Slurry Activation Through Flucto-CMP®

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Our Vision

- **Today, the same HVM CMP tool must be able to planarize substrates by removing 2 to 2E7 nm of a single layer without compromising performance – 7 orders of magnitude difference!**

- **In addition to platen temperature modulation, there are very few mechanical knobs (e.g., controls, hydraulics, pneumatics, kinematics and the like) that can be perfected in a polisher – Yet the chemical options are nearly infinite!**

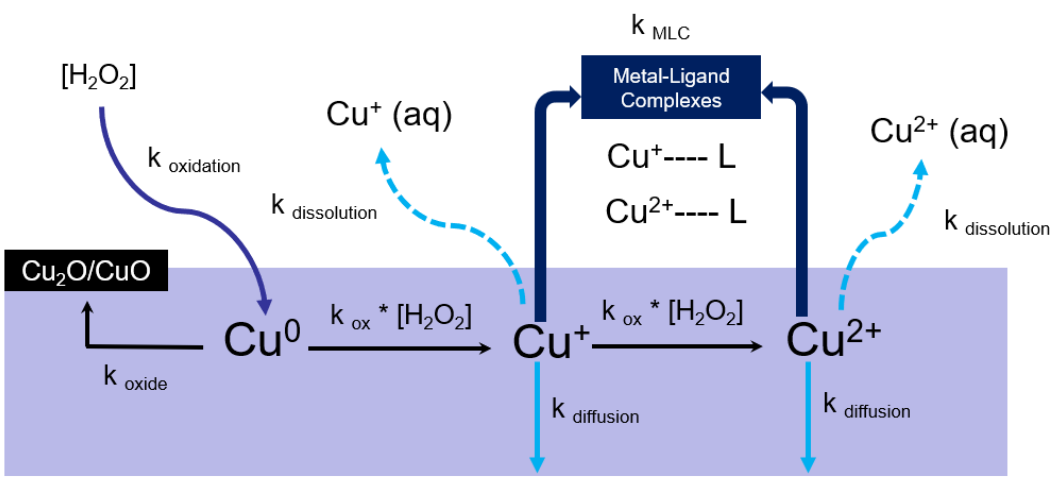
- **For 2 years, Araca has been working to partially merge the polisher and slurry roadmaps via our patent-pending Flucto-CMP® technology. Here, the combined slurry-polisher strengths complement each other to overcome their individual inherent weaknesses such as defects, gross vibrations, COO, slurry waste, RR, selectivity and WIWRRNU.**

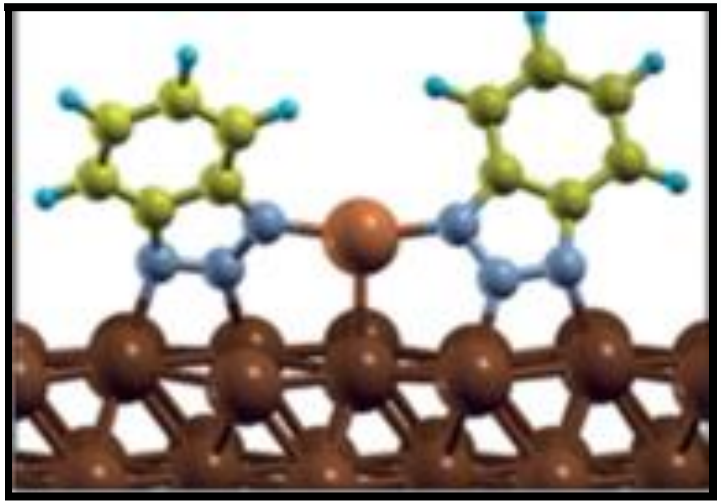
- **IC makers wish to migrate to a slurry whereby its main properties (such as copper-to-barrier RR selectivity) can be toggled instantaneously and on-demand.**

- **Flucto means WAVE in Latin – We now provide on-demand off-the-shelf slurry activation using megasonic waves through:**

  - **Add-on polisher equipment (subject of today's discussion) – Can also be combined with,**
  - **The addition of Sono-Activated® chemicals (some nuggets presented today).**

BTA Modes of Inhibition in Conventional Copper CMP





Numerous studies of the interaction of BTA with copper reveal that the BTA molecule forms a coordination polymer above the surface featuring a Cu(I) center bridging between two BTA molecules.

