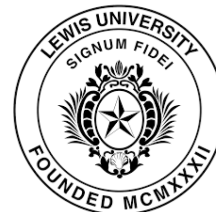
Pad-Level Spent Slurry Extraction During Polishing

Ara Philipossian and Yasa Sampurno – Araca, Inc.

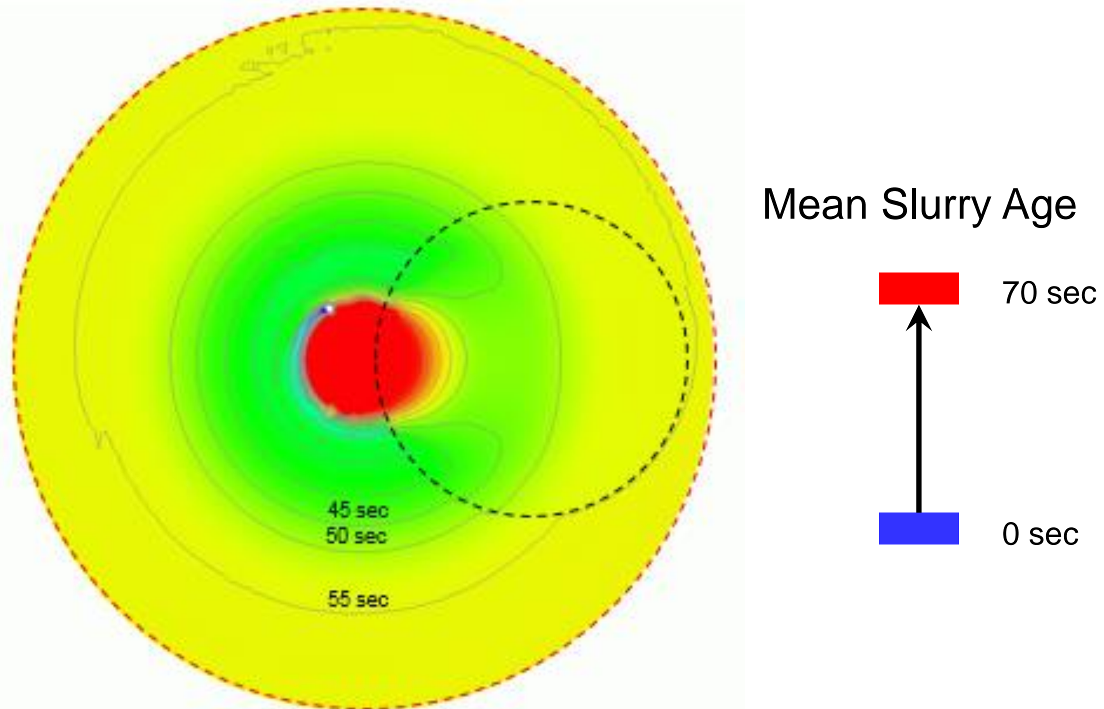
Jason Keleher – Lewis University



Problem Statement

- **Studying spent slurry is CRITICAL. But it must be done SAFELY!**

- **Slurry MRT (mean residence time) can be quite long (see below). Slurry has plenty of time to scavenge unwanted reaction by-products (from the film being polished) and pad shavings (from conditioning and the contacting retaining ring). These can increase wafer-level defects.**

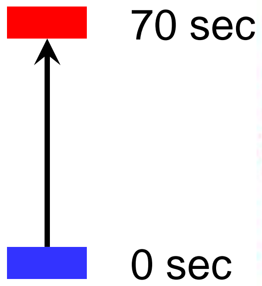


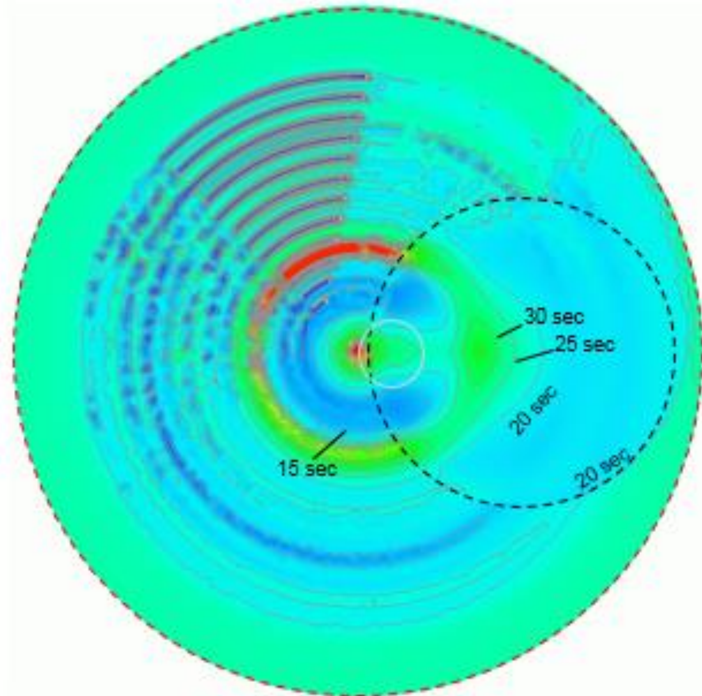
Source: Len Borucki (2012)

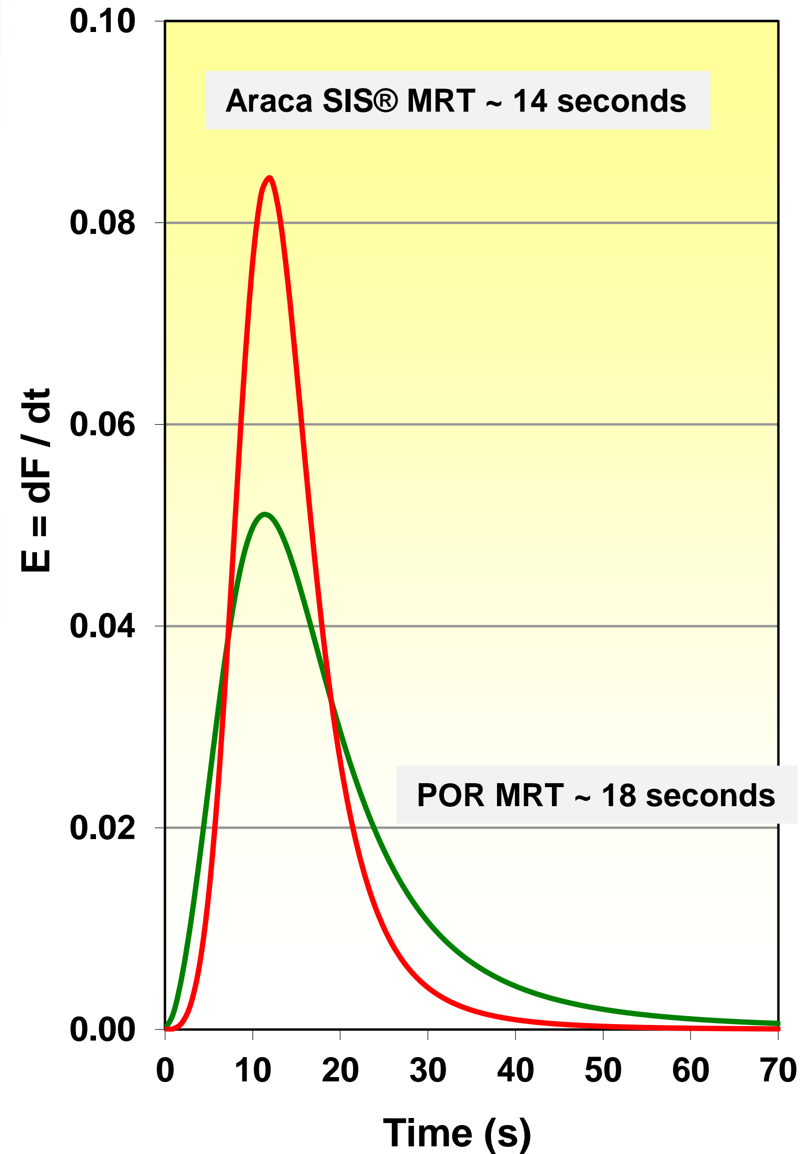
Simulated slurry age under the wafer is] Between 45 and 55 secs.

