Aggressive Diamond Characterization and Wear Analysis during Chemical Mechanical Planarization

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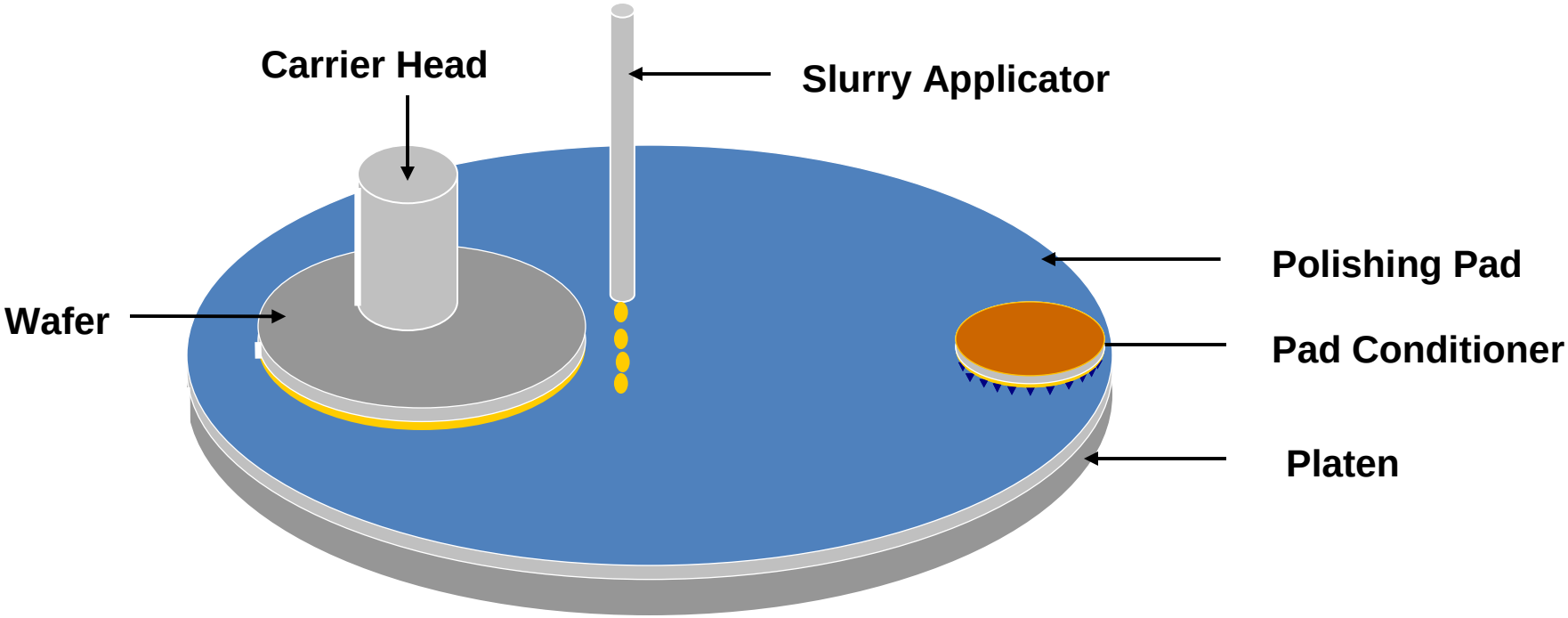
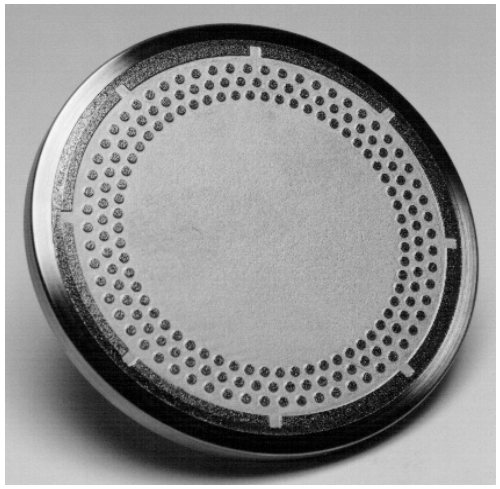
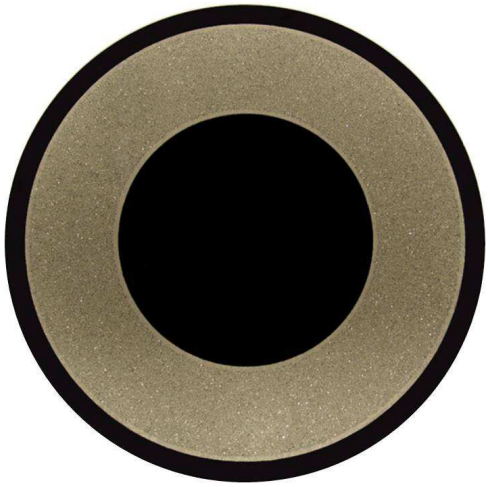
Generalized Schematic for CMP

