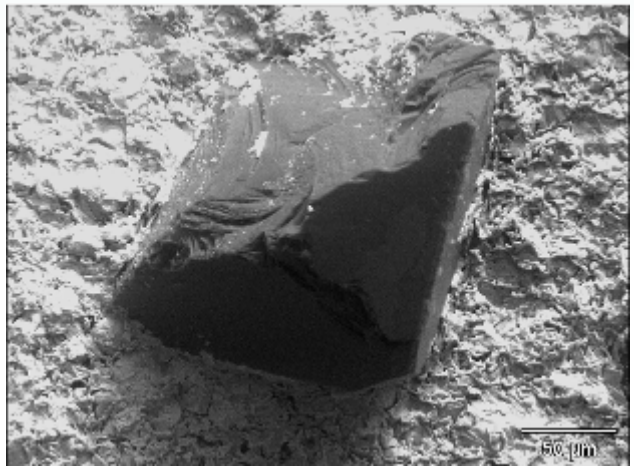



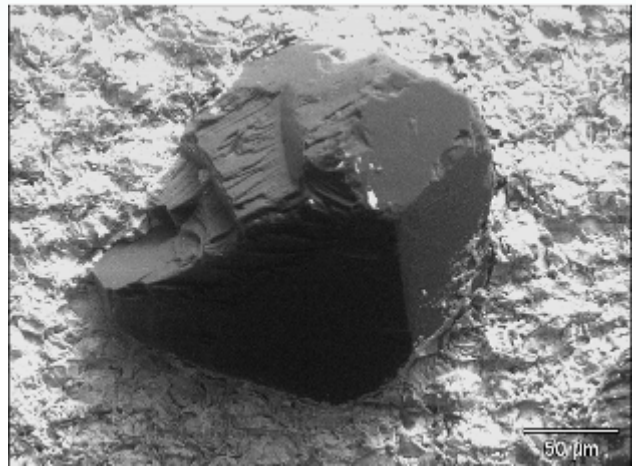

**There was micro wear on the cutting edges of aggressive diamonds.**
**There was no appreciable wear on the diamond disc substrate.**

# SEM Analysis – Aggressive Diamonds

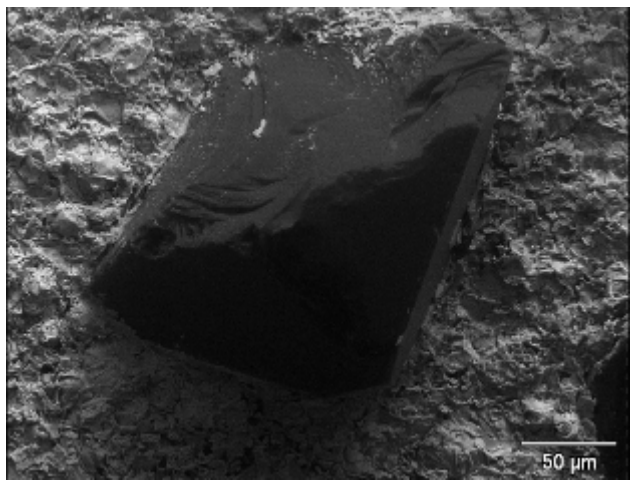
## D1 with Fujimi PL-7103 Slurry at 50 ºC

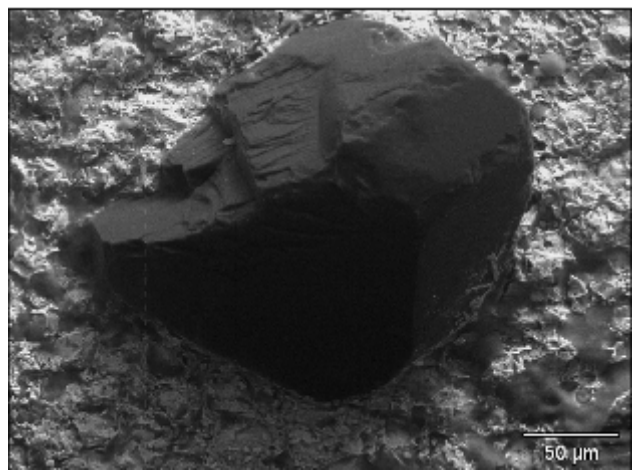
**Before Wear Test**




**After Wear Test**



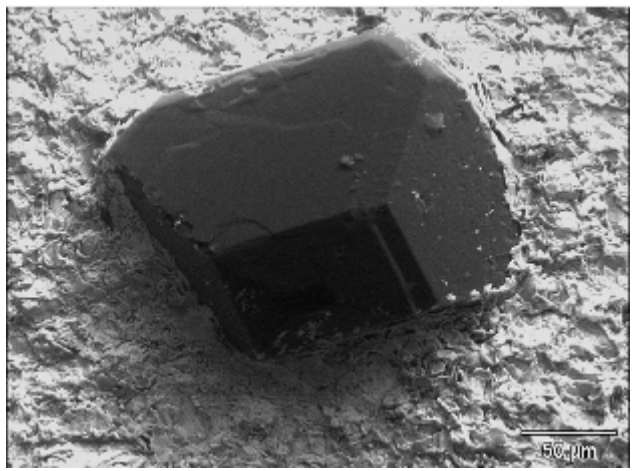



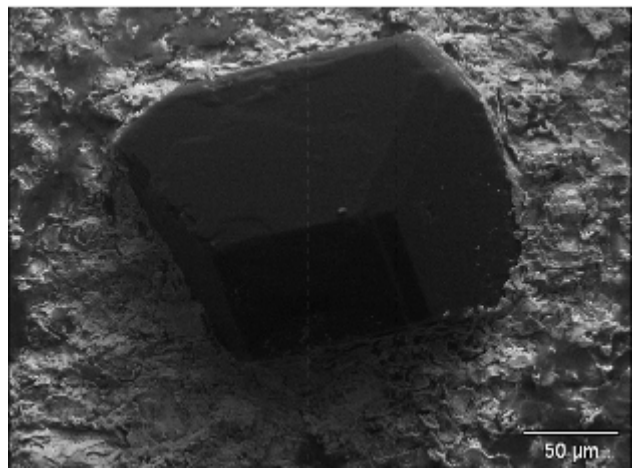

**There was micro wear on the cutting edges of aggressive diamonds.**
**There was no appreciable wear on the diamond disc substrate.**