Problem Statement

Source: Len Borucki (2012)



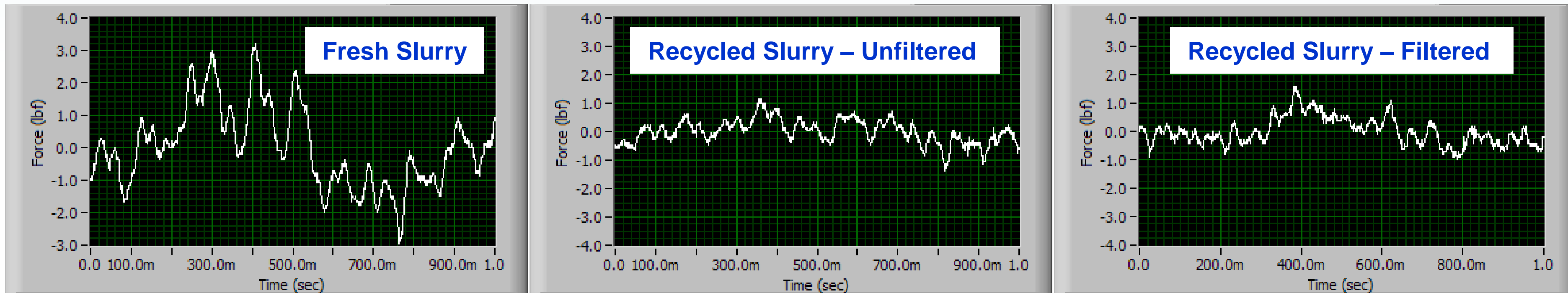




Simulated slurry age under the wafer is between 20 and 25 secs.

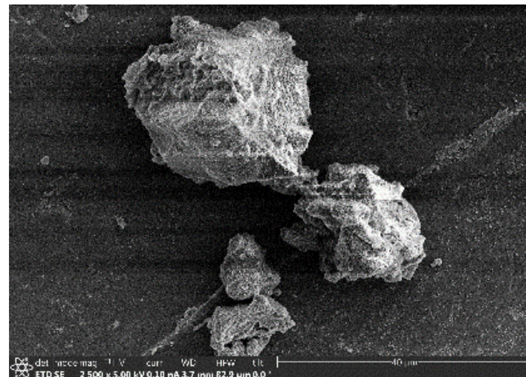
Problem Statement

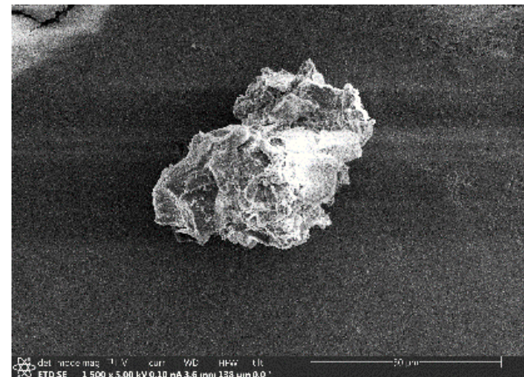
- Some NPs (nano-particles) may fracture under the ring during myriad stick-slip events in a 1-minute polish. Also, the ring itself sheds debris!



- Knowing the extent of debris uptake by the spent slurry during polishing and the extent of NP fracture is critical in ensuring efficient, high-quality, and high-yielding planarization processes.

PEEK Ring – Tungsten CMP with CMC Slurry



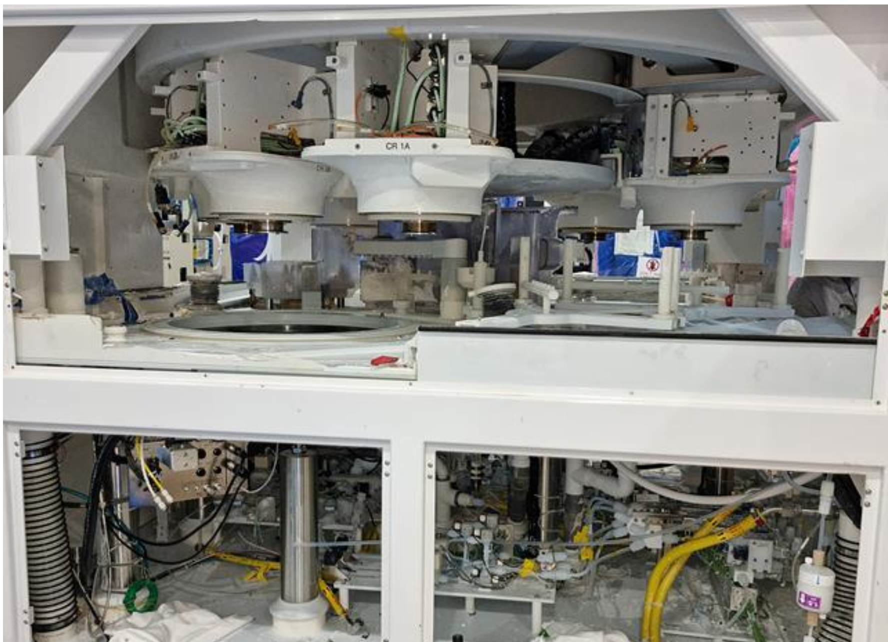


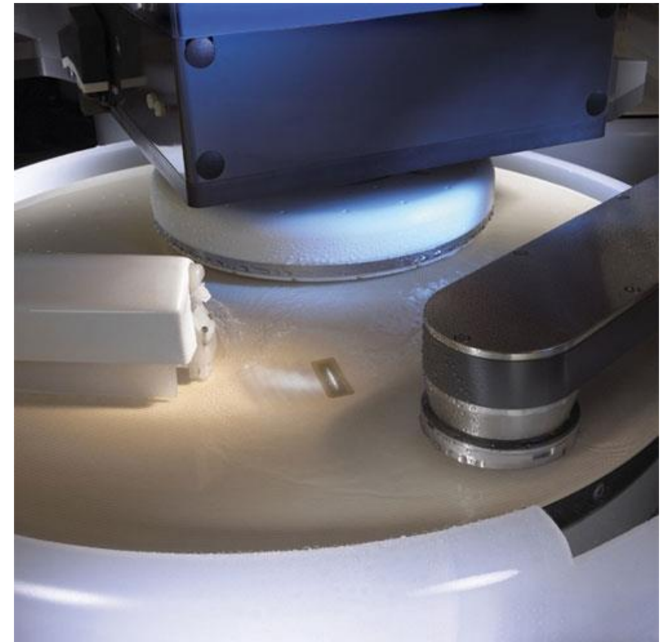
PEEK Ring – Polishing with UPW

Problem Statement

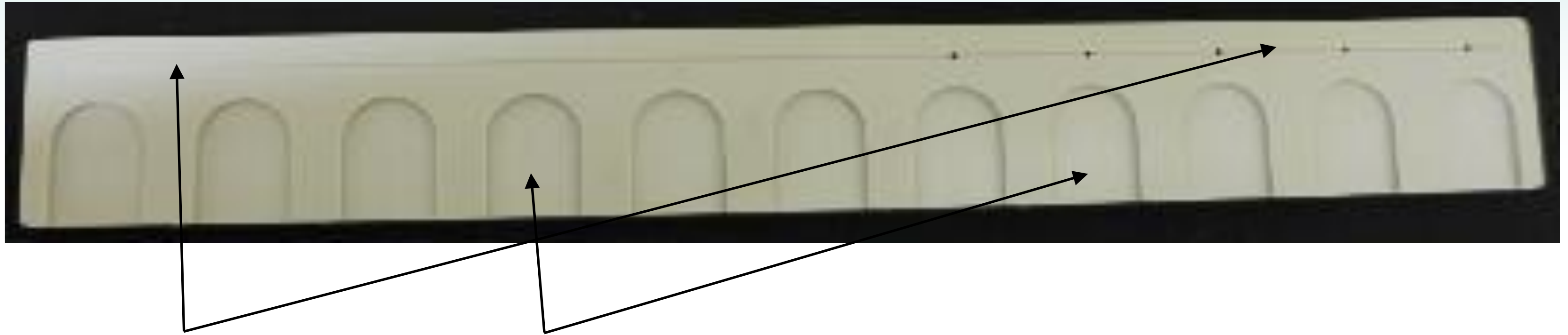
- Traditional ways to sample spent slurry during polishing are either through the slurry waste line or from inside the capture tub that surrounds the platen.

  - ❖ They cannot be done safely and without having a technician defeat the safety interlocks of the cabinetry that surrounds the polisher to get close to moving parts of the polisher.
  - ❖ The capture tub can be quite dirty and contaminated with myriad dried-out and co-mingled slurries and debris from runs performed over months of operation.
  - ❖ The waste line may be contaminated as well; it will surely contain residual water from rinsing steps.