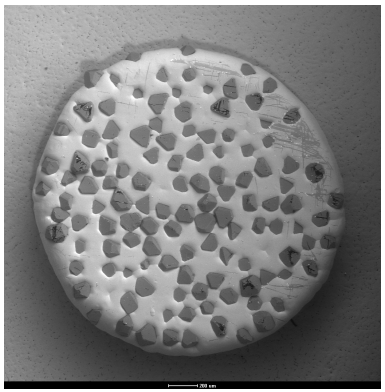


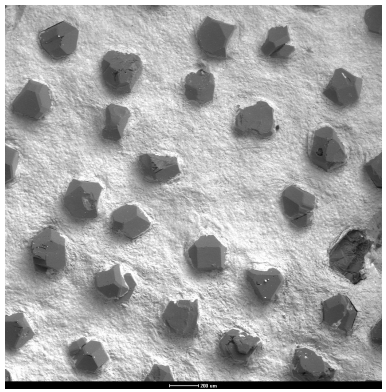
Rotary CMP Tool

Diamond Conditioner







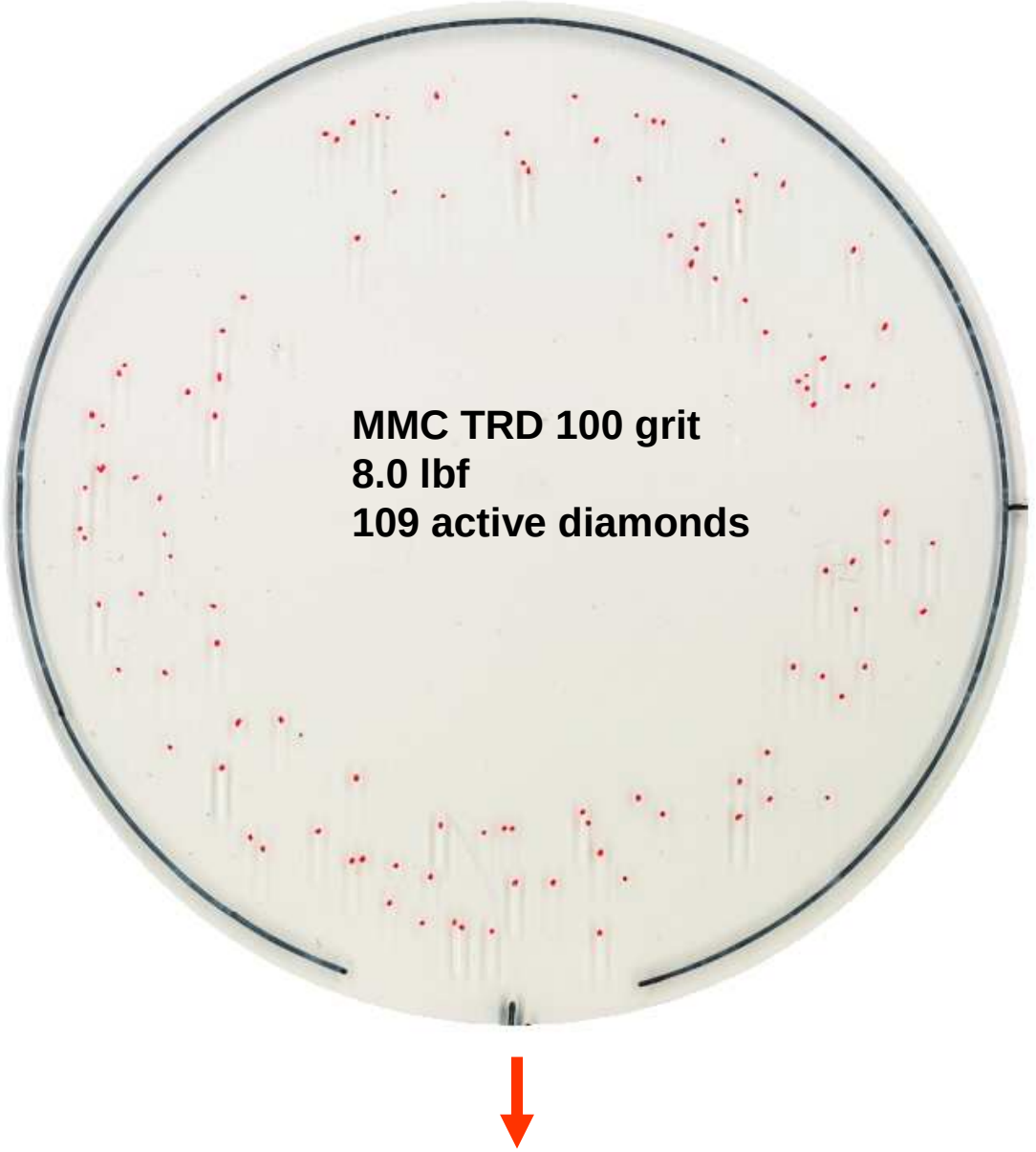


A typical conventional diamond disc has tens of thousands of diamonds embedded in the disc substrate.

Identify Active Diamonds - Short Draw Test

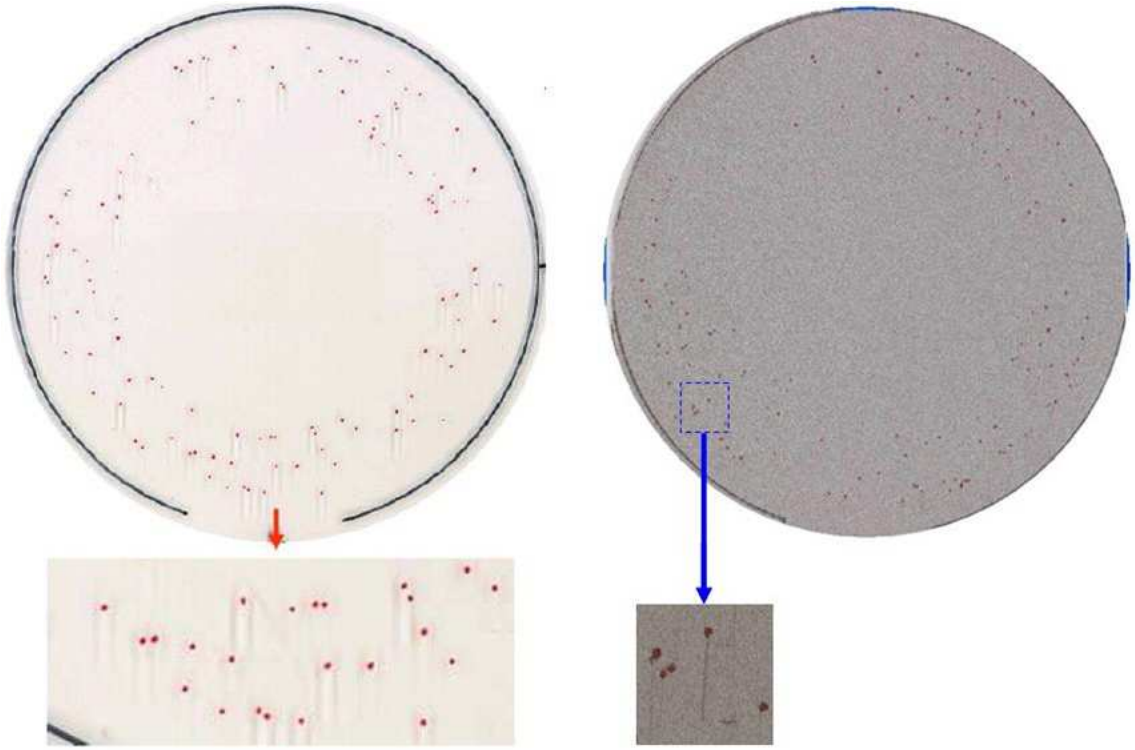
U.S. Patent 7,410,411

Conditioner is pulled only about ¼".



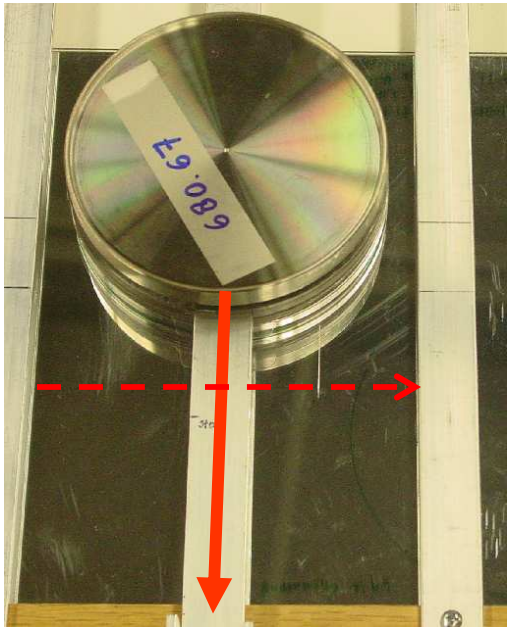
Scratch origins are marked.
- **Faint scratches**
- **Partial scratches**