# SEM Analysis – Inactive Diamond

## D1 with Fujimi PL-7103 Slurry at 50 ºC

**Before Wear Test**



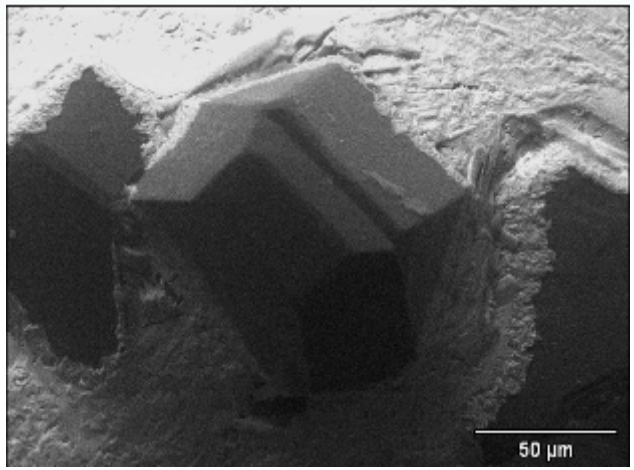

**After Wear Test**

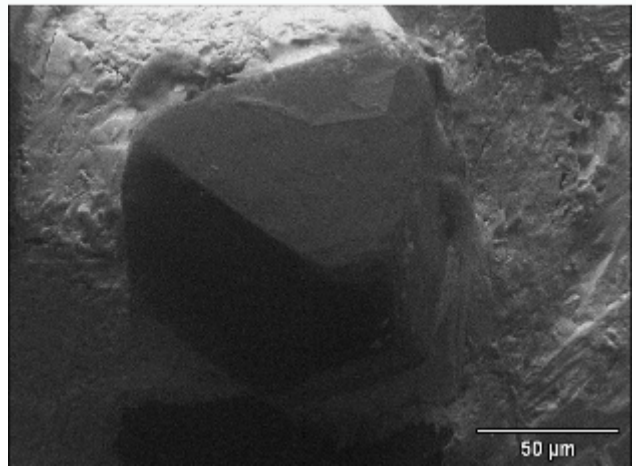
**There was no appreciable wear on the inactive diamond and diamond disc substrate.**

# SEM Analysis – Aggressive Diamonds

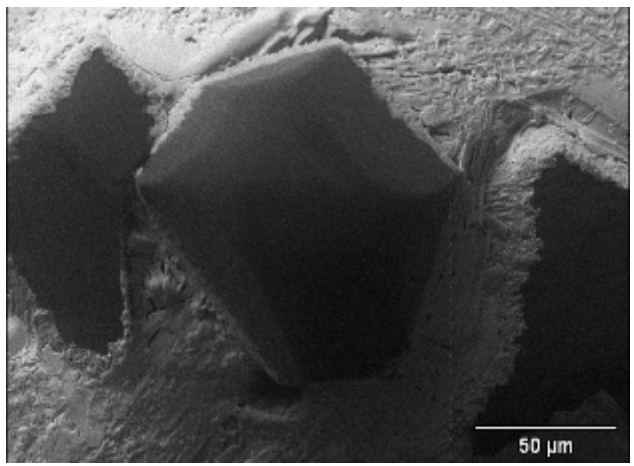
## D2 with CMC iCue 600Y75 Slurry at 25 ºC

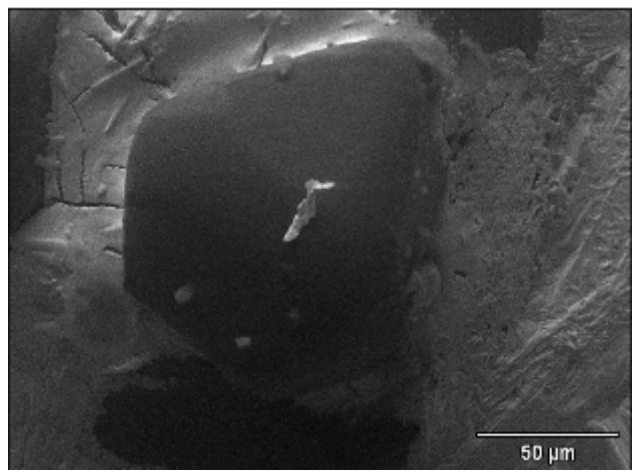
**Before Wear Test**




**After Wear Test**



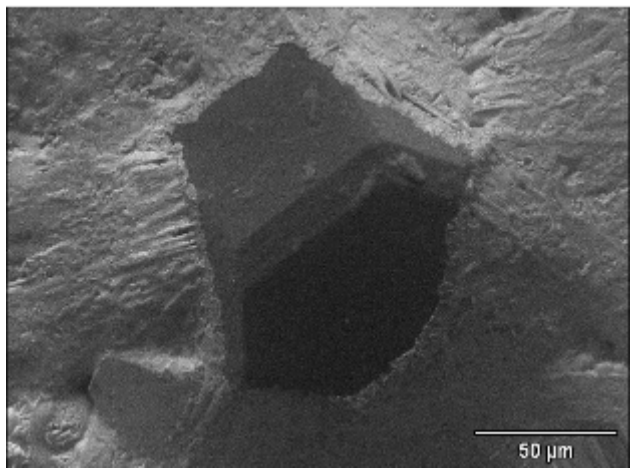



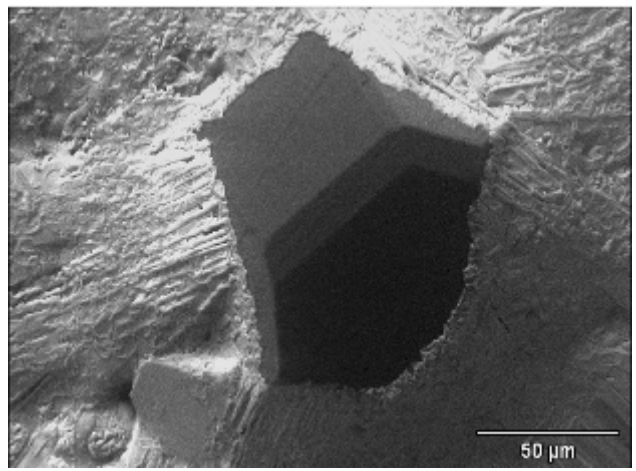

**There was micro wear on the cutting edges of aggressive diamonds. Micro cracks formed on the diamond disc substrate.**

# SEM Analysis – Inactive Diamond

## D2 with CMC iCue 600Y75 Slurry at 25 ºC

**Before Wear Test**



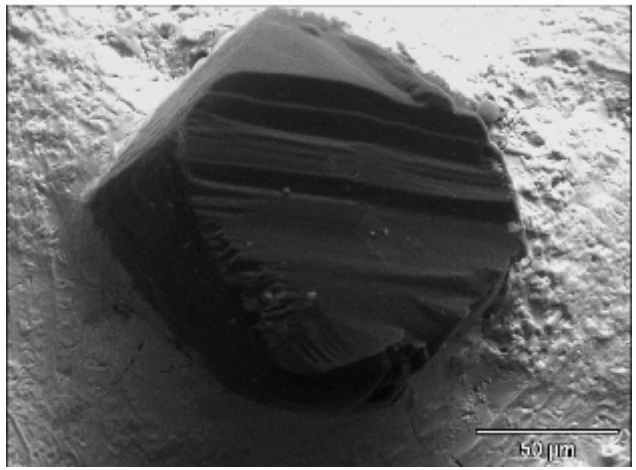

**After Wear Test**

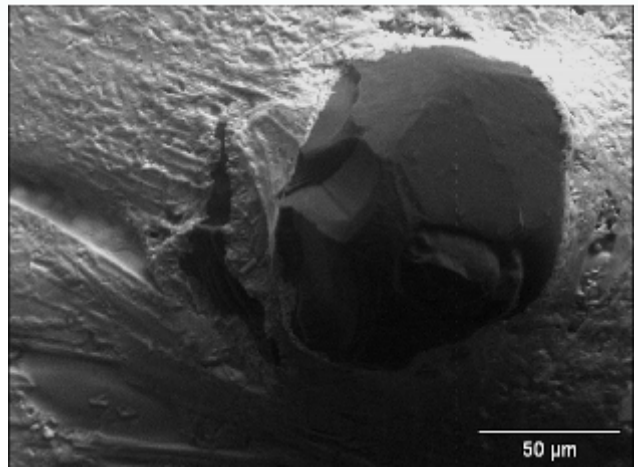
**There was no appreciable wear on the inactive diamond.**
**There was appreciable surface corrosion on the diamond disc substrate.**