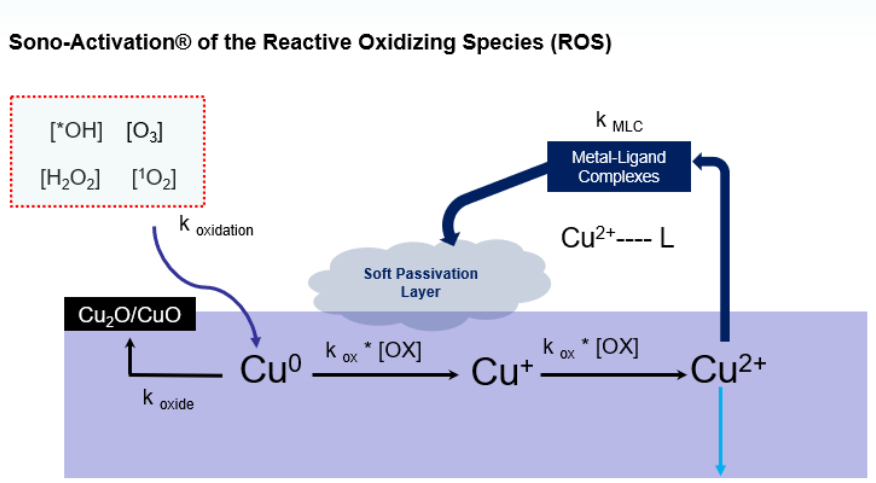
This polymerization leads to the formation of a DENSE and RUGGED passivation layer that causes large levels of vibration and requires significant mechanical action to remove at appreciable polish rates.

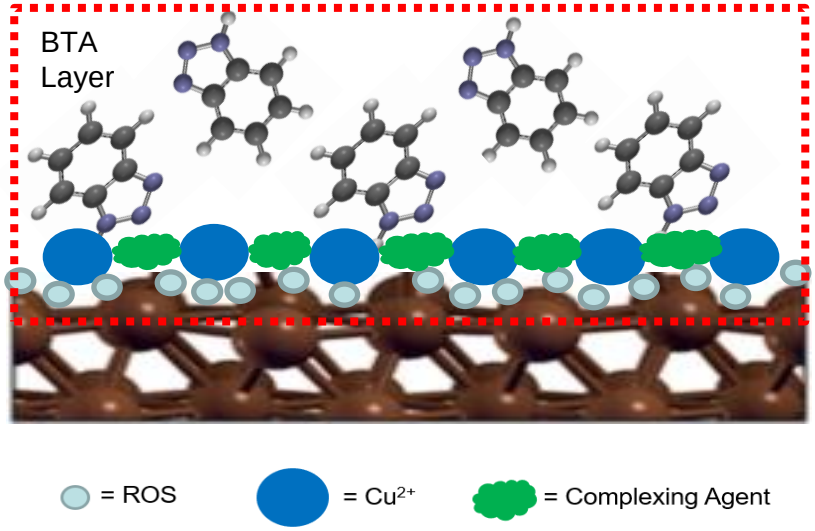
Non-Covalent Passivation Dynamics of Fluct-CMP®

- **In Fluct-CMP®, when it comes to material removal, it's all about one's ability to control the interface.**

- **Enhanced CMP performance evolves from a balance of kinetic and thermodynamic processes. Modulation of these processes get activated by external stimuli such as sonication.**

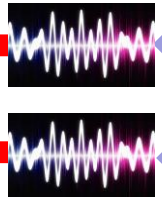
- **The subsequent softer and less dense film formation dynamics results in effective material removal at less mechanically-aggressive conditions. This reduces vibration as well as wafer-level defects.**





The Flucto-CMP® Setup at Araca

- **The new Araca-Fujikoshi RDP-500® and APD-800 tools are the POR in-house polishers for Flucto-CMP®.**
- **Equipped with two highly-confidential continuously flowing closed megasonic reactors connected in parallel.**
- **Flucto-CMP® can be easily retrofitted on any HVM AMAT or Ebara polisher.**