Comparison between Polycarbonate Sheet and Pad

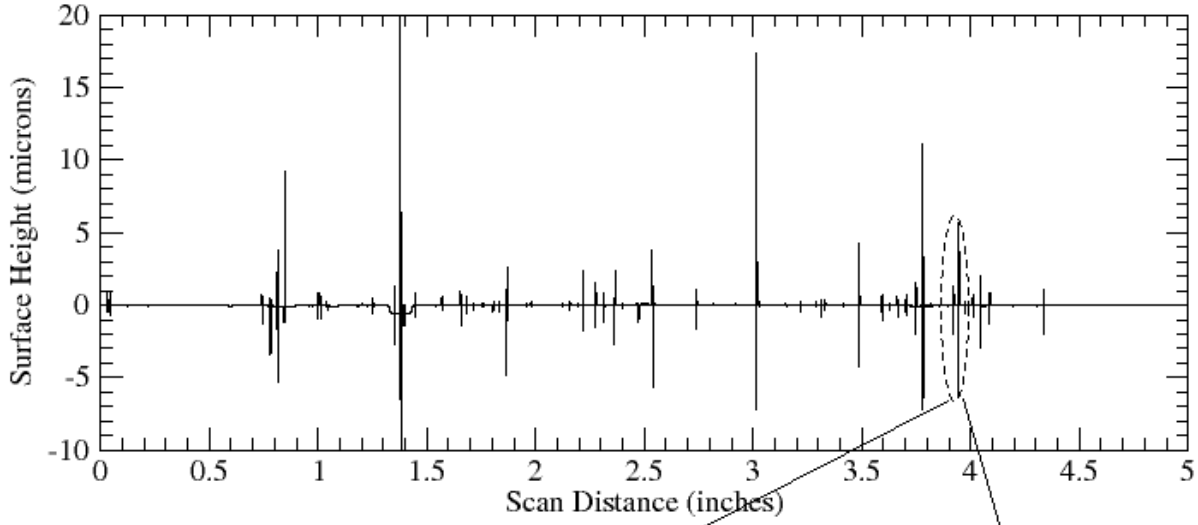


	Polycarbonate Sheet	Hard CMP Pad
Shore D Hardness	80	50 - 70
Tensile Strength (MPa)	66	45 - 95

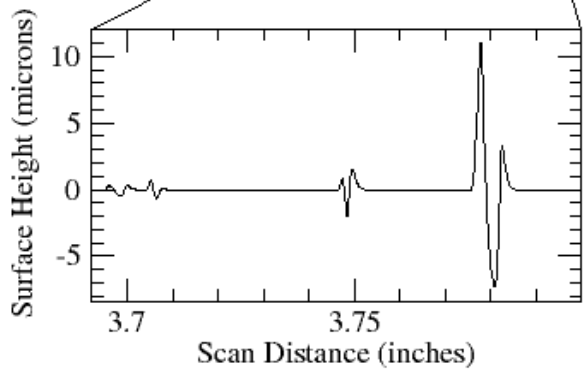
Identify Aggressive Diamonds - Long Draw Test



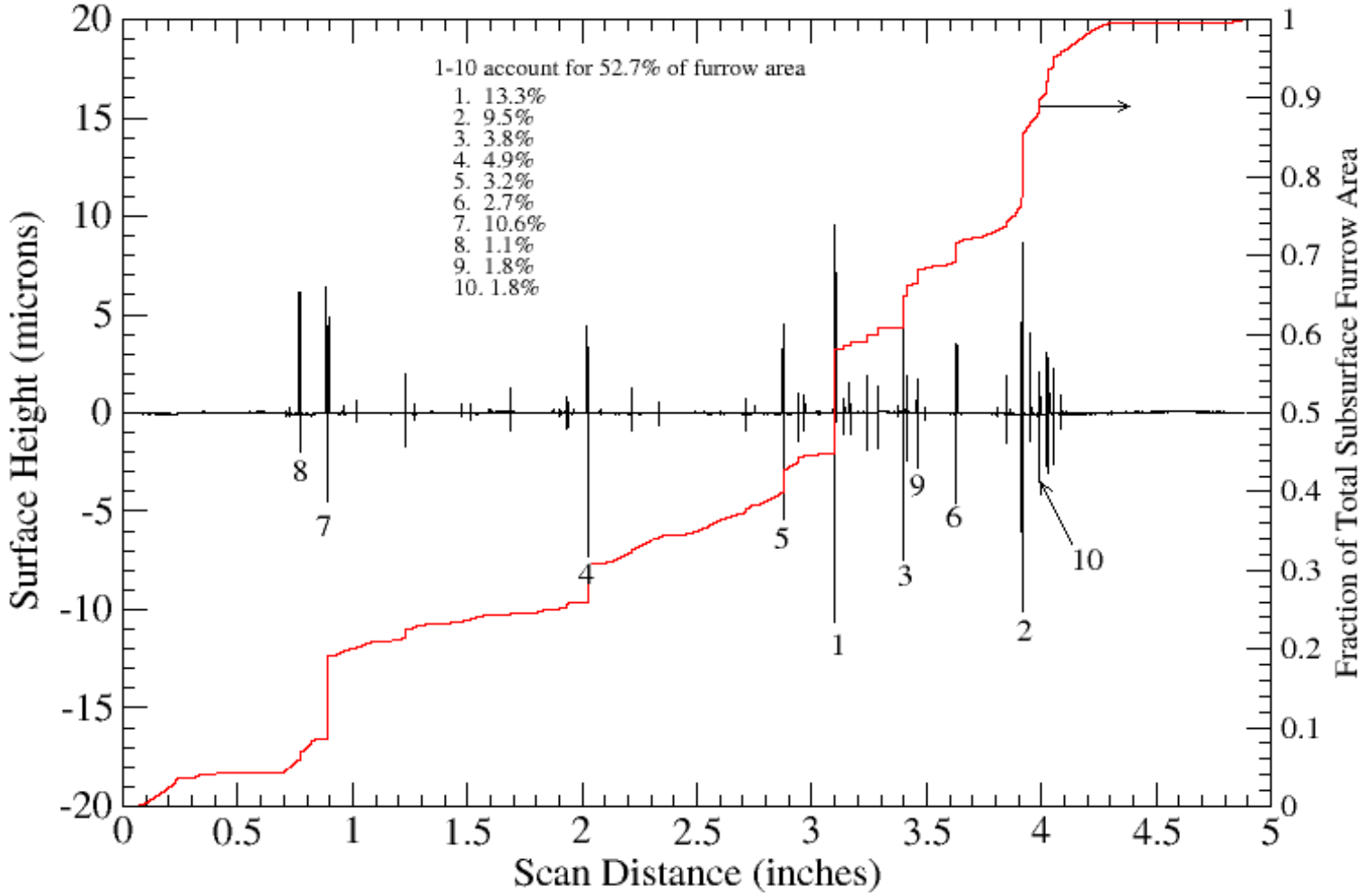
Conditioner is pulled more than one diameter.