# SEM Analysis – Aggressive Diamonds

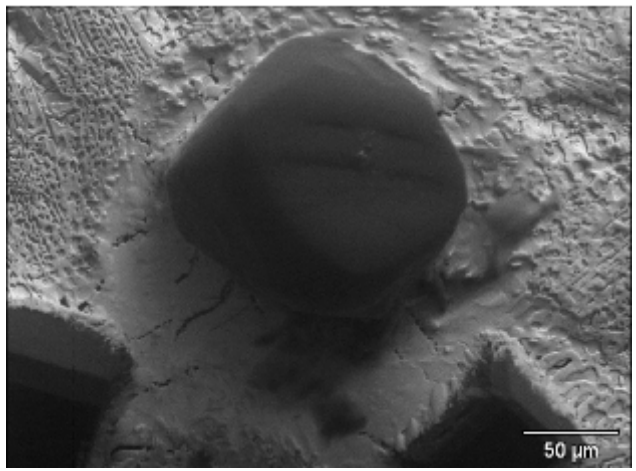
## D2 with CMC iCue 600Y75 Slurry at 50 ºC

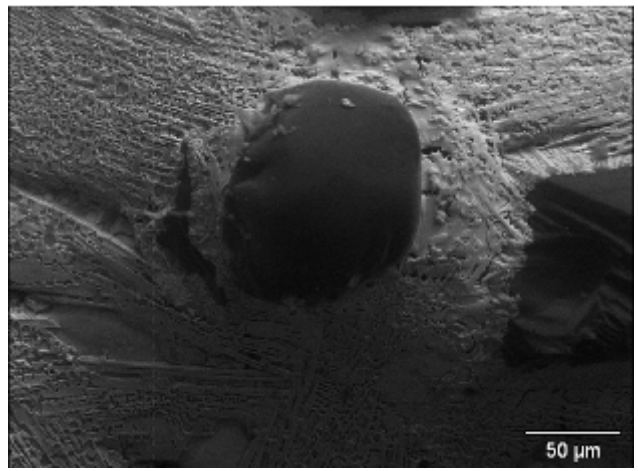
**Before Wear Test**




**After Wear Test**



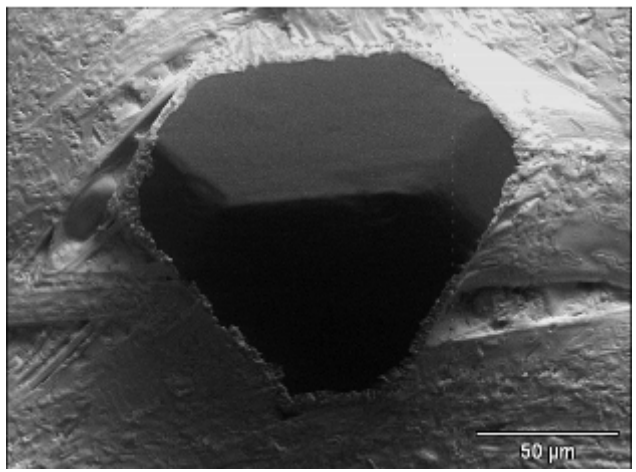



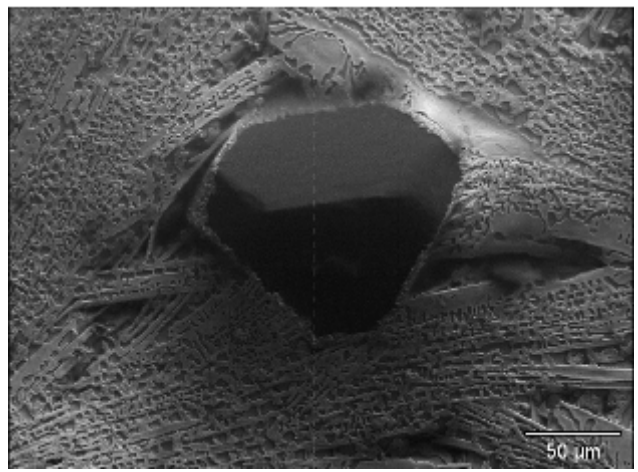

**There was micro wear on the cutting edges of aggressive diamonds.**
**There was apparent surface corrosion on the diamond disc substrate.**

# SEM Analysis – Inactive Diamond

## D2 with CMC iCue 600Y75 Slurry at 50 ºC

**Before Wear Test**



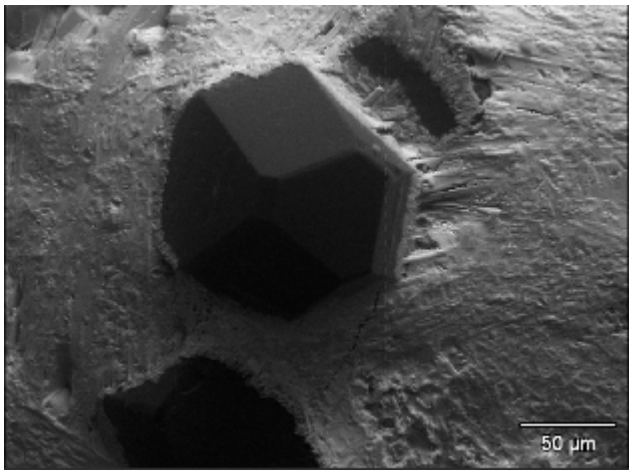

**After Wear Test**

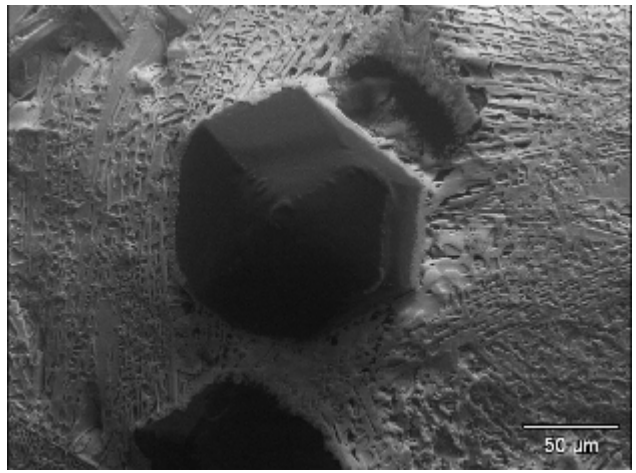
**There was no appreciable wear on the inactive diamond.**
**There was apparent surface corrosion on the diamond disc substrate.**