The Araca Effluent Slurry Extractor (ESE®)



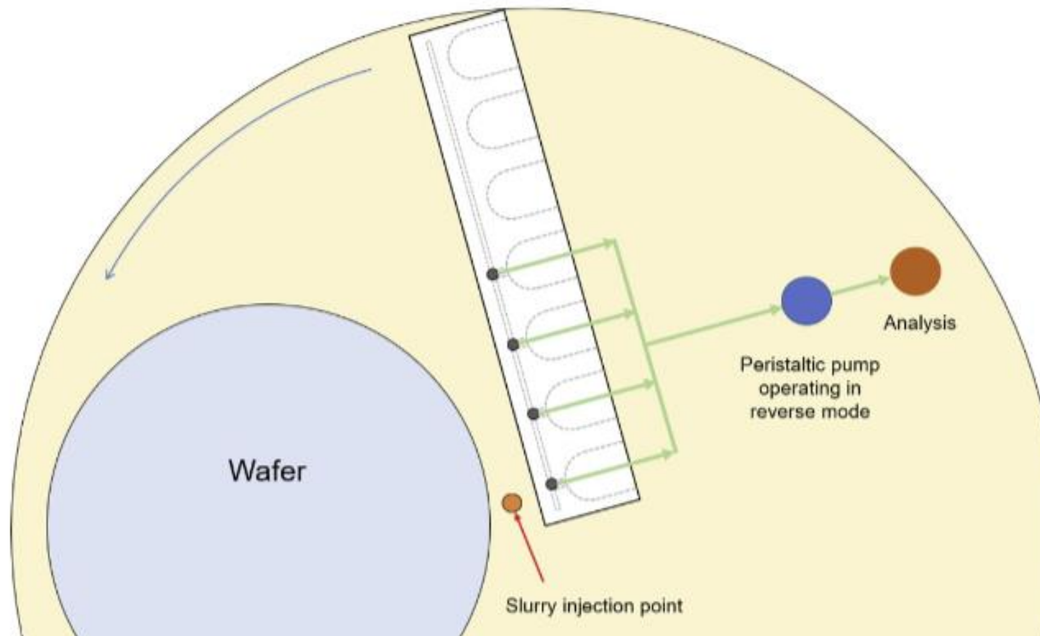
- The track and the arched pockets in the SIS® are designed to be isolated.
- For the ESE® to work, the SIS PEEK IBU (injector bottom unit) has to be machined to allow for the captured slurry to enter the slurry track that runs across the length of the part. These machined tracks act as gutters or "aquifers". Only then can the slurry be pumped off the surface of the pad.

The Araca Effluent Slurry Extractor – ESE®

- The ESE® allows for real-time pad-level extraction of slurry waste. We have systems for all Ebara, AMAT, Revasum, SFAM-IPEC and Accretech polishers.

- The stream may then be analyzed in-situ and ex-situ to determine slurry health:

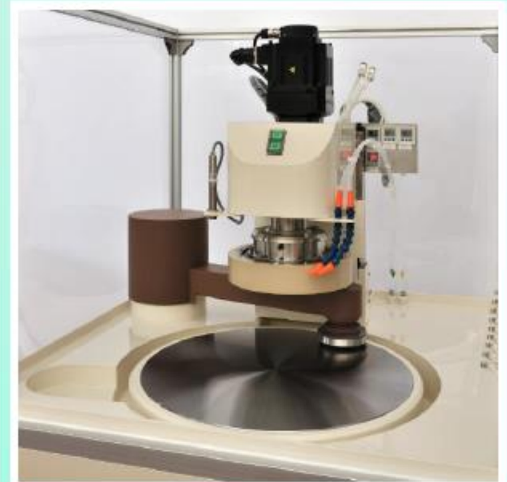
  - In-line pH, PSD and refractive index.
  - Off-line SEM to study LPCs and degrees of particle aggregation.
  - Off-line EDX for pad debris.
  - Off-line PSD and zeta-potential.



The Araca Effluent Slurry Extractor – ESE®

6421 North Nirvana Place, Tucson, AZ 85750 USA
Email: araca@aracainc.com
www.aracainc.com

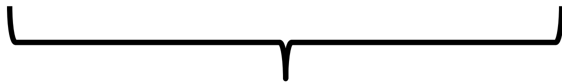
RDP-500 Polisher and Tribometer for R&D and Low-Volume Manufacturing

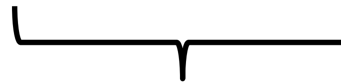


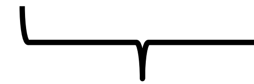
Specification

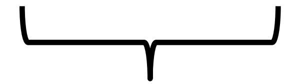
Manufacturer:	Fujikoshi Machinery Corporation (Nagano JAPAN). Sold exclusively in North America and the EU by Araca, Inc. (Tucson, AZ USA).
Wafer Size:	Coupons (25, 50, 75-mm) , 200, 150 and 100-mm with interchangeable wafer carriers.
Wafer Carrier:	Pressure range of 0.5 to 10 PSI. Independent pressure control (2 zones for the wafer and 1 zone for the retaining ring). Rotation range of 20 to 200 RPM. Rotation and vertical displacement controlled via servo motors. Head oscillation range of ± 40 mm (can be adjusted).
Platen:	508 mm in diameter stainless steel (SUS410) with integrated heating and cooling capability (chiller and heater to be provided by the customer). Rotation rate of 20 to 200 RPM. Rotation control via inverter motor.
Conditioner:	100 mm in diameter (can accommodate most standard CMP discs) Rotation rate range of 20 to 200 RPM. Sweep velocity range of 0 to 700 mm/sec through 10 independently controlled zones and dwell times. Down force range of 2 to 12 kg-force. In-situ and ex-situ capability.
Chemical Delivery Systems:	Two computer-controlled, 10-liter, chemical-resistant, removable tanks each with an impeller mixer, roller pump and level sensor. Flow rate range of 10 to 300 cc/min.
Pad Rinse:	Dedicated high flow rate (up to 3,000 cc/min) water rinse with an optional bristle brush end effector for through-the-grooves pad cleaning. Attached to the conditioner swing arm.
Force Sensors:	Shear force transducer above the carrier head and normal force transducers below the platen.
Temperature Sensor:	Single-point pad surface IR detector.
Wafer Slip Sensor:	Adjustable single-point slip sensor interlocked with the main operational features of the polisher for safety.
Control & Monitoring:	Intuitive programmable touch-screen controller for complete polisher operation.
Data Capture vs. Time:	Powered by Araca's FSX-500X® proprietary force acquisition and data analysis. Data capture frequency up to 2,300 Hz recording the following: Platen and carrier rotational velocities, shear force, normal force, and pad surface temperature.
Data Analysis & Reporting:	FSX-500X® off-line data analysis software (with user-friendly GUI) developed by Araca, Inc. Capable of reporting (vs. polish time) shear and normal forces, coefficient of friction and temperature. Advanced features include shear and normal force Fast Fourier Transform (FFT), force cluster plots, Stribeck+ curves and kinetic curves.
W × L × H & Weight:	92 × 92 × 186 cm and 1,082 Kg (for the polisher). 50 × 72 × 81 cm and 35 Kg (for the 2 chemical delivery systems).
Utilities:	200 V – 3 Phase, 60 Hz, 25kVA; minimum CDA pressure of 75 PSI (50 KPa); vacuum 95 PSI (65 KPa).
Enclosure & Exhaust:	Enclosed and sealed polishing chamber with 10 cm diameter standard tool exhaust port.
Warranty:	One year parts and labor warranty included. Optional extended warranties and service contracts available.

Extracted Samples









Reference Samples

SiC Samples Gentle and Aggressive Conditioning

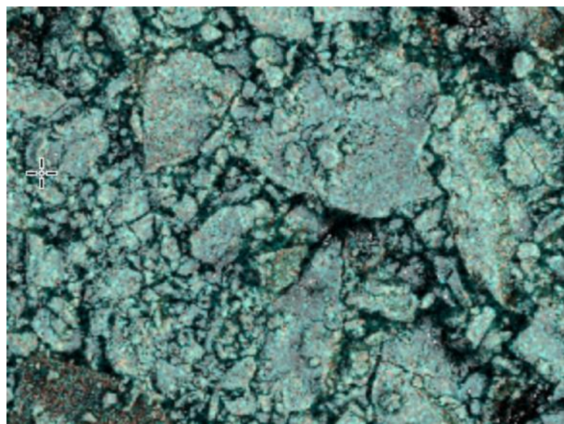
STI Samples Gentle and Aggressive Conditioning

Copper Samples Gentle and Aggressive Conditioning

STI Slurry Extracted from Pad During Polishing

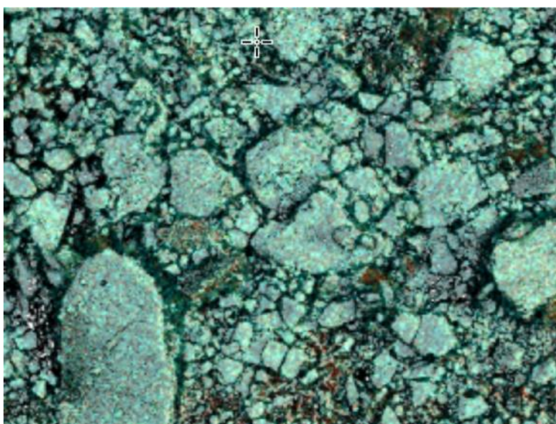
Slurry allowed to dry on a graphite strip (with 100 percent coverage) and measured by a JEOL NeoScope JCM-7000 SEM-EDX