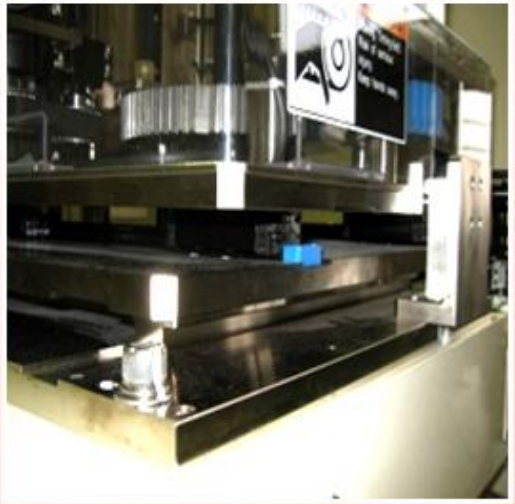


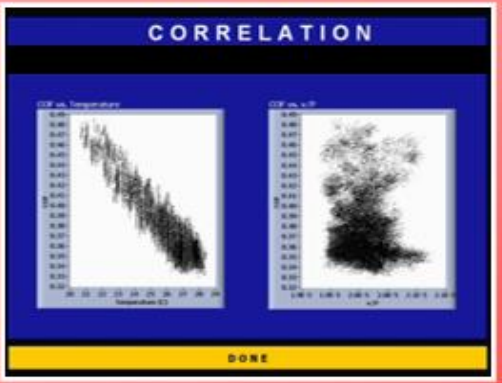
Flucto-CMP® Reactors with 1 MHz Transducers and a Power Density of 1 W/cm^2

Day-Tank Containing off-the-Shelf Cu, Ta or W Slurry with H_2O_2

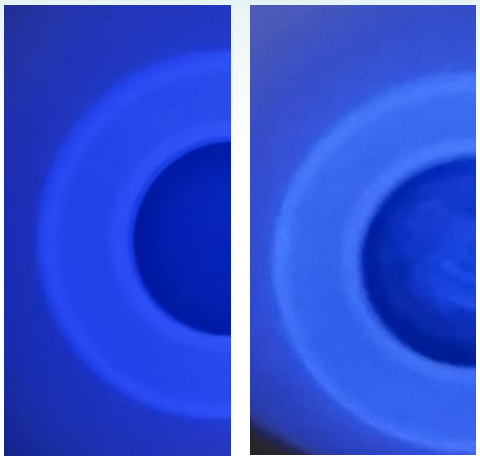
2550 East River Road, Suite 12204, Tucson, AZ 85718 USA
Email: araca@aracainc.com
www.aracainc.com