Polycarbonate surface is profiled

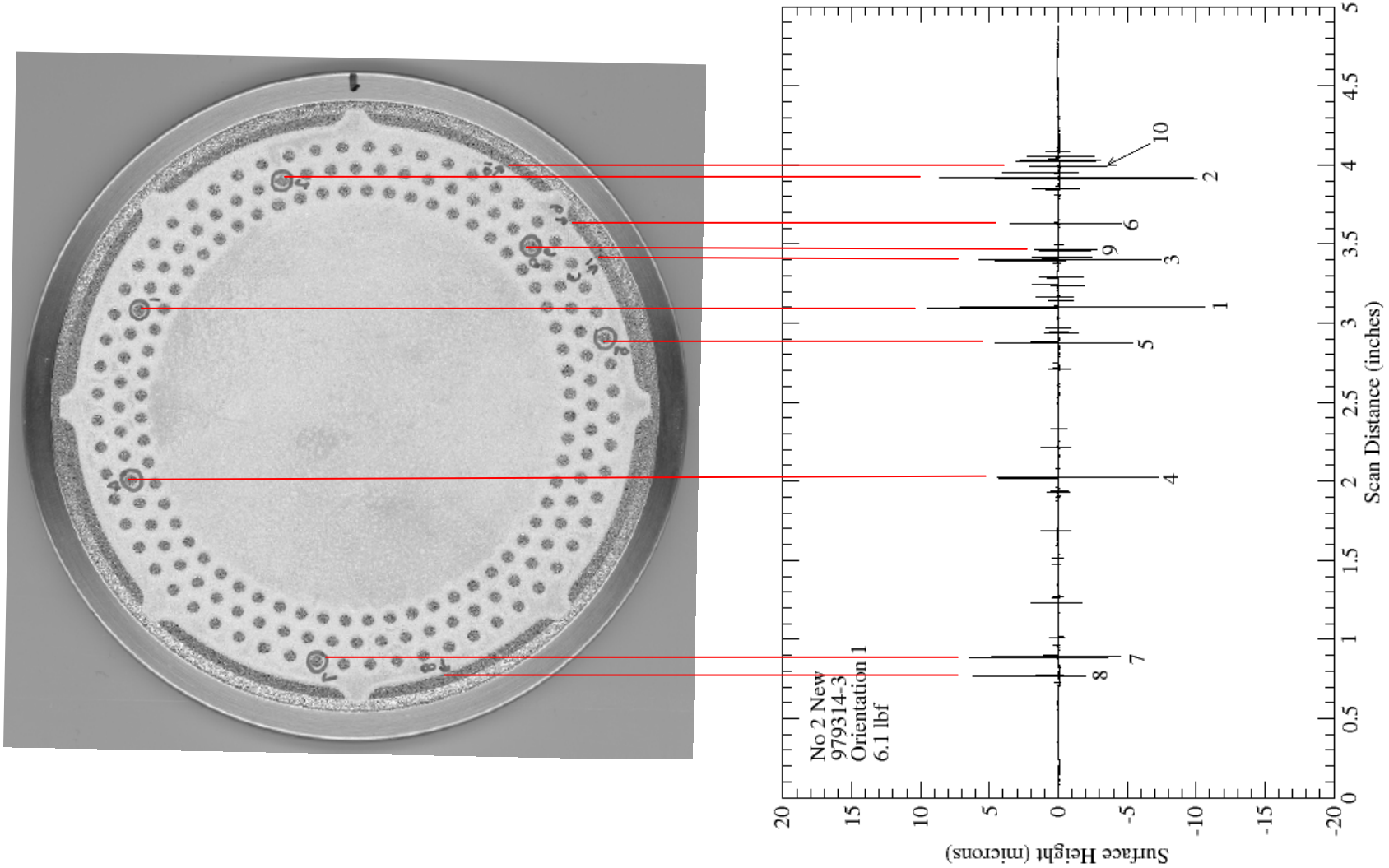


Furrow Surface Area Analysis

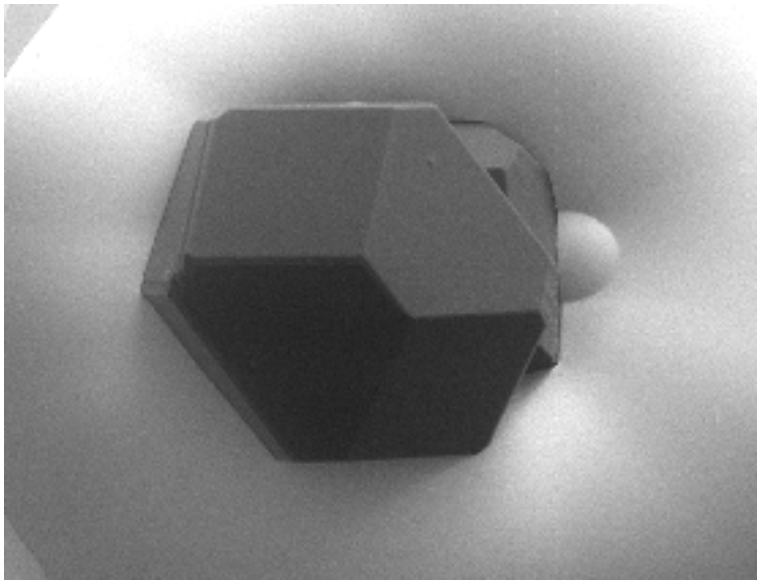


The ten most aggressive diamonds account for more than 50% of pad wear rate during pad conditioning.