Reference



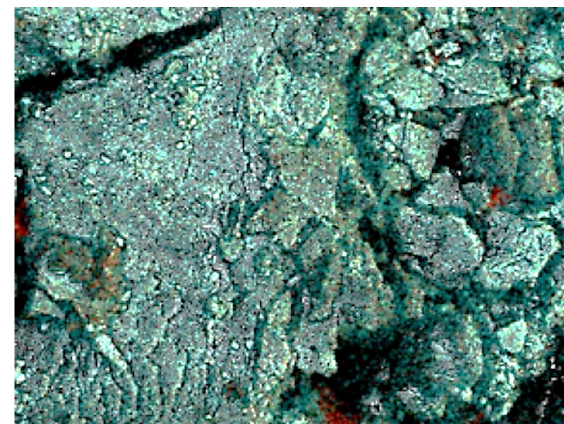
Element	Mass%	Atom%
C	3.32±0.04	15.51±0.20
O	14.73±0.14	51.67±0.51
Si	0	0
Ce	81.95±0.59	32.82±0.24

Gentle



Element	Mass%	Atom%
C	4.46±0.05	19.46±0.22
O	15.32±0.15	50.19±0.49
Si	0.22±0.02	0.41 ±0.04
Ce	80.00±0.59	29.93±0.22

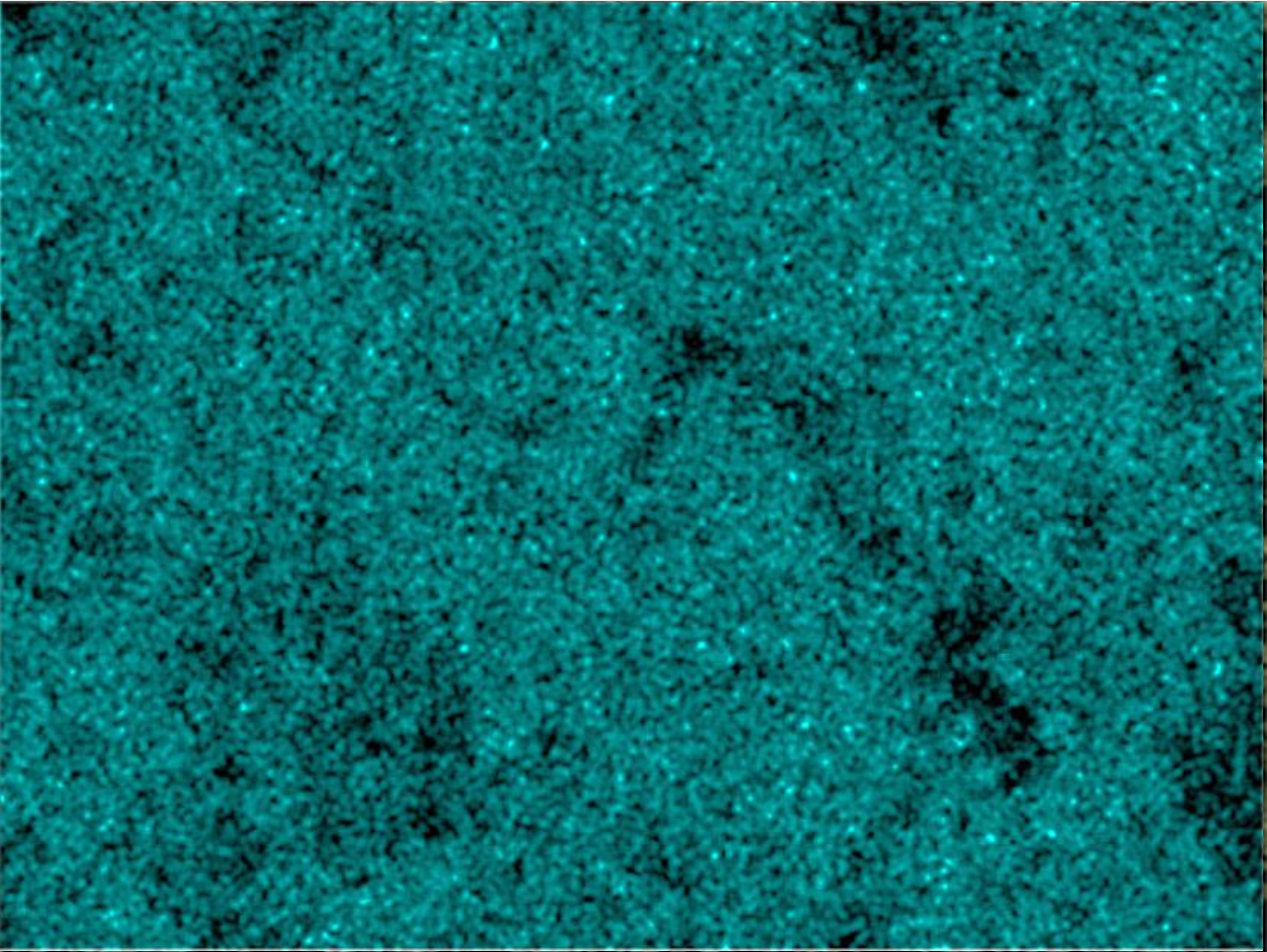
Aggressive



Element	Mass%	Atom%
C	5.17±0.06	22.96±0.27
O	13.73±0.16	45.82±0.53
Si	0.21±0.02	0.39±0.05
Ce	80.90±0.66	30.83±0.25

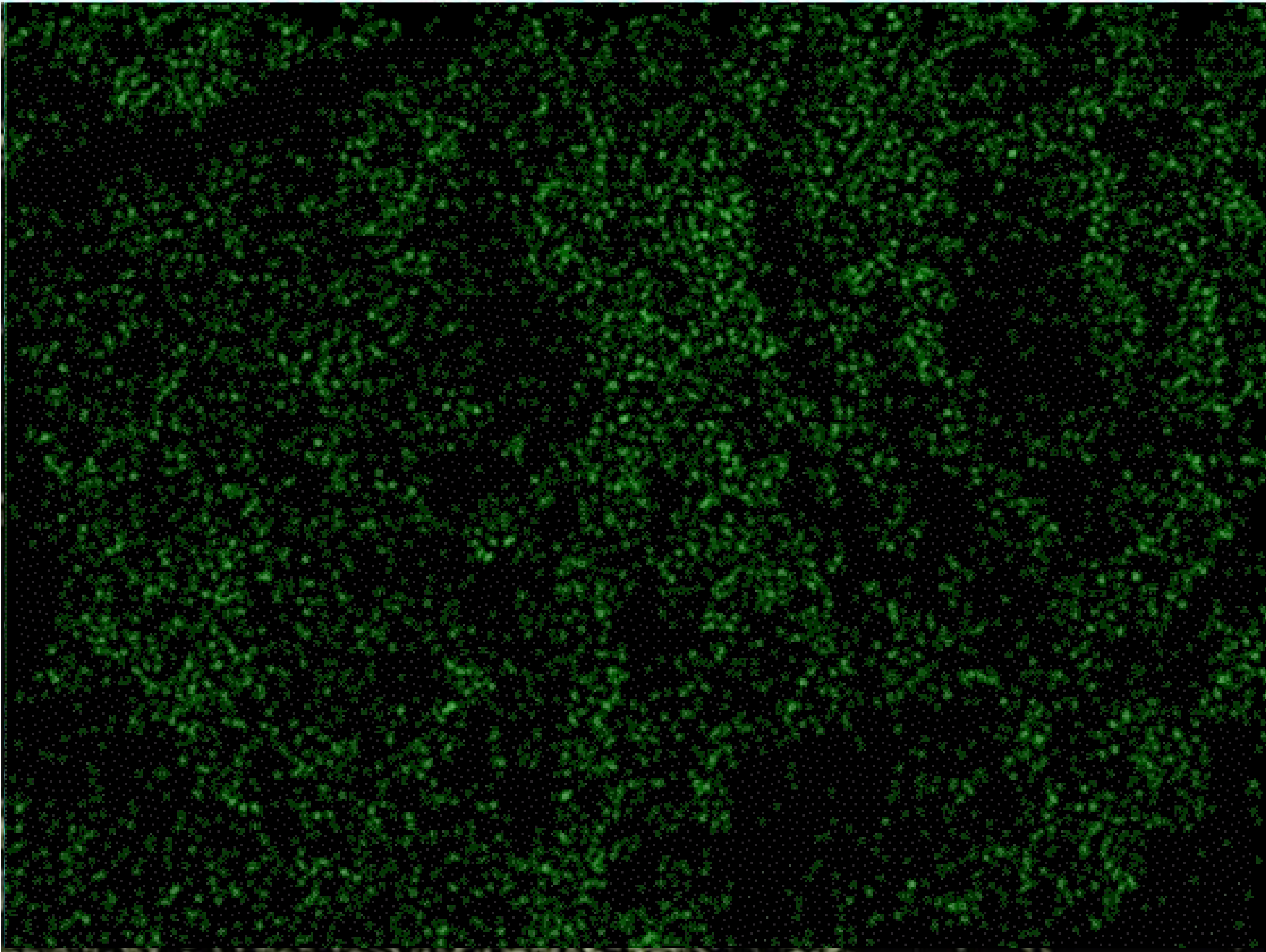
Elemental Speciation in the Case of Reference STI Slurry