APD-800 Polisher and Tribometer for R&D and Low-Volume Manufacturing



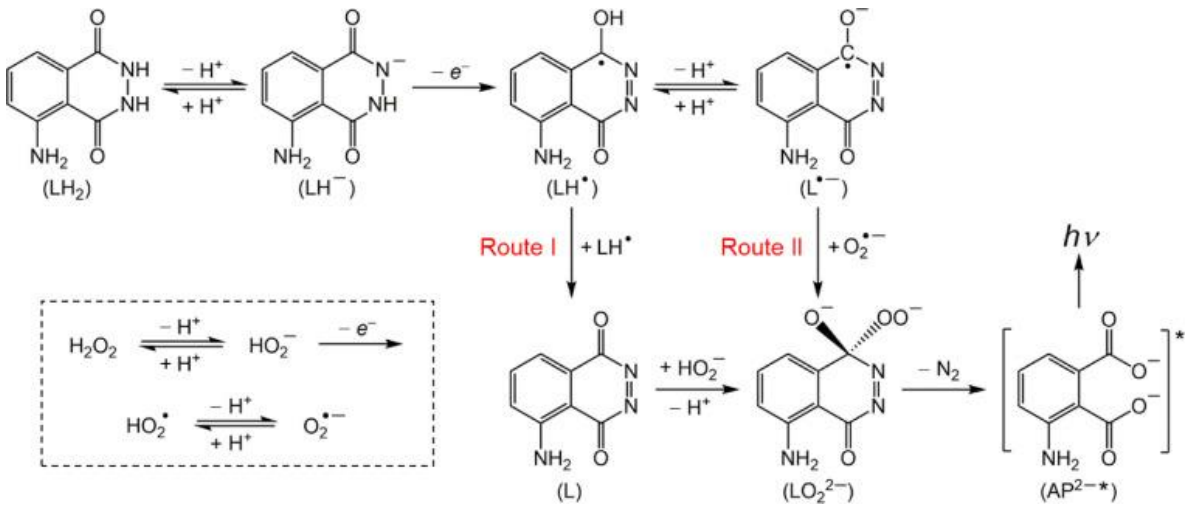


Reactive Oxidizing Species Creation – Luminol® Tests

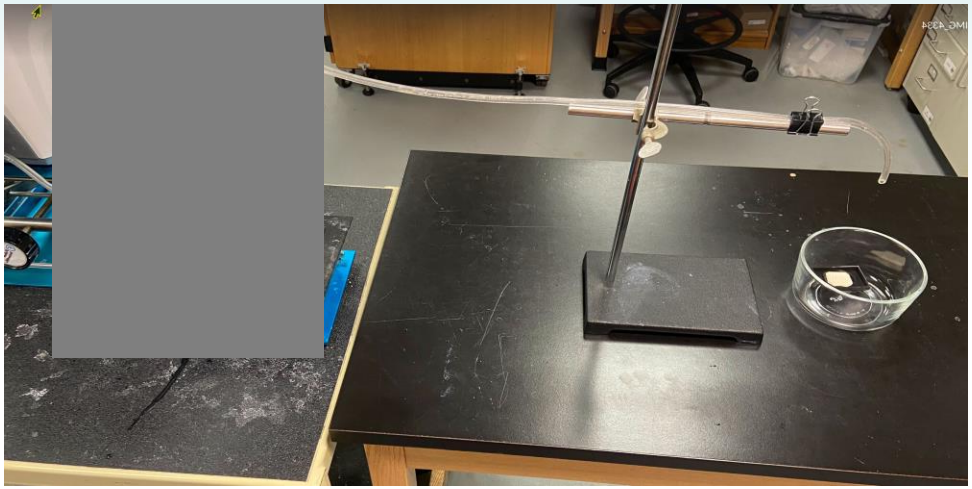


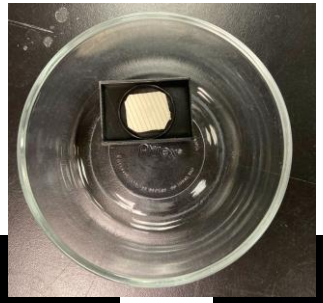
Supplier A – Bulk Copper Slurry with H_2O_2 – After 5-sec (left) and 60-sec (right) exposure to Flucto-CMP®

Supplier A – Bulk Copper Slurry Post Flucto-CMP® – Without H_2O_2 (left) and with H_2O_2 (right)

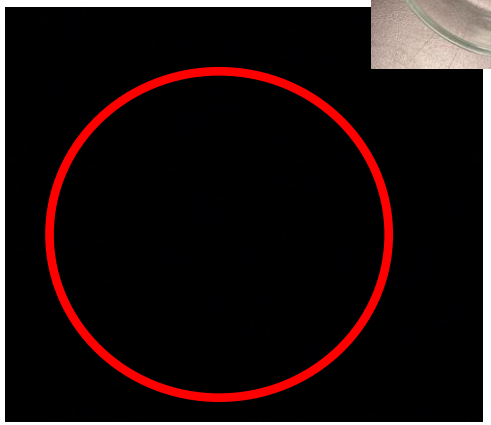


Reactive Oxidizing Species Creation – Luminol® Tests





No Flucto-CMP®
at 30 sec



Flucto-CMP®
at 30 sec

RR with Fluctо-CMP® on Blanket Substrates – Off-the-Shelf Slurries

- **Early results (on 100-mm wafers):**
  - ✓ Bulk Cu RR increase – 40% (Supplier A, C, D)
  - ✓ TSV Cu RR increase – 15% (Supplier A)
  - ✓ W RR increase – 25% (Supplier A, B)
  - ✓ Ta RR increase – 25% (Supplier A)
  - ✓ ILD RR increase – 100% (Supplier A STI CeO2)
- **APD-800 polisher with one or two Flucto-CMP® reactor (on 300-mm wafers):**
  - ✓ Bulk Cu RR increase – 15% (Supplier A)
  - ✓ W RR increase – 10% (Supplier A)
  - ✓ Great RTR repeatability →
  - ✓ DRACO® hard mask – 35% (Supplier C)
- **RDP-500 polisher (on 200-mm wafers) with two Flucto-CMP® reactors:**
  - ✓ Bulk Cu RR increase – 35% (Supplier A)
  - ✓ W RR increase – 15% (Supplier A)
  - ✓ Great RTR repeatability →