# SEM Analysis – Aggressive Diamond

## D2 with Fujimi PL-7103 Slurry at 25 ºC

**Before Wear Test**



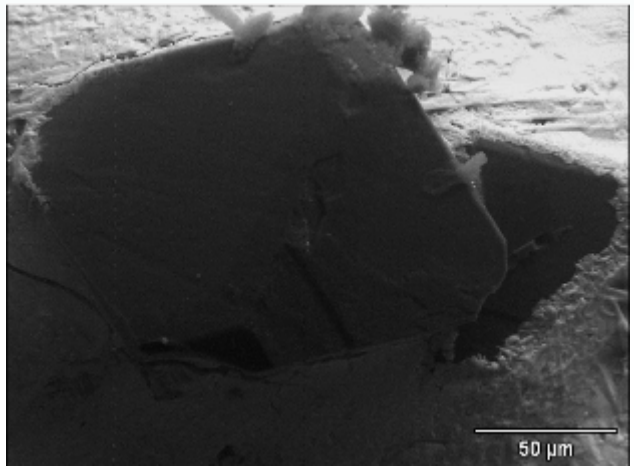

**After Wear Test**

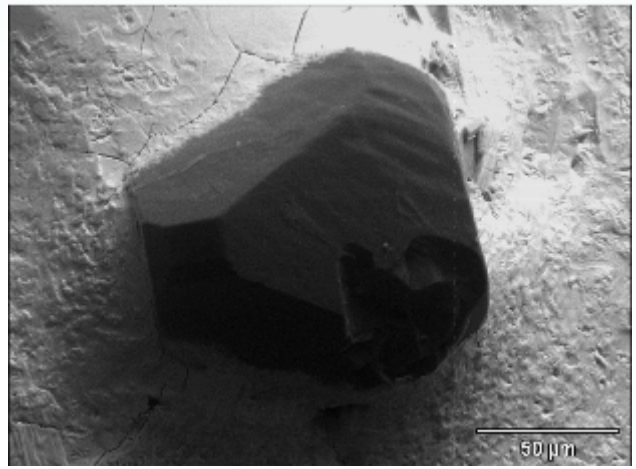
**There was micro wear on the cutting edges of aggressive diamond.**
**There was apparent surface corrosion on the diamond disc substrate.**

# SEM Analysis – Aggressive Diamonds

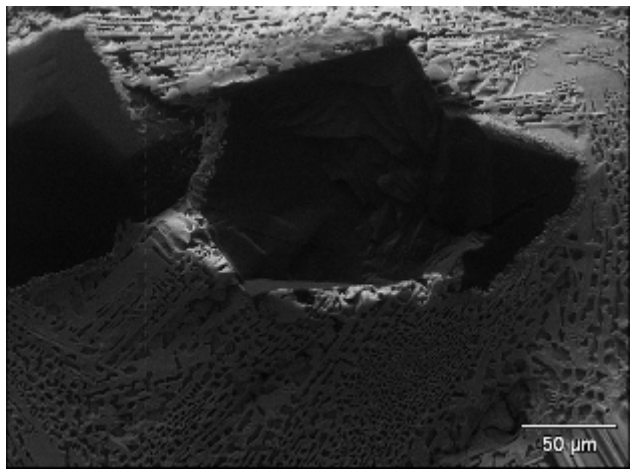
## D2 with Fujimi PL-7103 Slurry at 50 ºC

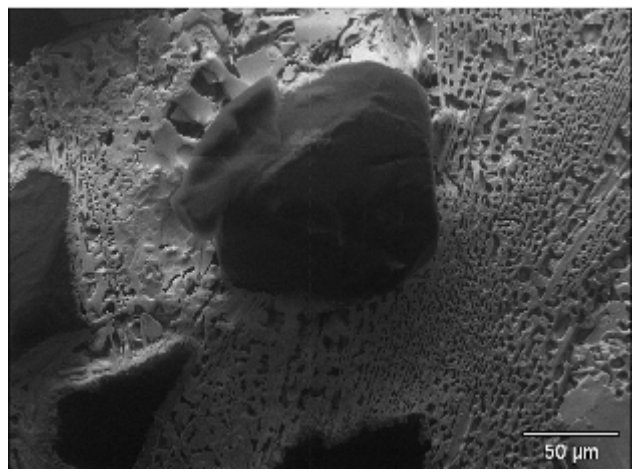
**Before Wear Test**




**After Wear Test**



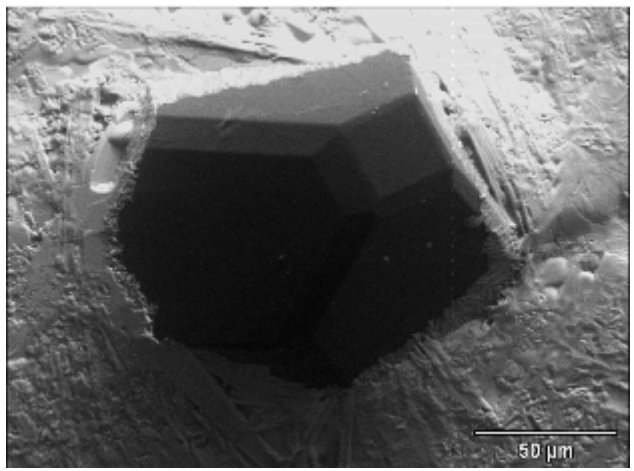



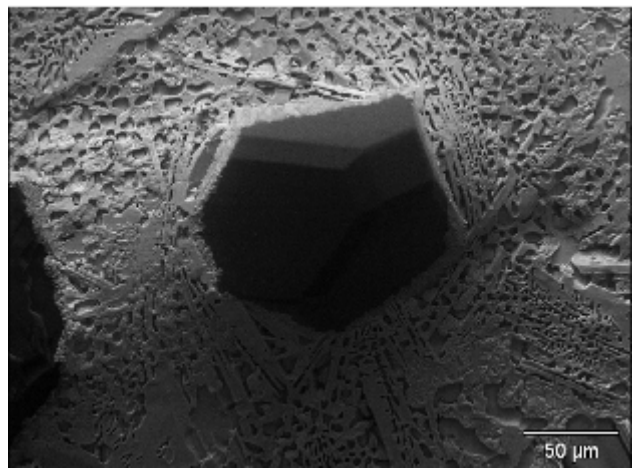

**One aggressive diamond broke from the diamond disc substrate.**
**There was micro wear on the cutting edges of the other aggressive diamond.**
**There was apparent surface corrosion on the diamond disc substrate.**