C-K
O-K
Si-K
Ce-L



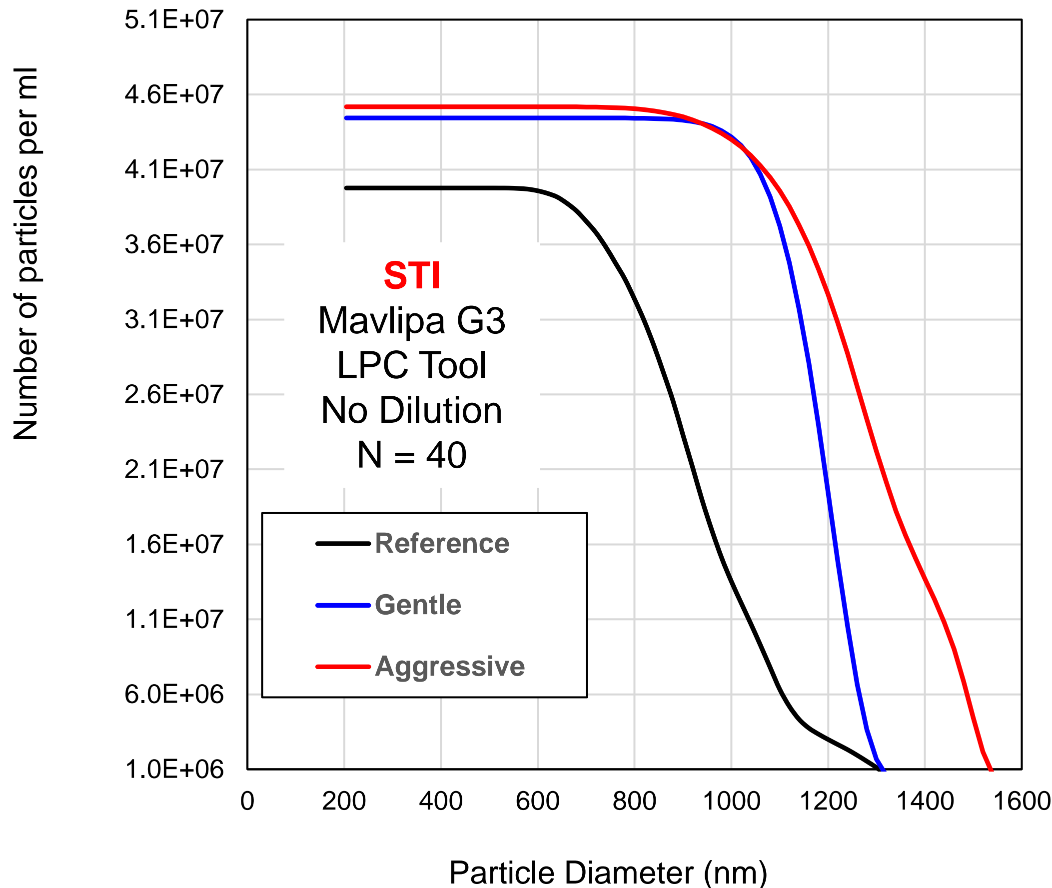
Elemental Speciation in the Case of Aggressive Conditioning – STI

C-K
O-K
Si-K
Ce-L



Large Particle Count (LPC) in STI Slurry Extracted During CMP

- **200 mm TEOS-based SiO_2 wafers polished with STI calcined ceria slurry diluted 1-to-3 with UPW – Flow at 200 cc per minute**



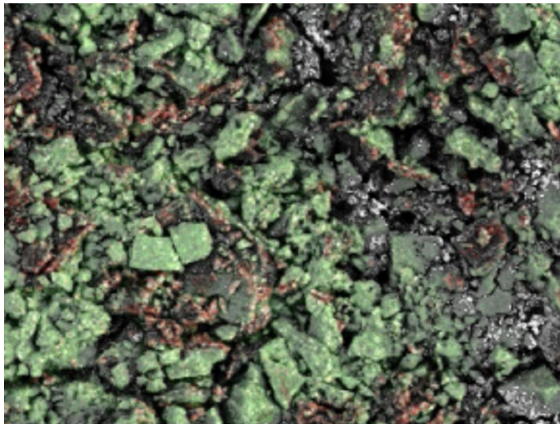
- **Dupont IC-1010 In-Situ Pad Conditioning**
  - **Gentle – 3M Trizact B5 disc rotating at 95 RPM with sinusoidal sweeping schedule of 10 per min and at 5 lb-force.**
  - **Aggressive – 3M A165 disc rotating at 95 RPM with sinusoidal sweeping schedule of 10 per min and at 10 lb-force.**

- **Polishing Conditions**
  - **Wafer/Ring pressure = 0.8/1.1 PSI**
  - **Platen/Wafer rotation rates = 61/59 RPM (0.8 m/s)**

Copper Slurry Extracted from Pad During Polishing

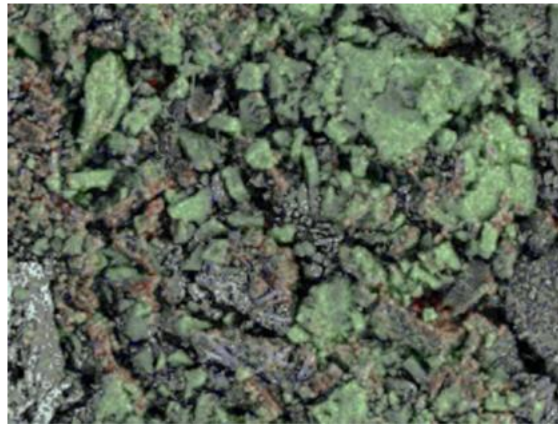
Slurry allowed to dry on a graphite strip (with 100 percent coverage) and measured by a JEOL NeoScope JCM-7000 SEM-EDX

Reference



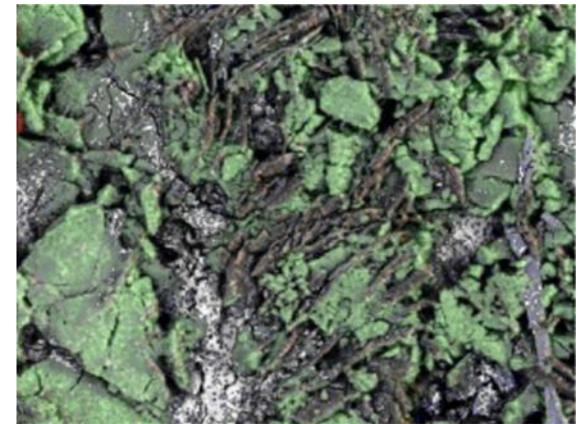
Element	Mass%	Atom%
C	20.62±0.21	27.77±0.28
N	7.04±0.25	8.13±0.29
O	51.53±0.42	52.10±0.42
Si	20.81+0.16	11.99+0.09
Cu	0	0

Gentle



Element	Mass%	Atom%
C	19.76±0.20	27.03±0.27
N	8.44±0.26	9.90±0.31
O	50.38±0.41	51.74±0.42
Si	17.74±0.15	10.38±0.09
Cu	3.68±0.22	0.95±0.06