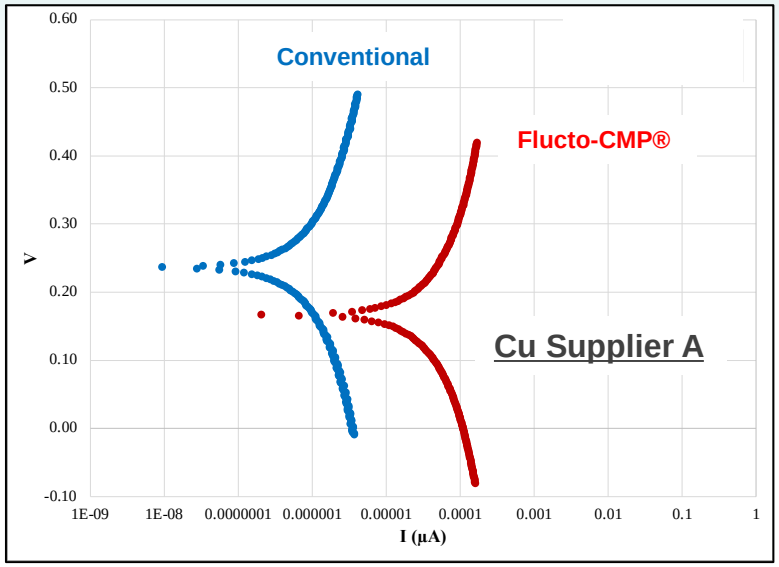
COPPER

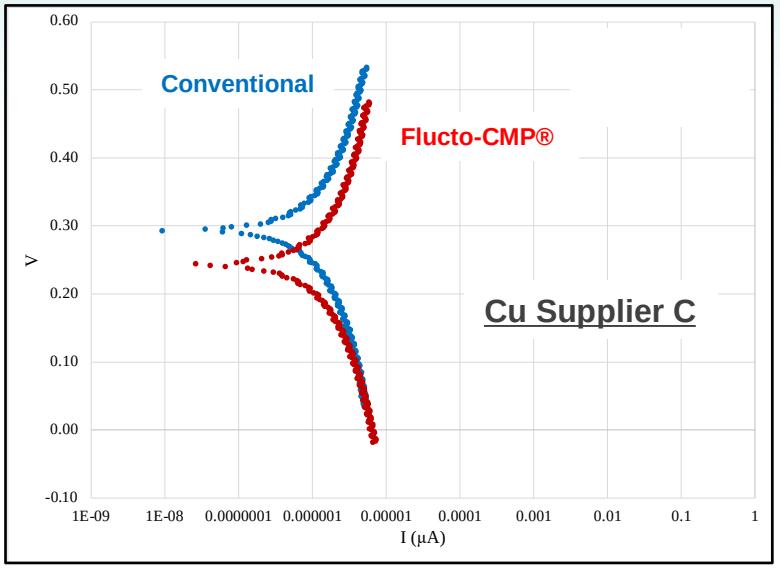
Run	Mean COF	Mean Pad Temp. (°C)	Mean Removal Rate (A/min)
1	0.56	25.5	9190
2	0.532	25.8	8844
3	0.571	25.8	9025
4	0.543	25.7	8858
5	0.551	25.6	9175
6	0.562	26	9215
7	0.548	25.6	8957
8	0.542	25.7	9041
9	0.562	26.2	9038
10	0.554	26.2	8854
11	0.539	25.9	8958
12	0.565	25.5	9124
Average	0.552	25.8	9023
Standard Deviation (%)	2.2%	0.9%	1.5%