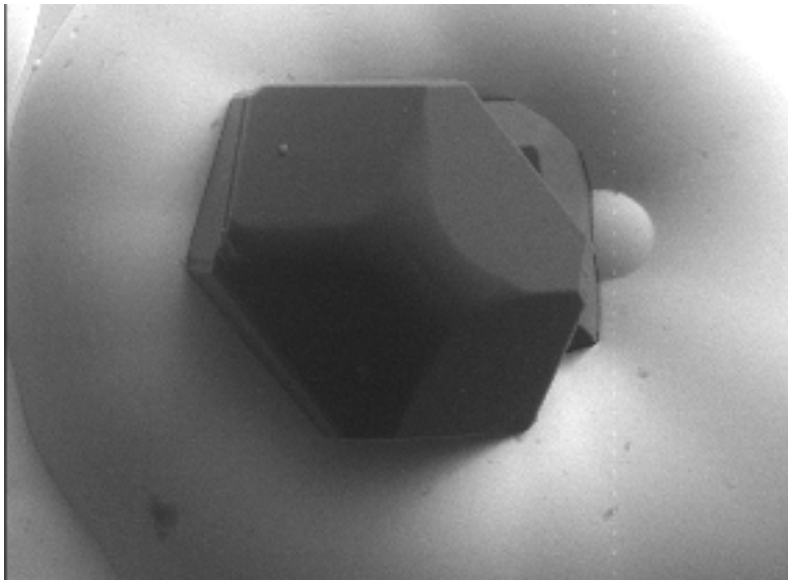
Locate Aggressive Diamonds



Wear on Aggressive Diamond



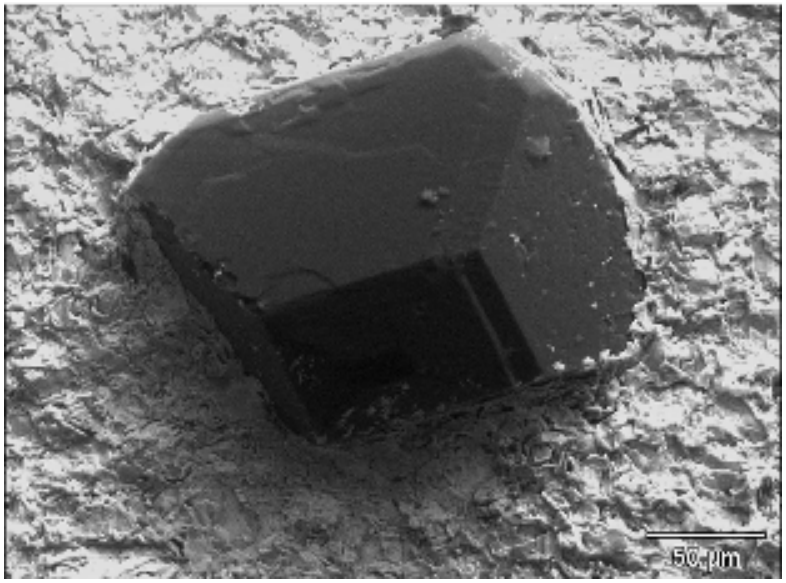
New aggressive diamond



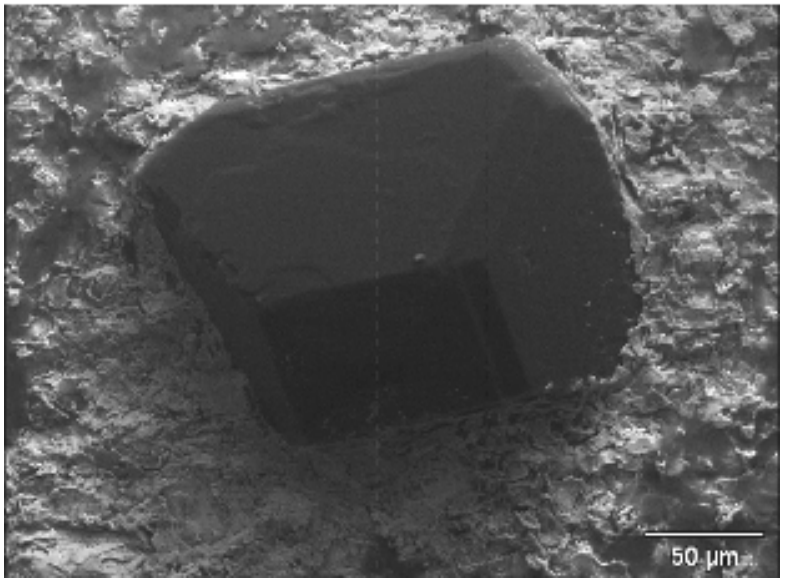
Same diamond after wear test

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

Wear on Inactive Diamond



New inactive diamond



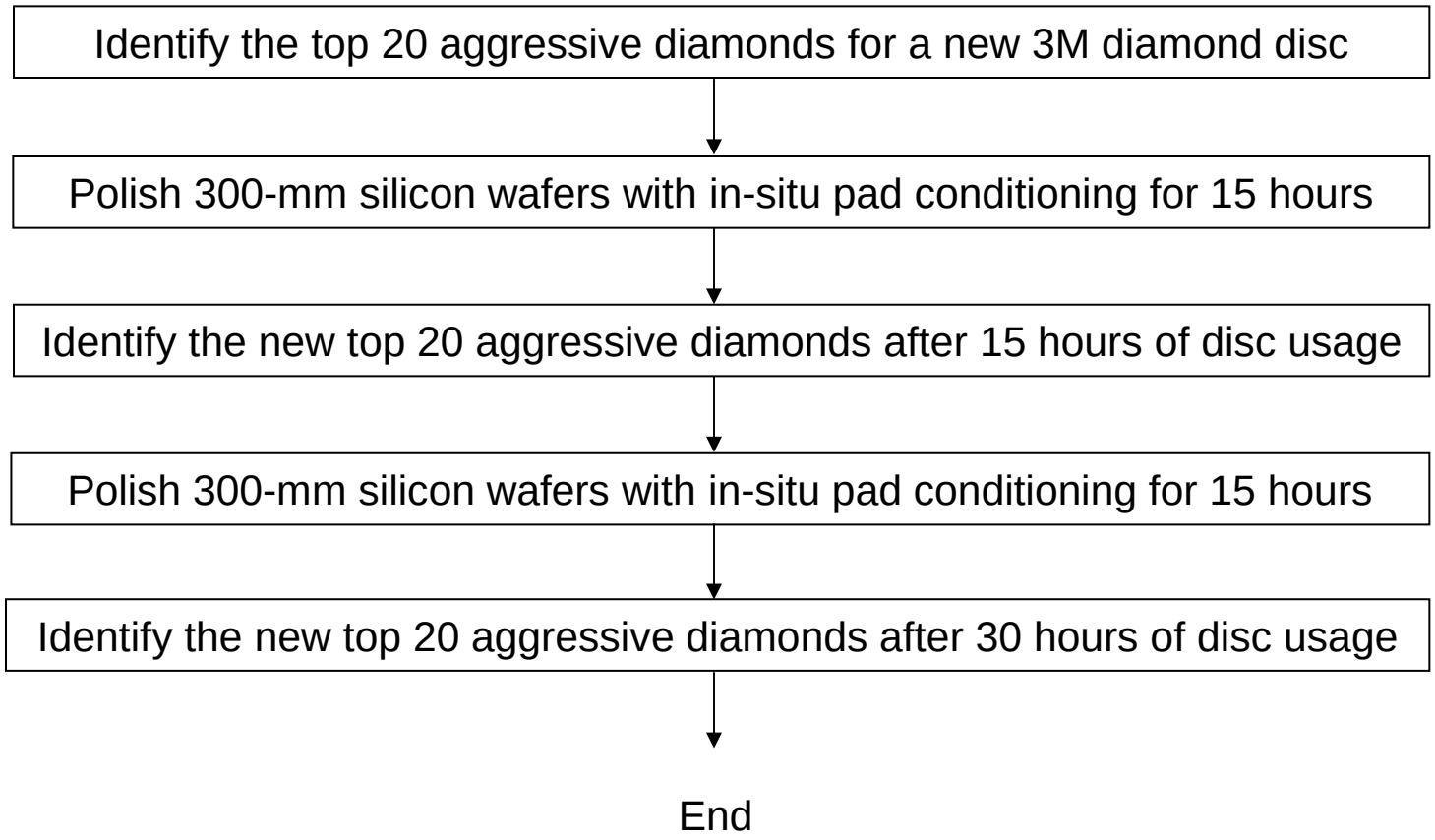
Same diamond after wear test

There was no appreciable wear on the inactive diamond.

Unanswered Questions

- **Do new aggressive diamonds appear as the original aggressive diamonds wear throughout the life of the disc?**
- **How do these new aggressive diamonds impact disc efficiency (or aggressiveness)?**
- **How does the disc aggressiveness change throughout the life of the disc?**