# SEM Analysis – Inactive Diamond

## D2 with Fujimi PL-7103 Slurry at 50 ºC

**Before Wear Test**



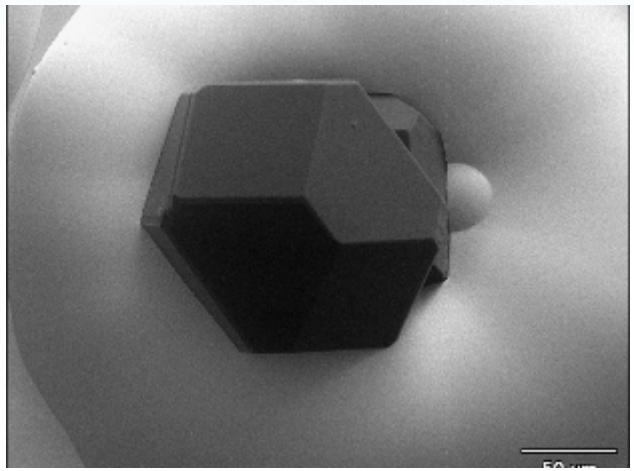

**After Wear Test**

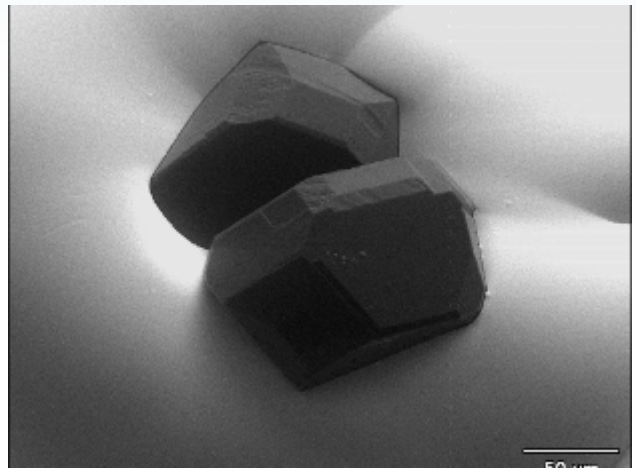
**There was no appreciable wear on the inactive diamond.**
**There was apparent surface corrosion on the diamond disc substrate.**

# SEM Analysis – Aggressive Diamonds

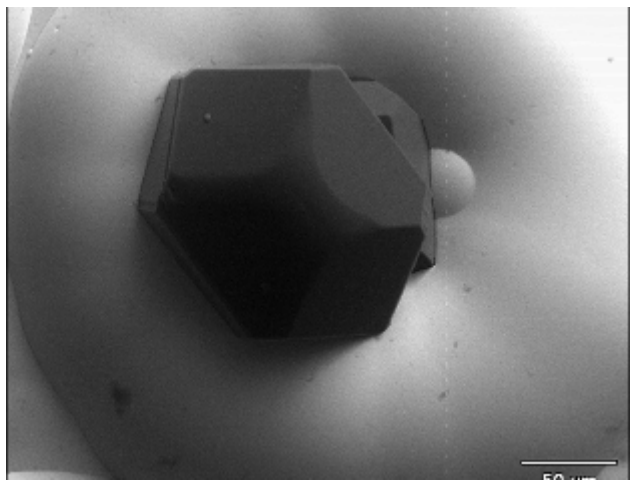
## D3 with CMC iCue 600Y75 Slurry at 25 ºC

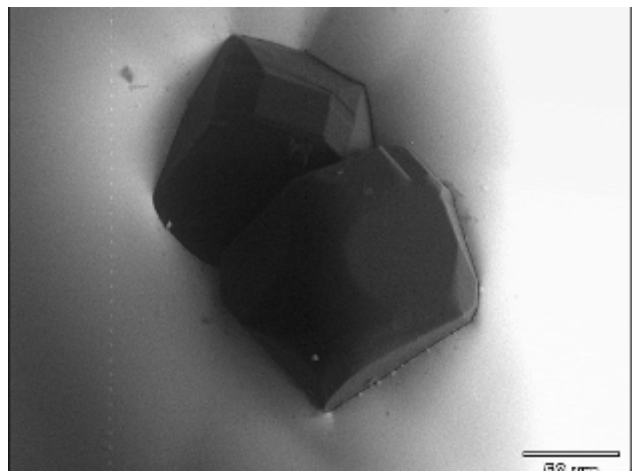
**Before Wear Test**





**After Wear Test**



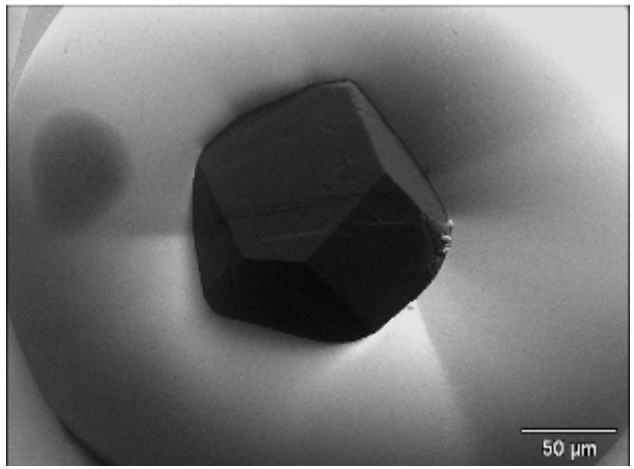


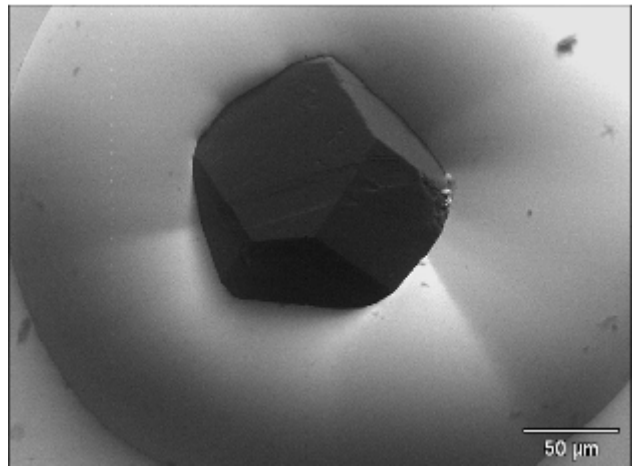
**There was micro wear on the cutting edges of aggressive diamonds.**
**There was no appreciable wear on the diamond disc substrate.**

# SEM Analysis – Inactive Diamond

## D3 with CMC iCue 600Y75 Slurry at 25 ºC

**Before Wear Test**



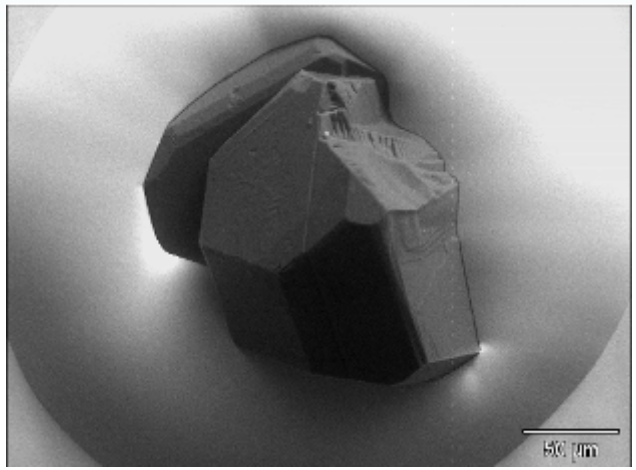

**After Wear Test**

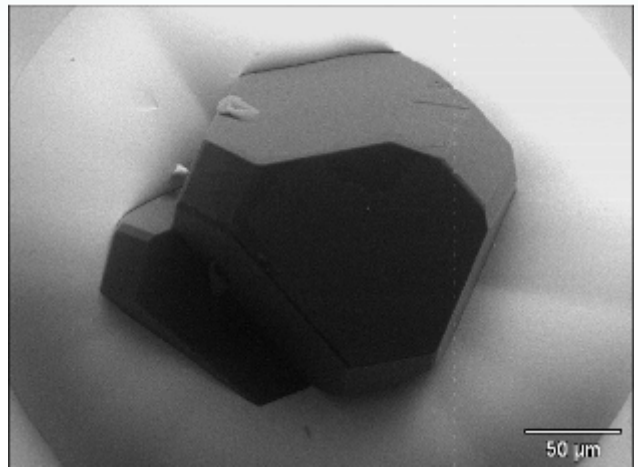
**There was no appreciable wear on the inactive diamond and diamond disc substrate.**