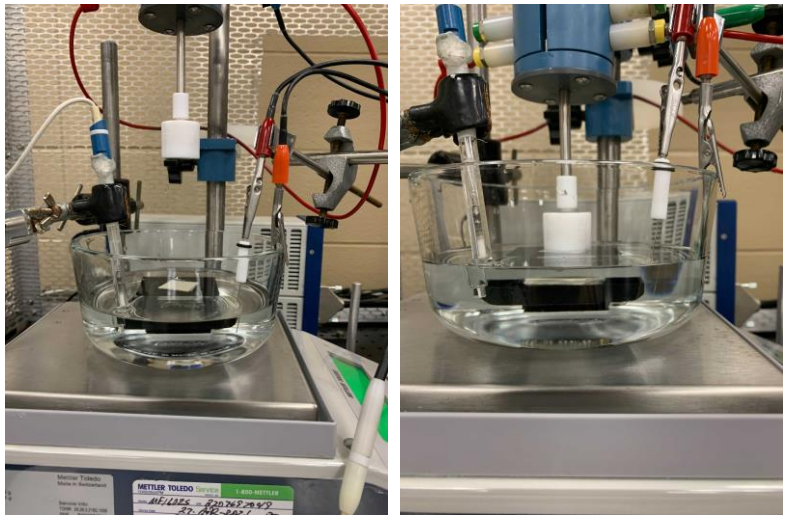
TUNGSTEN

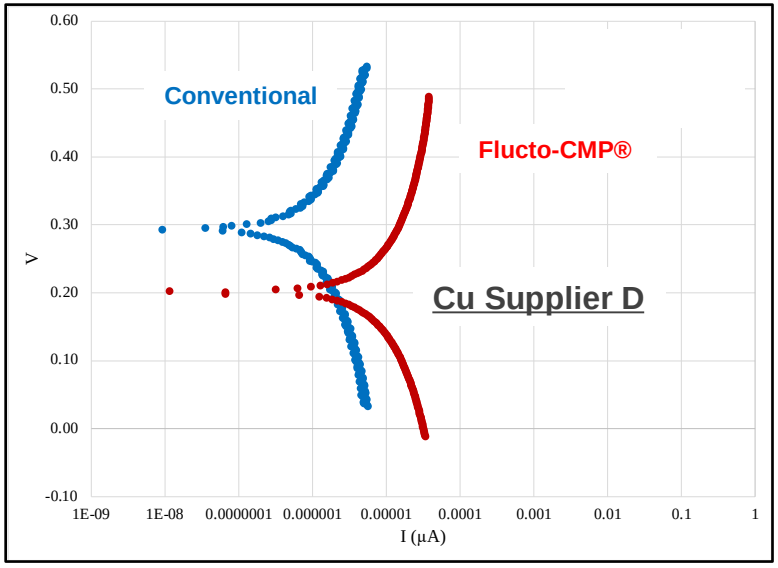
Run	Mean COF	Mean Pad Temp. (°C)	Mean Removal Rate (A/min)
1	0.318	37.8	2435
2	0.299	37.2	2503
3	0.309	36.6	2453
4	0.308	36.9	2579
5	0.316	37.8	2471
6	0.301	36.9	2402
7	0.307	36.5	2475
8	0.294	37.1	2527
9	0.302	36.4	2481
10	0.294	36.9	2446
11	0.302	36.7	2490
12	0.301	37.6	2538
Average	0.304	37.0	2483
Standard Deviation (%)	2.5%	1.3%	2.0%