Case Study – Experimental Procedures

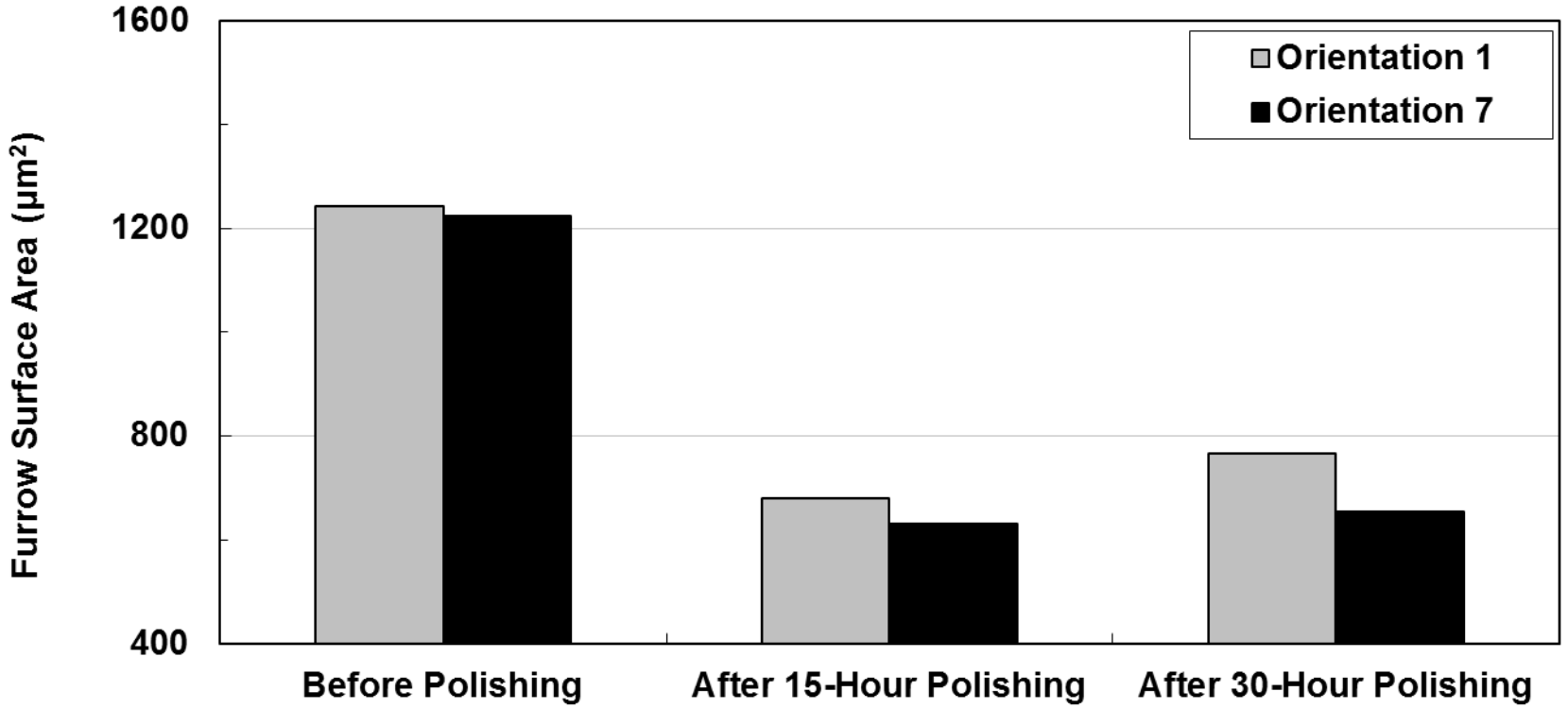


Polishing Conditions

- **Polisher**
  - **Araca APD-800 polisher**
- **Pad**
  - **Cabot Microelectronics Corporation D100 concentrically grooved pad**
- **Wafer**
  - **300-mm blanket silicon wafers**
- **DI Water Flow Rate**
  - **300 ml/min**
- **Pad Conditioning**
  - **3M A3700 diamond disc rotating at 95 RPM and sweeping at 10 times/min**
  - **In-situ pad conditioning at 3 lb_f**
- **Wafer Polishing**
  - **Polishing pressure: 1.5 PSI**
  - **Sliding velocity: 2.2 m/s**
  - **Polishing time: 30 hours**

Furrow Surface Area Analysis

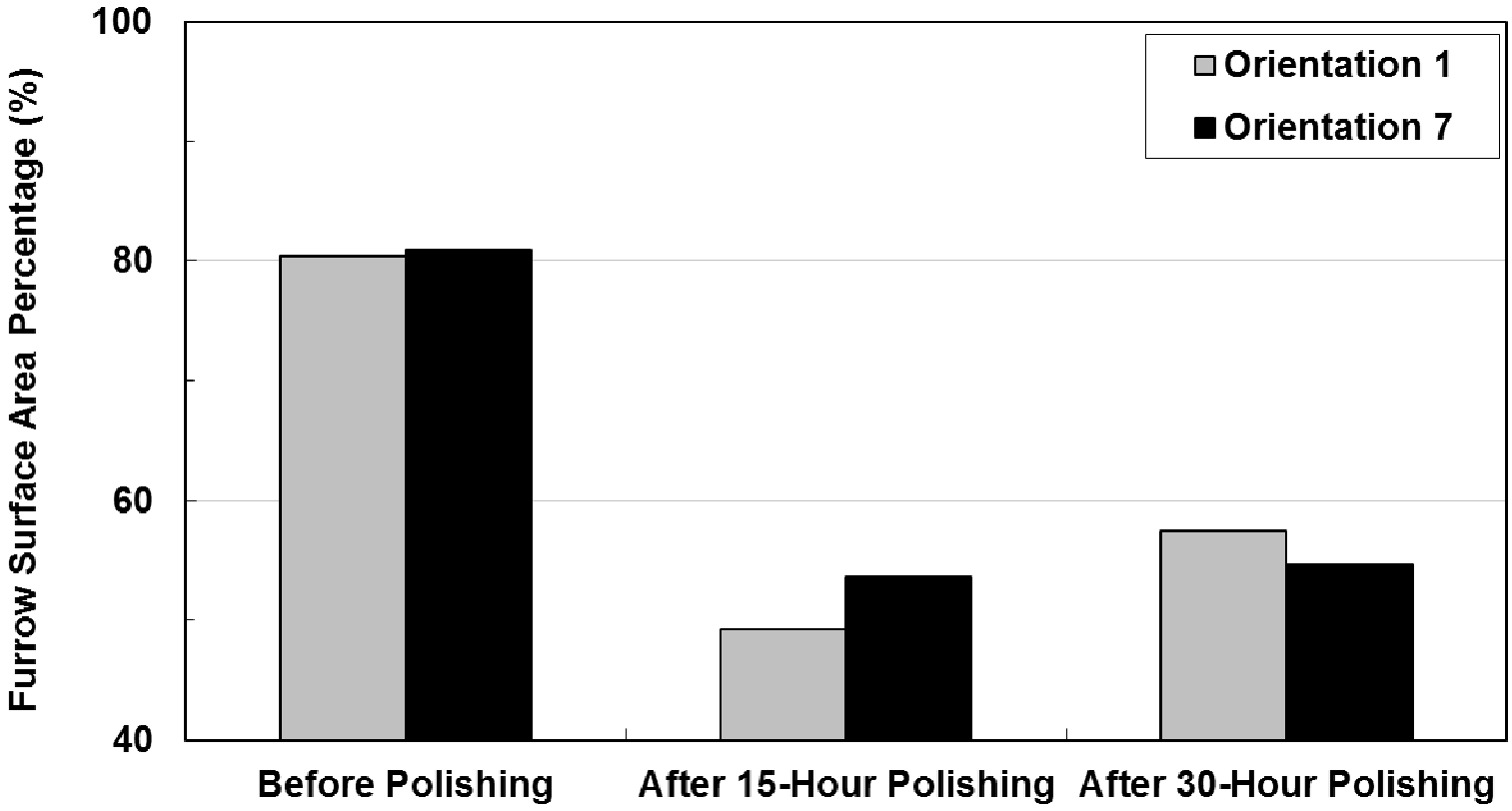
Original Top 20 Aggressive Diamonds



The furrow surface area of the original top 20 aggressive diamonds decreases significantly (by 45% and 48% for Orientation 1 and 7, respectively) after the first 15-hour polishing and remains relatively stable after the second 15-hour polishing.

Furrow Surface Area Percentage Analysis

Original Top 20 Aggressive Diamonds



After the first 15-hour polishing, the furrow surface area percentage of the original top 20 aggressive diamonds decreases significantly (from 81% to 49% for Orientation 1 and from 81% to 54% for Orientation 7).