# SEM Analysis – Aggressive Diamonds

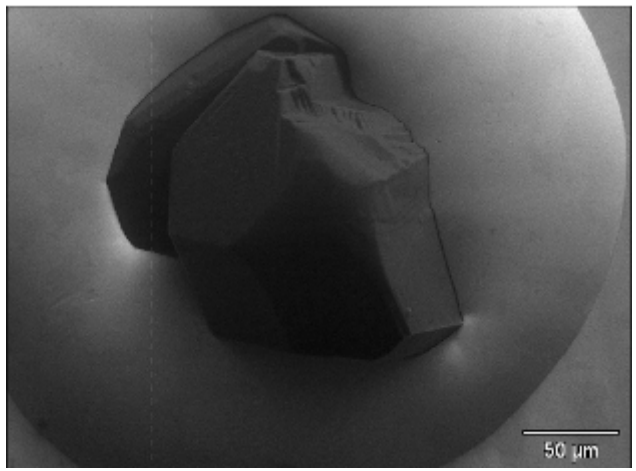
## D3 with CMC iCue 600Y75 Slurry at 50 ºC

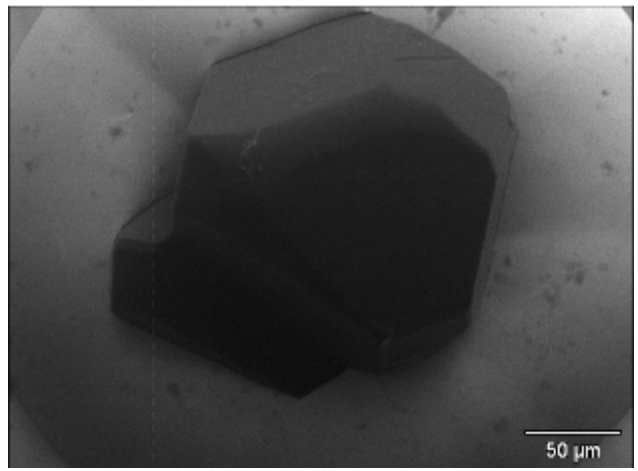
**Before Wear Test**




**After Wear Test**



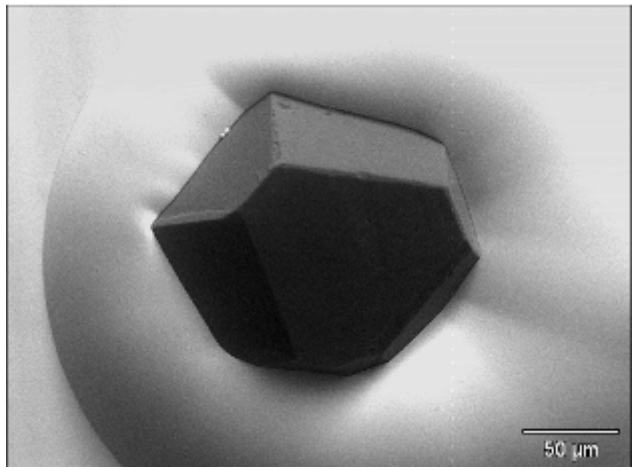



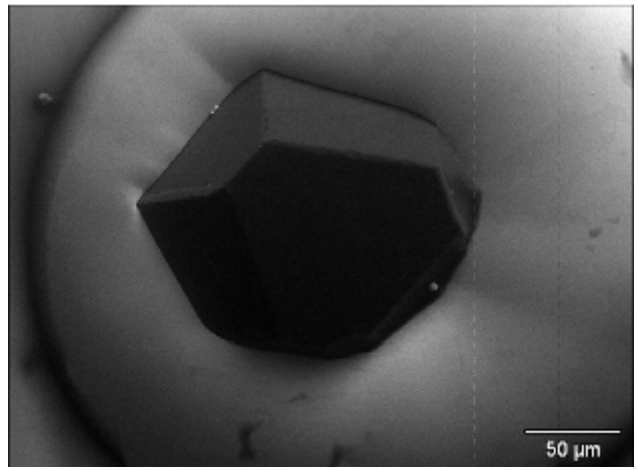

**There was micro wear on the cutting edges of aggressive diamonds.**
**There was no appreciable wear on the diamond disc substrate.**

# SEM Analysis – Inactive Diamond

## D3 with CMC iCue 600Y75 Slurry at 50 ºC

**Before Wear Test**



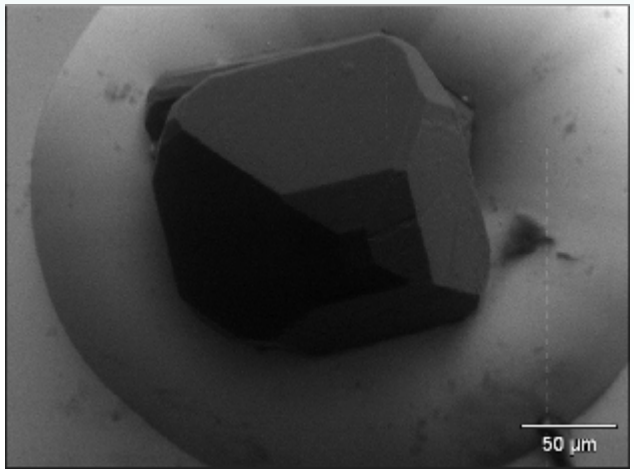

**After Wear Test**

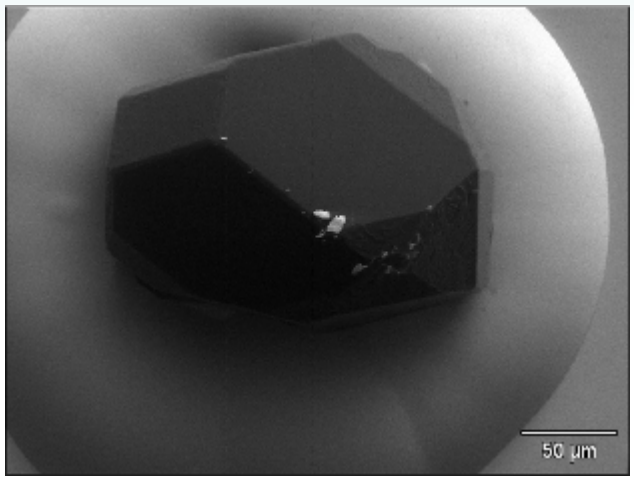
**There was no appreciable wear on the inactive diamond and diamond disc substrate.**