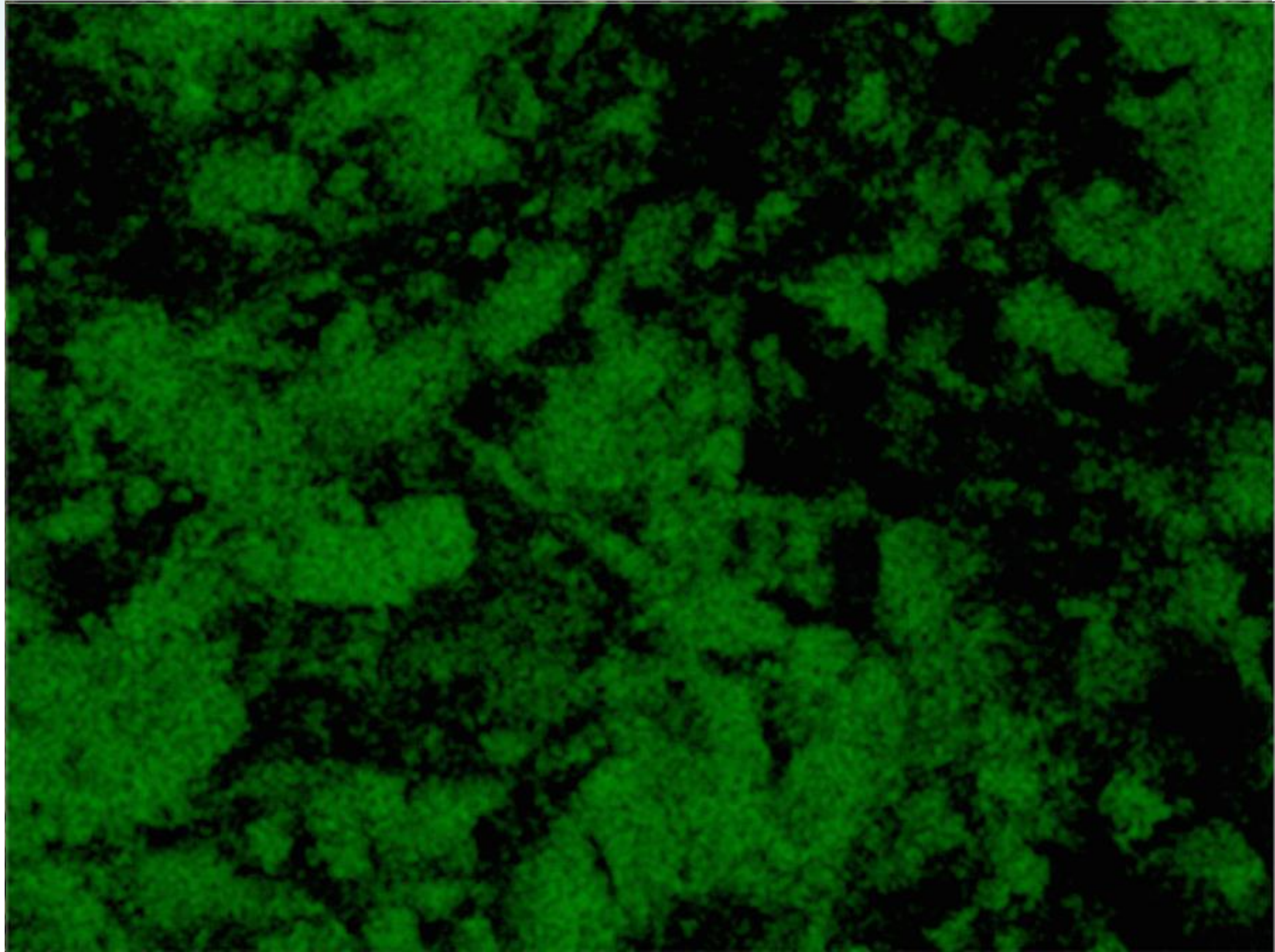
Aggressive



Element	Mass%	Atom%
C	19.60±0.20	26.98±0.28
N	8.29±0.27	9.79±0.31
O	49.48±0.41	51.13±0.43
Si	18.93±0.15	11.14±0.09
Cu	3.70±0.23	0.96±0.06

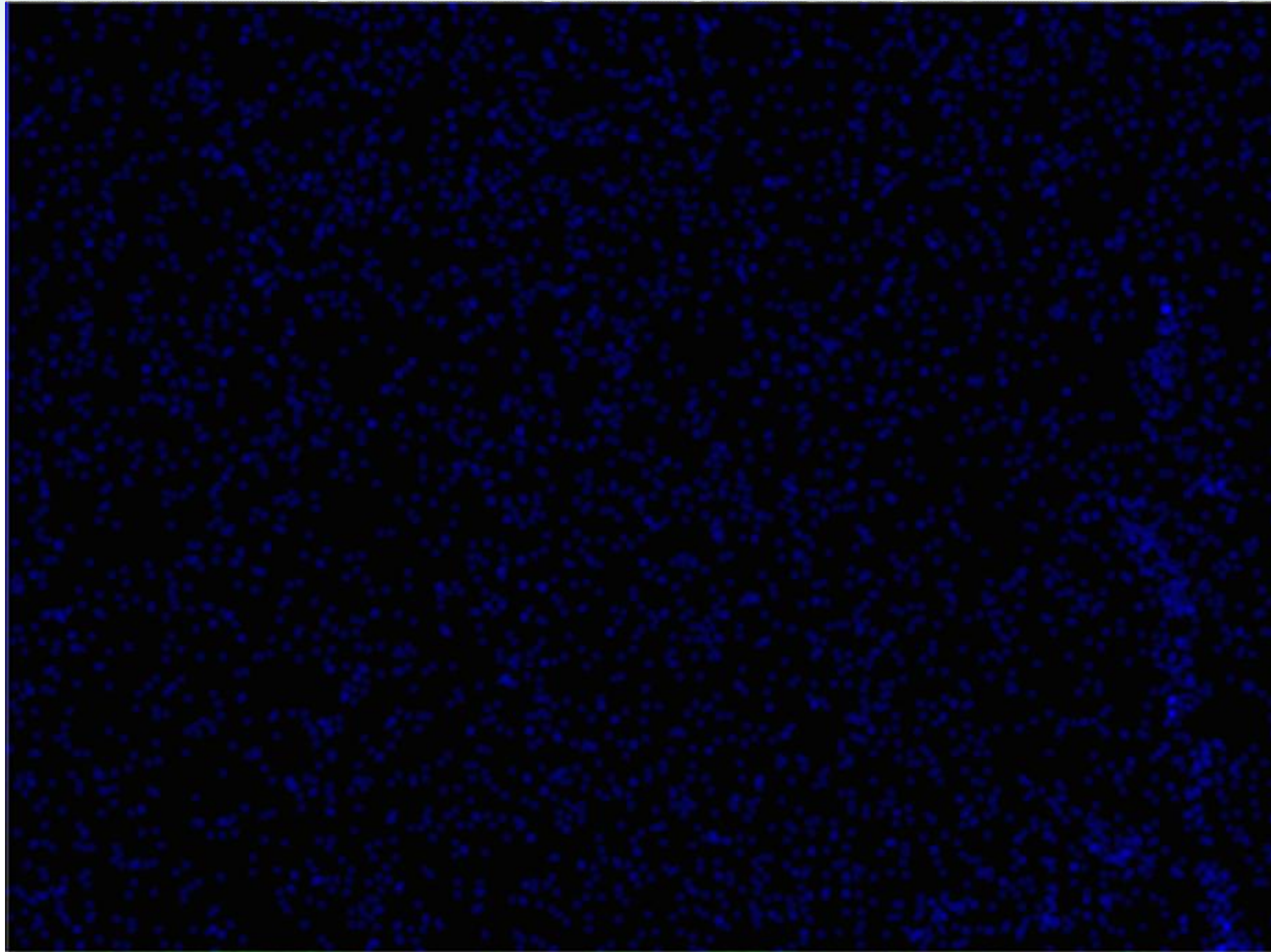
Elemental Speciation in the Case of Reference Cu Slurry