Furrow Surface Area and Percentage Analysis

New "born" Aggressive Diamonds After 15-Hour Polishing Test

Orientation 1

Rank	Furrow Surface Area (μm^2)	Percentage (%)
1	190	13.8
4	84	6.1
6	55	4.0
7	54	3.9
11	42	3.1
17	24	1.7
18	24	1.7
Sum	**473**	**34.3**

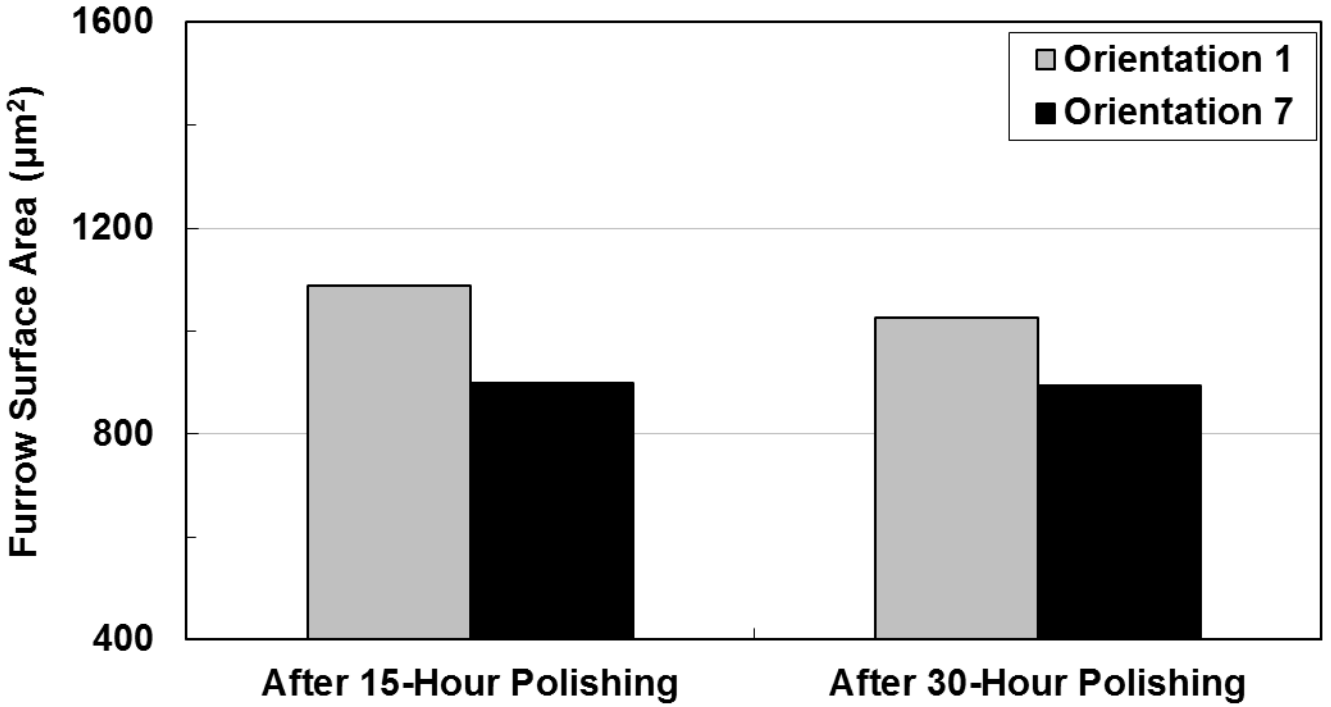
Orientation 7

Rank	Furrow Surface Area (μm^2)	Percentage (%)
2	73	6.2
3	68	5.8
7	49	4.1
11	33	2.8
13	32	2.7
18	24	2.0
19	24	2.0
Sum	**303**	**25.6**

For both orientations, 7 new aggressive diamonds are "born" after the 1st 15-hour polishing and join the top 20 aggressive diamond list. Their furrow surface area accounts for 34.3% and 25.6% of the total furrow surface area for Orientation 1 and 7, respectively.

Furrow Surface Area Analysis

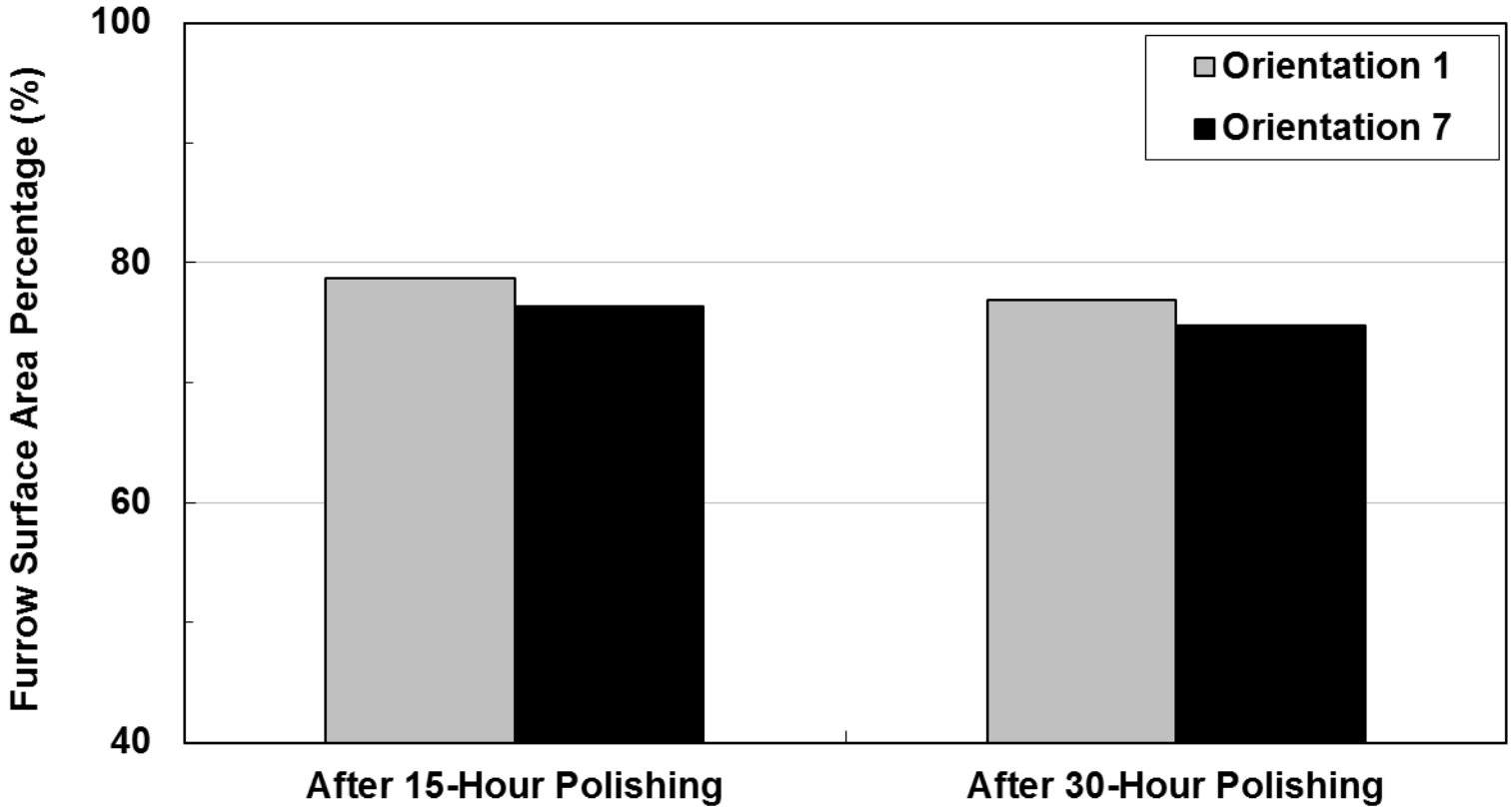
New Top 20 Aggressive Diamonds Identified after 15-hour Polishing



The furrow surface area of the new top 20 aggressive diamonds identified after 15-hour polishing does not change significantly after 30-hour polishing.

Furrow Surface Area Percentage Analysis

New Top 20 Aggressive Diamonds Identified after 15-hour Polishing



The furrow surface area percentage for the new top 20 aggressive diamonds identified after 15-hour polishing accounts for more than 75% of the total furrow surface area for both orientations and does not change significantly after 30-hour polishing.