# SEM Analysis – Aggressive Diamonds

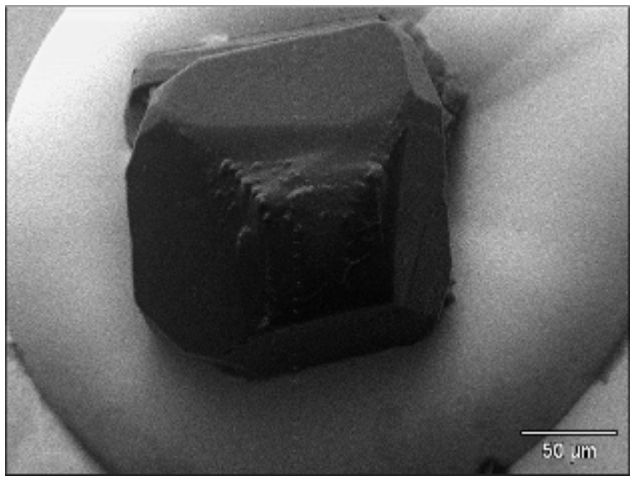
## D3 with Fujimi PL-7103 Slurry at 25 ºC

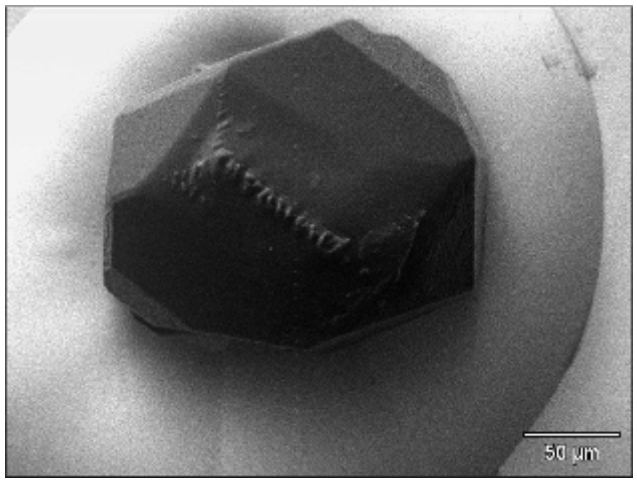
**Before Wear Test**




**After Wear Test**



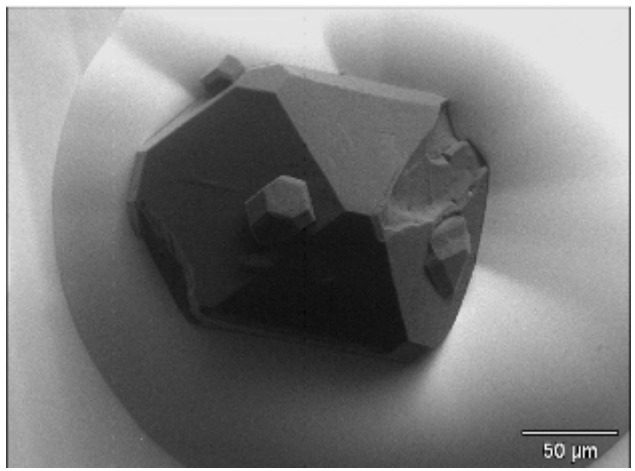



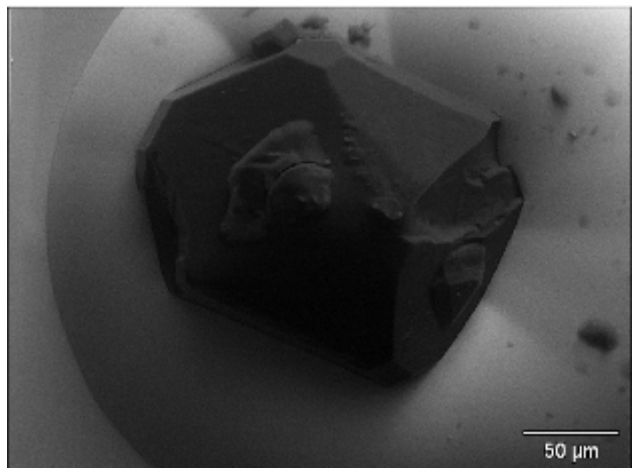

**There was micro wear on the cutting edges of aggressive diamonds.**
**There was no appreciable wear on the diamond disc substrate.**

# SEM Analysis – Aggressive Diamond

## D3 with Fujimi PL-7103 Slurry at 50 ºC

**Before Wear Test**



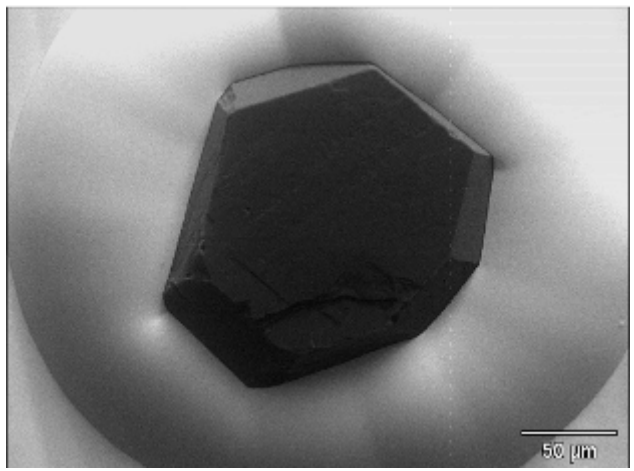

**After Wear Test**

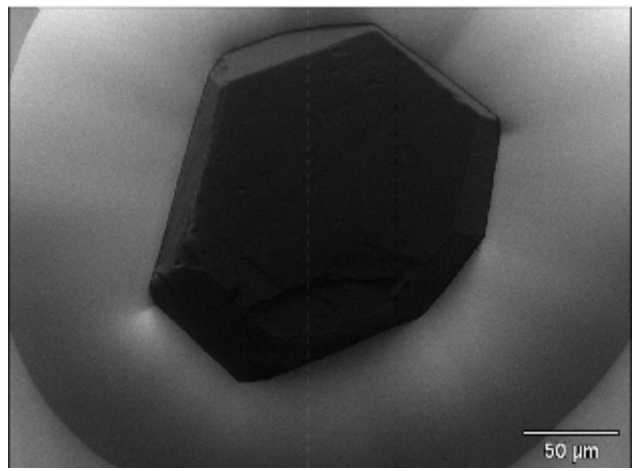
**There was micro wear on the cutting edges of aggressive diamond.**
**There was no appreciable wear on the diamond disc substrate.**

# SEM Analysis – Inactive Diamond

## D3 with Fujimi PL-7103 Slurry at 50 ºC

**Before Wear Test**



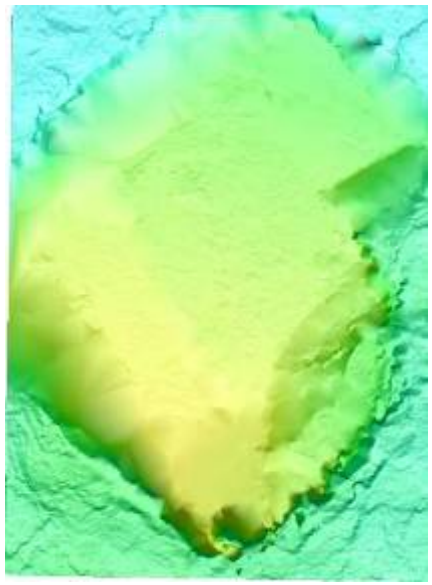



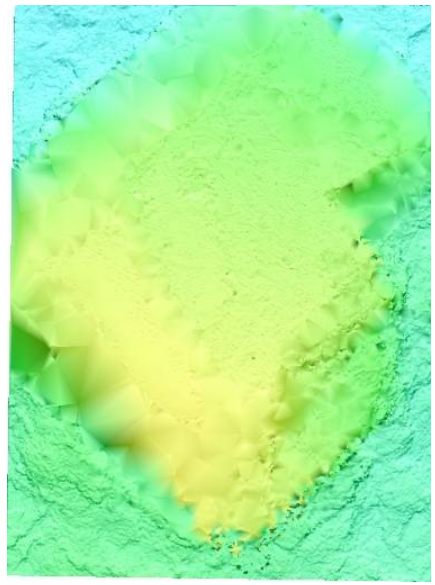

**After Wear Test**

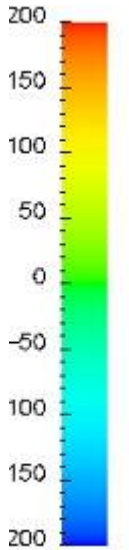
**There was no appreciable wear on the inactive diamond and diamond disc substrate.**