C-K
N-K
O-K
Si-K
Cu-K



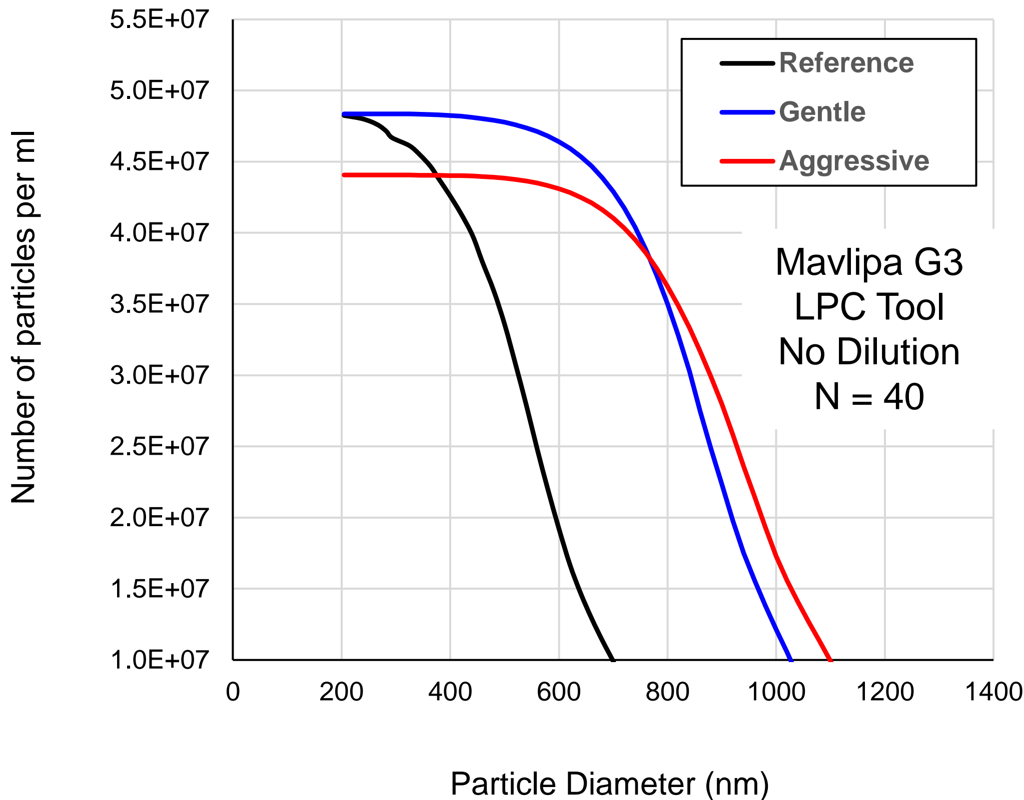
Elemental Speciation in the Case of Aggressive Conditioning – Cu

C-K
N-K
O-K
Si-K
Cu-K



Large Particle Count (LPC) in Copper Slurry Extracted During CMP

- **200 mm blanket copper wafers polished with an HVM copper slurry mixed as per supplier specifications – Flow at 200 cc per minute**

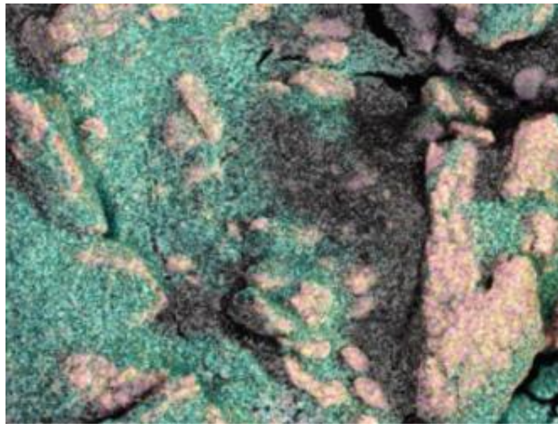


- **Dupont IC-1010 In-Situ Pad Conditioning**
  - ❖ **Gentle – 3M Trizact B5 disc rotating at 95 RPM with sinusoidal sweeping schedule of 10 per min and at 5 lb-force.**
  - ❖ **Aggressive – 3M A165 disc rotating at 95 RPM with sinusoidal sweeping schedule of 10 per min and at 10 lb-force.**
- **Polishing Conditions**
  - ❖ **Wafer/Ring pressure = 0.8/1.1 PSI**
  - ❖ **Platen/Wafer rotation rates = 61/59 RPM (0.8 m/s)**

SiC Slurry Extracted from Pad During Polishing

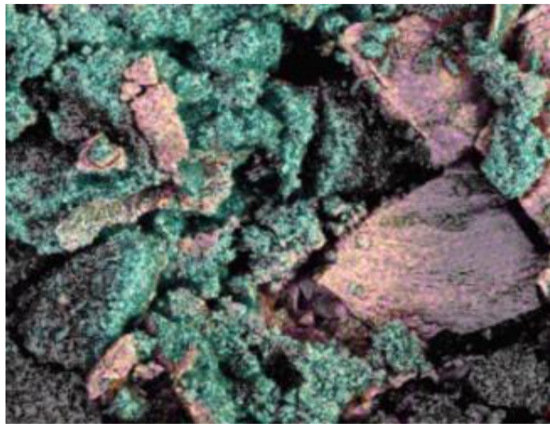
Slurry allowed to dry on a graphite strip (with 100 percent coverage) and measured by a JEOL NeoScope JCM-7000 SEM-EDX

Reference



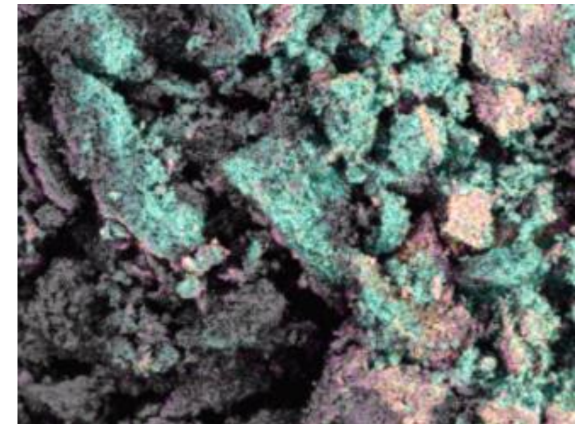
Element	Mass%	Atom%
C	4.87±0.10	8.48±0.18
O	46.67±0.35	61.00±0.45
Al	26.80±0.19	20.77±0.15
K	9.77±0.13	5.22±0.07
Mn	11.89±0.25	4.53±0.09

Gentle



Element	Mass%	Atom%
C	5.08±0.12	9.26±0.22
O	41.53±0.38	56.84±0.52
Al	26.85±0.22	21.79±0.18
K	9.39±0.15	5.26±0.08
Mn	17.15±0.34	6.84±0.14

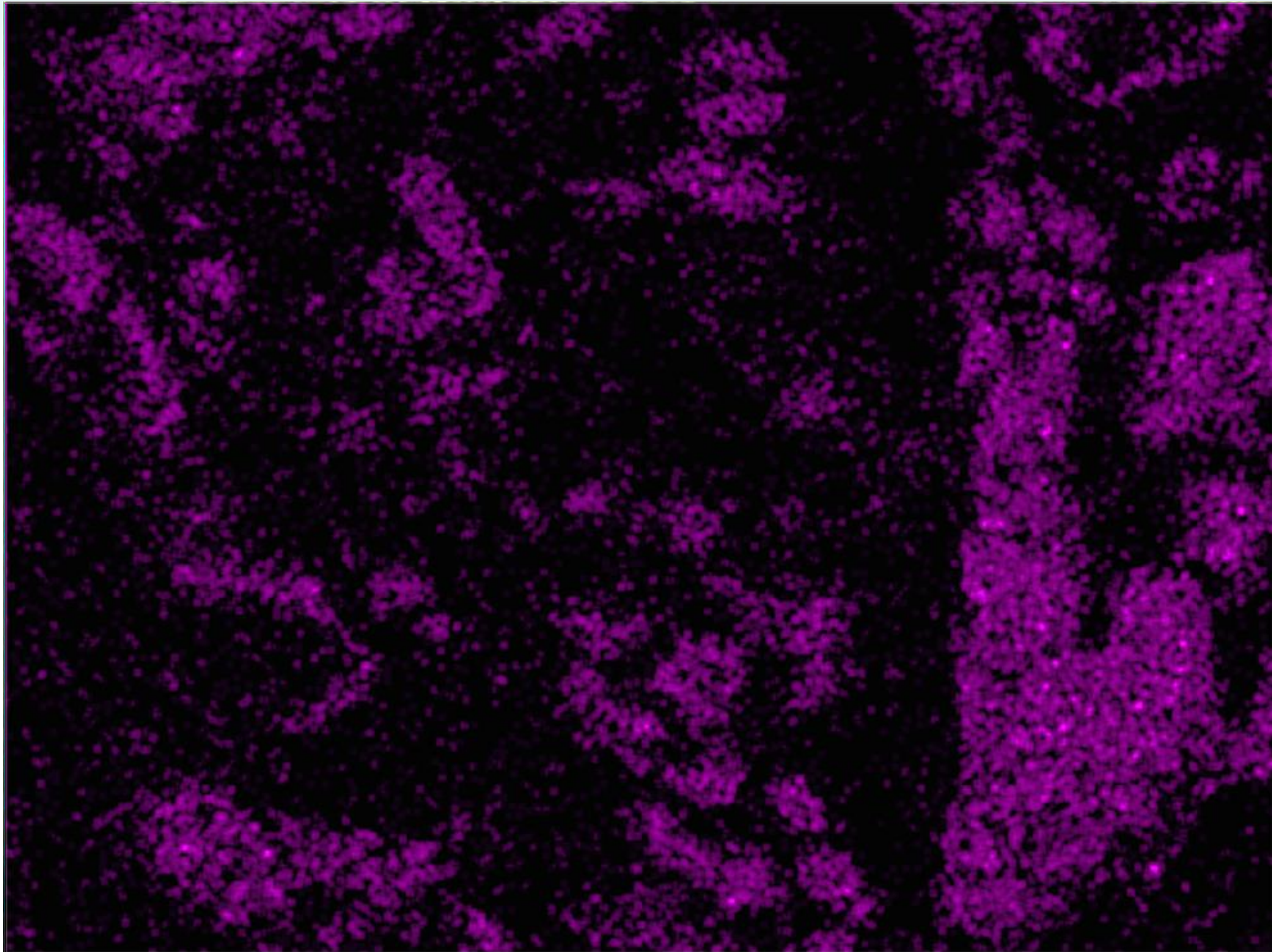
Aggressive



Element	Mass%	Atom%
C	5.03±0.13	9.09±0.24
O	42.09±0.40	57.17±0.54
Al	27.97±0.24	22.52±0.19
K	8.50±0.15	4.72±0.09
Mn	16.42±0.36	6.49±0.14