Furrow Surface Area and Percentage Analysis

New "born" Aggressive Diamonds After 30-Hour Polishing Test

Orientation 1

Rank	Furrow Surface Area (μm^2)	Percentage (%)
14	33	2.5
17	26	1.9
18	24	1.8
19	22	1.6
20	21	1.6
Sum	**126**	**9.4**

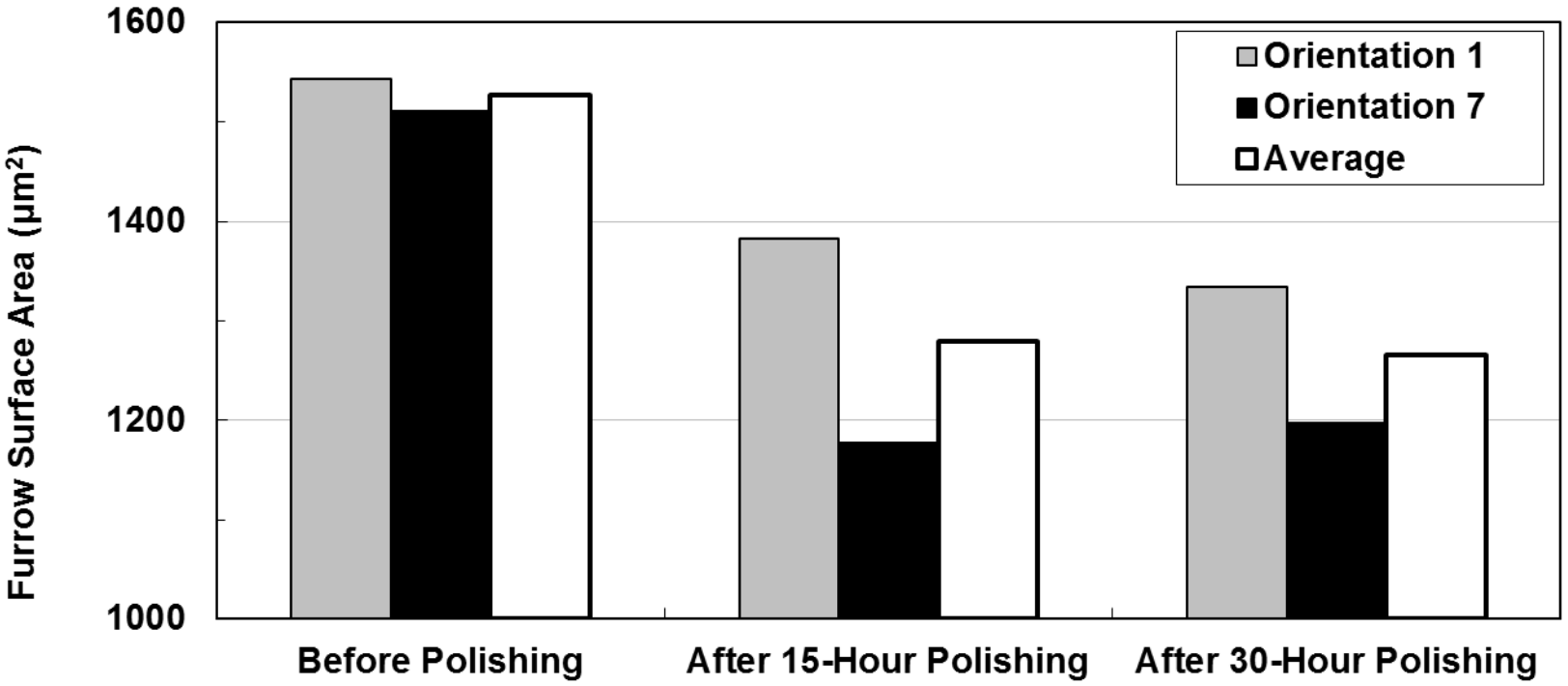
Orientation 7

Rank	Furrow Surface Area (μm^2)	Percentage (%)
8	42	3.5
11	33	2.8
14	29	2.5
15	28	2.4
16	27	2.3
18	20	1.7
19	17	1.4
Sum	**196**	**16.6**

A few new aggressive diamonds are "born" after 30-hour polishing. However, their furrow surface area percentage (9.4% and 16.6% for Orientation 1 and 7, respectively) is significantly lower than the new "born" aggressive diamonds after 15-hour polishing (34.3% and 25.6% for Orientation 1 and 7, respectively).

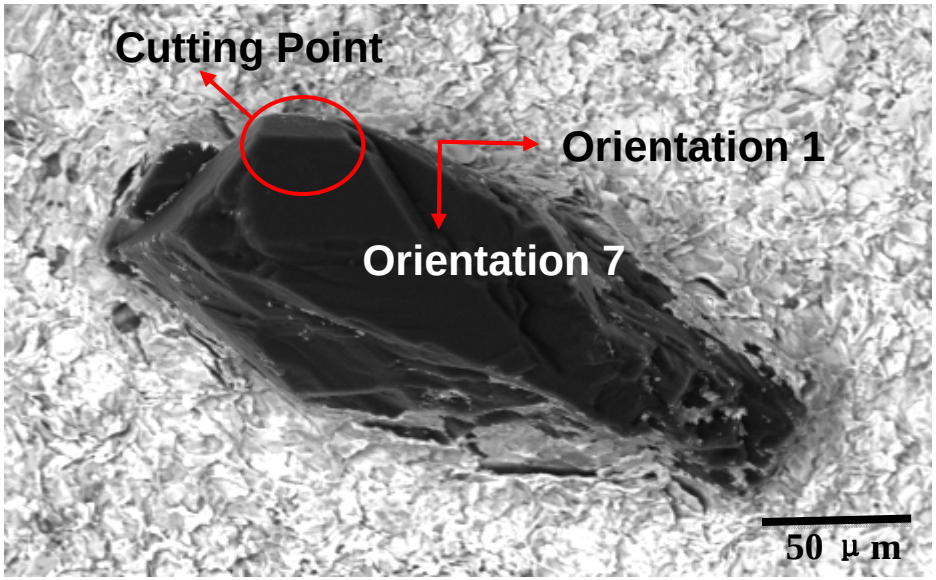
Furrow Surface Area Analysis

All Active Diamonds



The total furrow surface area decreases after the first 15 hours and does not change significantly after 30-hour polishing.

Common Aggressive Diamonds for Different Disc Orientations



	Number of Common Aggressive Diamonds
Before Polishing	6
After 15-hour Polishing	7
After 30-hour Polishing	5

Summary

- **Furrow surface area generated by active and aggressive diamonds on polycarbonate sheets was analyzed and its evolution was examined through a 30-hour polishing test.**

- **The top 20 aggressive diamonds accounted for more than 75% of the total furrow surface area, confirming that they were the dominant working diamonds in pad conditioning.**

- **The original top 20 aggressive diamonds identified before wafer polishing experienced wear after the first 15 hours of polishing, indicated by the significant decrease (45% and 48% for Orientation 1 and 7, respectively) in their furrow surface area. Seven new aggressive diamonds were "born" and they made a significant contribution (34% and 26% for Orientation 1 and 7, respectively) to the total furrow surface area.**

- **Furrow surface area generated by the new top 20 aggressive diamonds identified after the first 15-hour polishing was significantly lower (by 20%) than the original top 20 aggressive diamonds, leading to the loss of disc aggressiveness. The disc aggressiveness was maintained after the second 15-hour wafer polishing.**

Acknowledgement

- **SRC Engineering Research Center for Environmentally Benign Semiconductor Manufacturing**