# Interferometric Analysis – Aggressive Diamond

## D1 with CMC iCue 600Y75 Slurry at 25 ºC



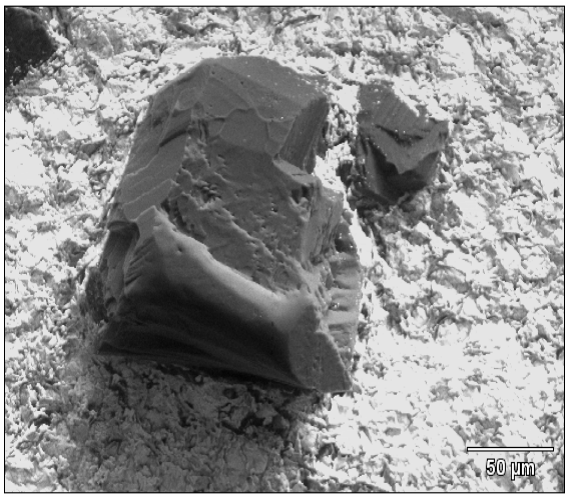




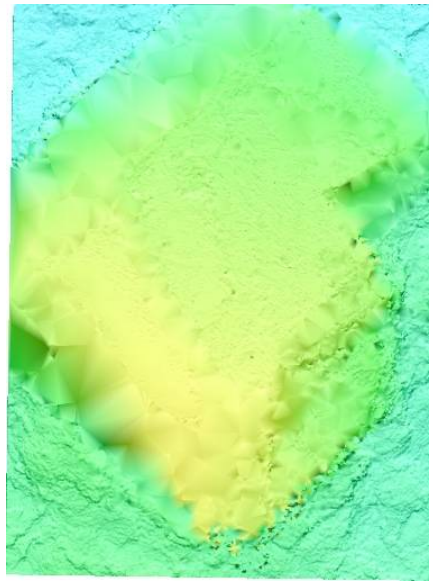

**Before Wear Test**

**After Wear Test**

# SEM vs. Inteferometer vs. Confocal Microscope




SEM Image



Interferometric Image

Confocal Microscopic Image

# Average Pad Cut Rate

| Temperature | D1 (μm/hour) | | D2 (μm/hour) | | D3 (μm/hour) | |
|---|---|---|---|---|---|---|
| | Fujimi PL-7103 | CMC iCue 600Y75 | Fujimi PL-7103 | CMC iCue 600Y75 | Fujimi PL-7103 | CMC iCue 600Y75 |
| **25 ºC** | 14.33 | 3.03 | 7.87 | 2.32 | 6.05 | 0.93 |
| **50 ºC** | 10.84 | 2.05 | 11.09 | 2.90 | 4.98 | 0.88 |

# Summary

# Static Etch Tests – SEM Analysis

| | | D1 | | D2 | | D3 | |
|---|---|---|---|---|---|---|---|
| | | **Fujimi PL-7103** | **CMC iCue 600Y75** | **Fujimi PL-7103** | **CMC iCue 600Y75** | **Fujimi PL-7103** | **CMC iCue 600Y75** |
| **25 ºC** | **Diamond** | No appreciable wear | | | | | |
| | **Diamond Disc Substrate** | No appreciable wear | | Apparent surface corrosion | No appreciable wear | No appreciable wear | |
| **50 ºC** | **Diamond** | No appreciable wear | | | | | |
| | **Diamond Disc Substrate** | No appreciable wear | | Apparent surface corrosion | | No appreciable wear | |

# Static Etch Tests – ICPMS and Interferometric Analysis

**With Fujimi PL-7103 slurry, ICPMS analysis indicated that the Ni concentration in the slurry increased appreciably at 25 and 50 ºC for Disc D1; the Ni concentration in the slurry increased significantly at 25 ºC and increased dramatically at 50 ºC for Disc D2.**

**With CMC iCue 600Y75 slurry, ICPMS analysis indicated that the Ni concentration in the slurry increased appreciably at 25 and 50 ºC for Disc D1; the Ni concentration in the slurry increased appreciably at 25 ºC and increased dramatically at 50 ºC for Disc D2, resulting in an extremely high activation energy for Ni corrosion.**

**ICPMS analysis indicated that for both Fujimi PL-7103 and CMC iCue 600Y75 slurries, there was barely any increase in the Ni concentration in the slurry at 25 and 50 ºC for Disc D3.**

**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.**

# Wear Tests – SEM Analysis

| | | D1 | | D2 | | D3 | |
|---|---|---|---|---|---|---|---|
| | | **Fujimi PL-7103** | **CMC iCue 600Y75** | **Fujimi PL-7103** | **CMC iCue 600Y75** | **Fujimi PL-7103** | **CMC iCue 600Y75** |
| **25 ºC** | Aggressive Diamond | Micro wear on cutting edges | | | | | |
| | Inactive Diamond | No appreciable wear | | | | | |
| | Diamond Disc Substrate | No appreciable wear | | Apparent surface corrosion | | No appreciable wear | |
| **50 ºC** | Aggressive Diamond | Micro wear on cutting edges | | Micro wear on cutting edges / broken diamond | | Micro wear on cutting edges | |
| | Inactive Diamond | No appreciable wear | | | | | |
| | Diamond Disc Substrate | No appreciable wear | | Apparent surface corrosion | | No appreciable wear | |

# Wear Tests – Pad Wear Rate and Interferometric Analysis

**The pad wear rate analysis indicated that:**

**For both Fujimi PL-7103 and CMC iCue 600Y75 slurries at 25 ºC, Disc D1 generated the highest pad wear rate while Disc D3 generated the lowest pad wear rate. On the other hand, Disc D2 generated the highest pad wear rate while Disc D3 generated the lowest pad wear rate for both slurries at 50 ºC.**

**For both Fujimi PL-7103 and CMC iCue 600Y75 slurries, the pad wear rate decreased with the increase of the platen temperature for Disc D1 and Disc D3. On the other hand, the pad wear rate increased with the platen temperature for Disc D2 for both slurries.**

**For all three types of discs, the pad wear rate for Fujmi PL-7103 slurry was significantly higher than CMC iCue 600Y75 slurry, indicating slurry abrasives and abrasive concentration have significant impacts on the pad wear rate.**

**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.**

# Acknowledgements

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