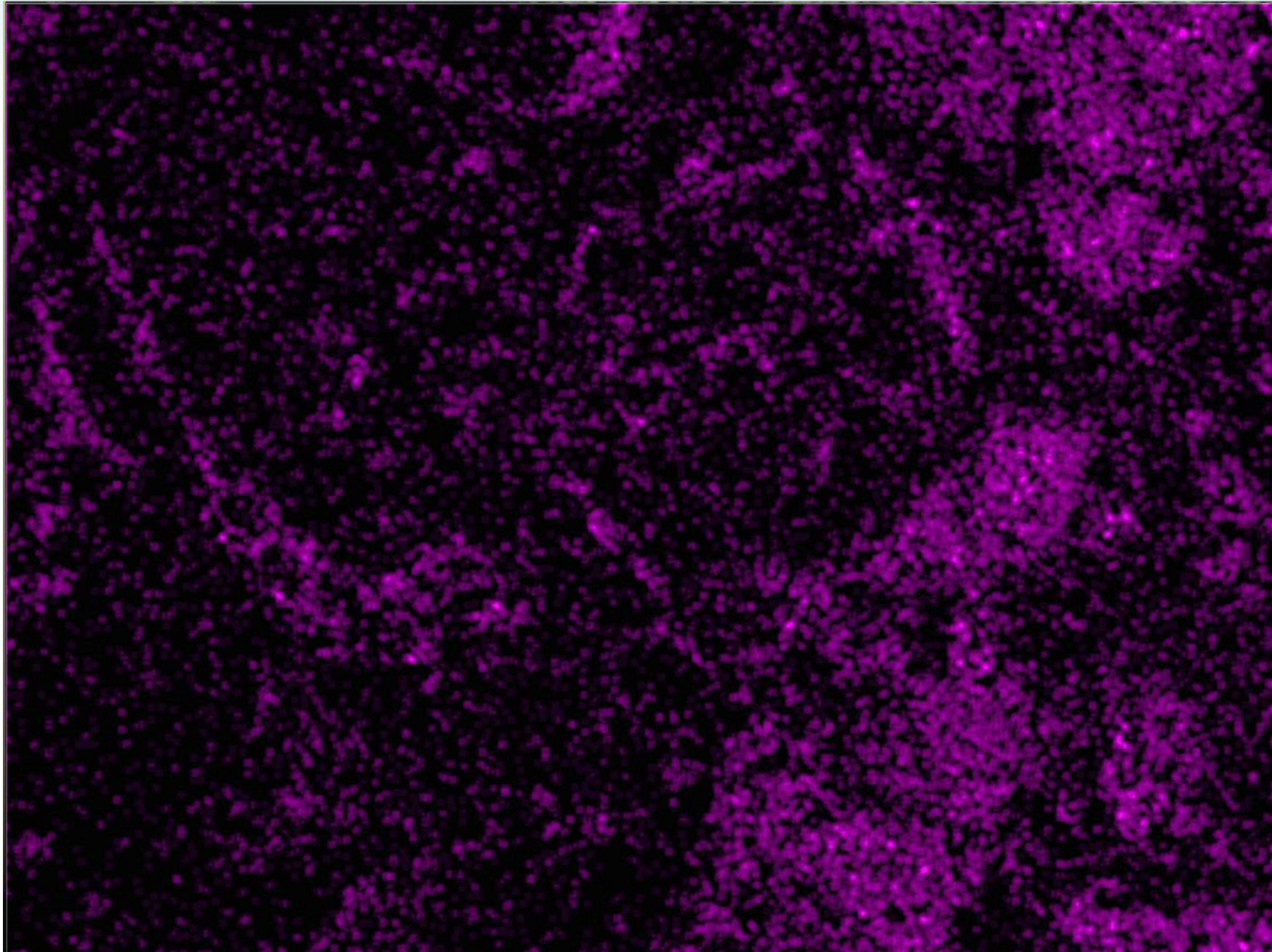
Elemental Speciation in the Case of Reference <u>SiC</u> Slurry

C-K
O-K
Al-K
K-K
Mn-K



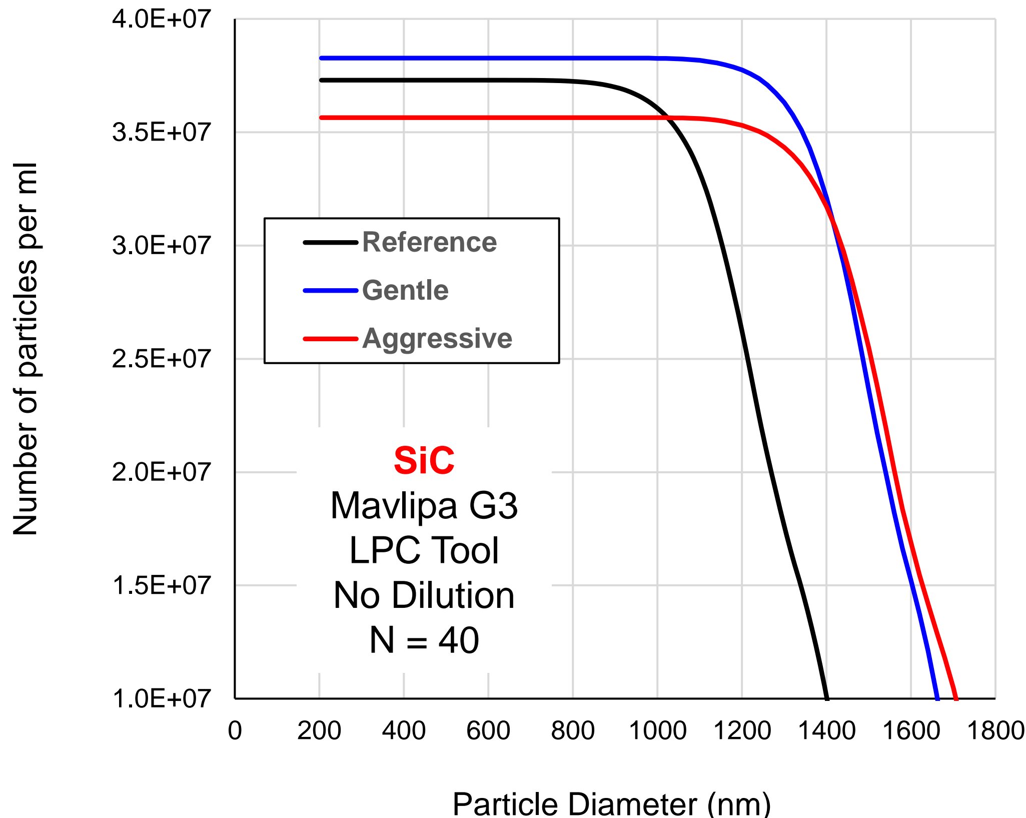
Elemental Speciation in the Case of Aggressive Conditioning – SiC

C-K
O-K
Al-K
K-K
Mn-K



Large Particle Count (LPC) in SiC Slurry Extracted During CMP

- **150 mm blanket silicon carbide substrates polished with an HVM SiC slurry mixed as per supplier specifications – Flow at 200 cc per minute**



- **Dupont IC-1010 In-Situ Pad Conditioning**
  - **Gentle – 3M Trizact B5 disc rotating at 95 RPM with sinusoidal sweeping schedule of 10 per min and at 5 lb-force.**
  - **Aggressive – 3M A165 disc rotating at 95 RPM with sinusoidal sweeping schedule of 10 per min and at 10 lb-force.**

- **Polishing Conditions**
  - **Wafer/Ring pressure = 0.8/1.1 PSI**
  - **Platen/Wafer rotation rates = 61/59 RPM (0.8 m/s)**

A Final Thought – Partial Slurry Capture for Reprocessing and Reuse

The Premier Provider of Services and Equipment to the Semiconductor Polishing and Planarization Industries

Thank You!

Questions?

Answers.