Electrochemical Analysis of Flucto-CMP®

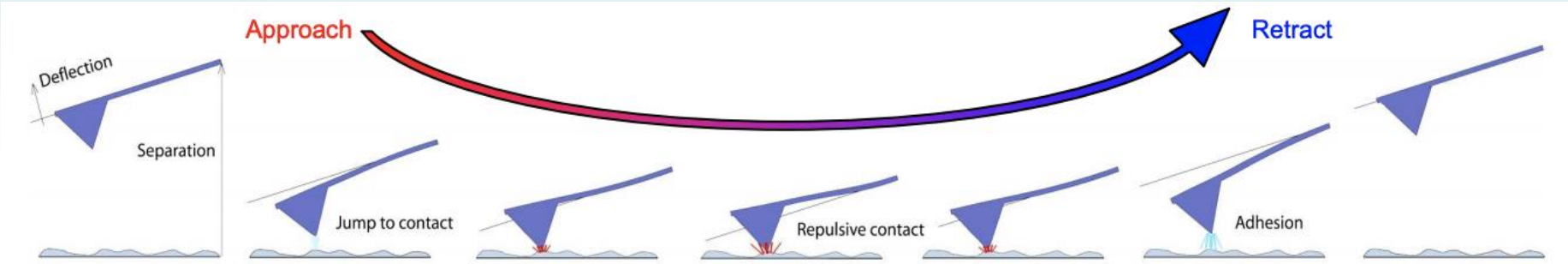


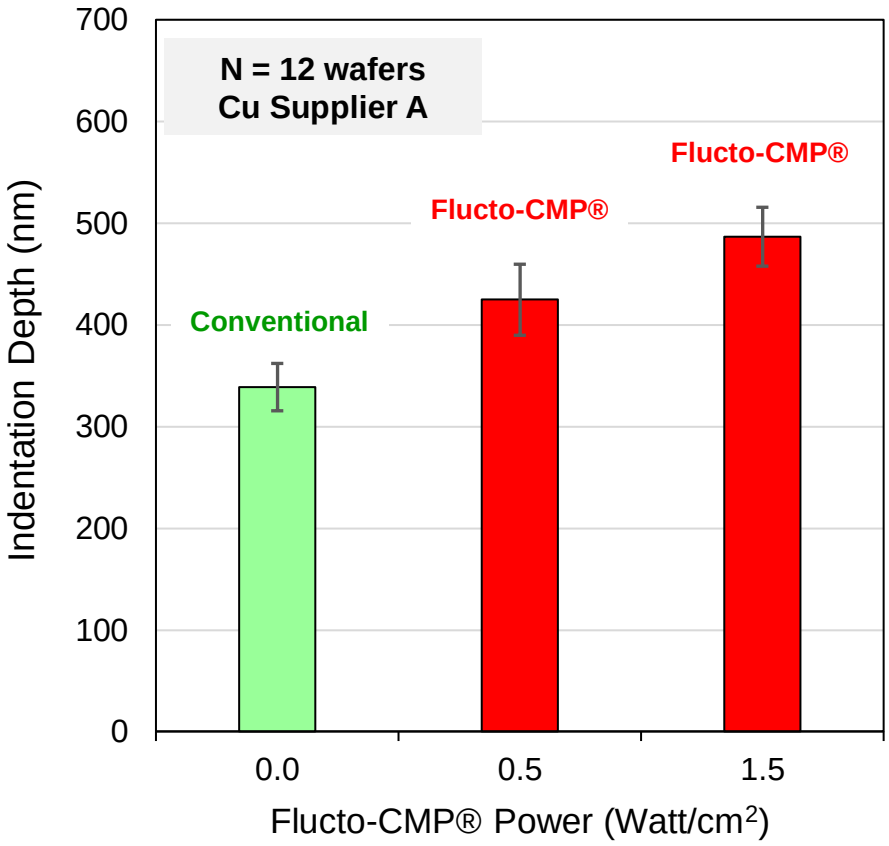


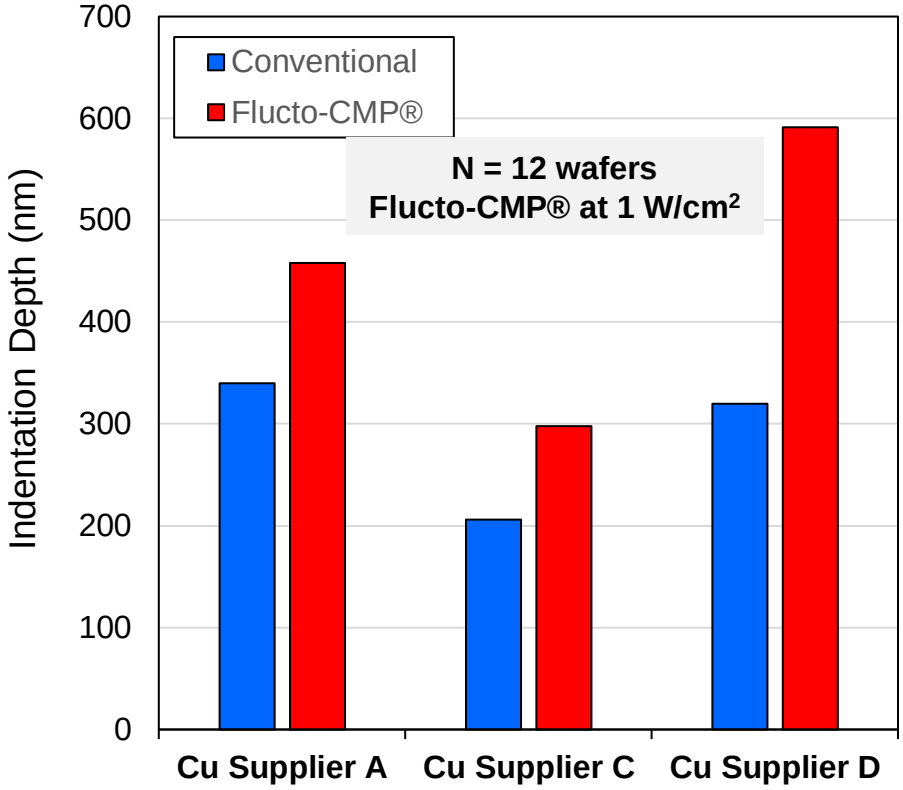




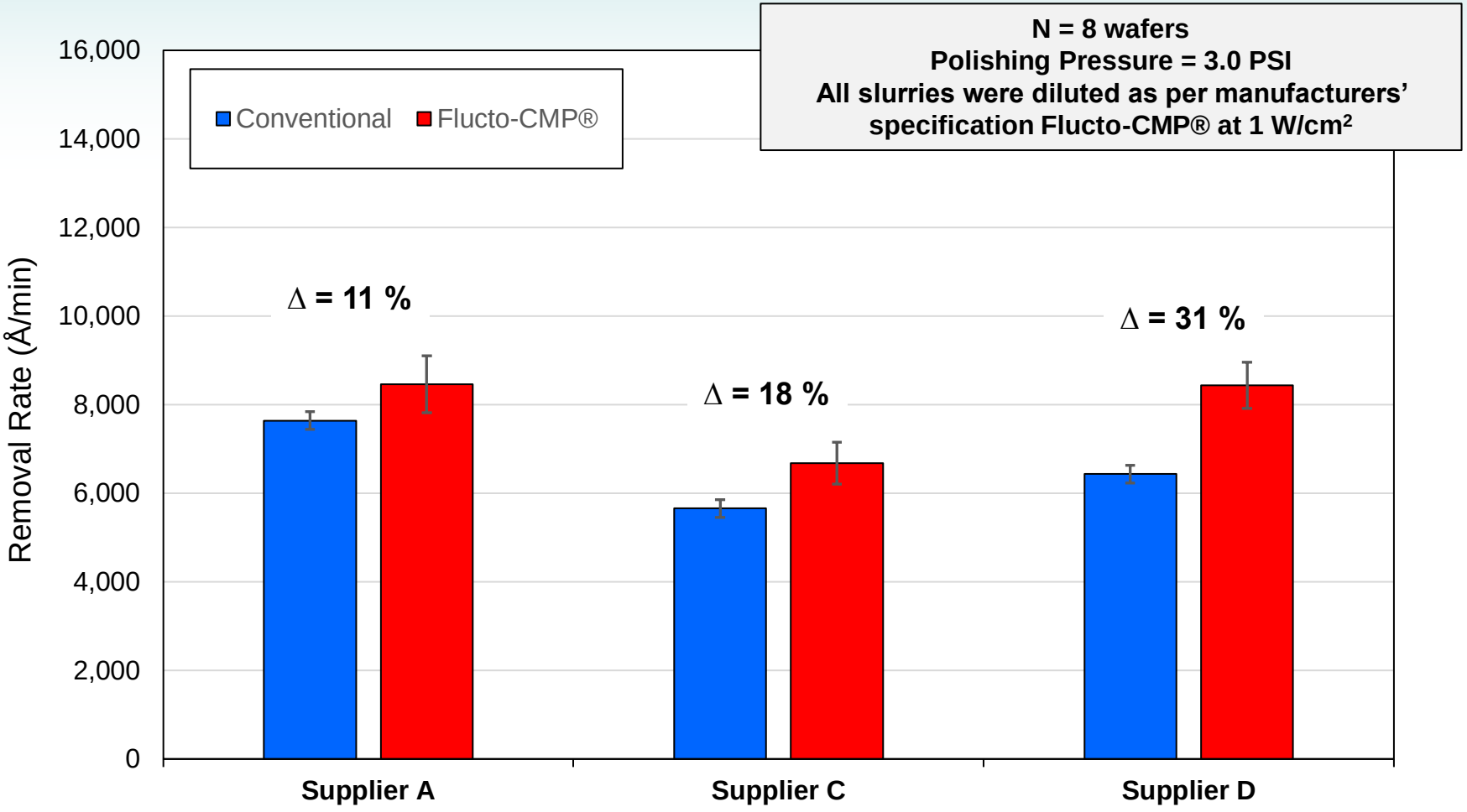
AFM Tip Indentation Depth of the Passivation Layer







Slurry Supplier Performance Comparison



REMEMBER – THE FASTER YOU POLISH, THE LESS SLURRY YOU USE AND THE LESS WASTE YOU HAVE TO DEAL WITH –

Flucto-CMP® CAN OFFER ATTRACTIVE ENVIRONMENTAL BENEFITS!

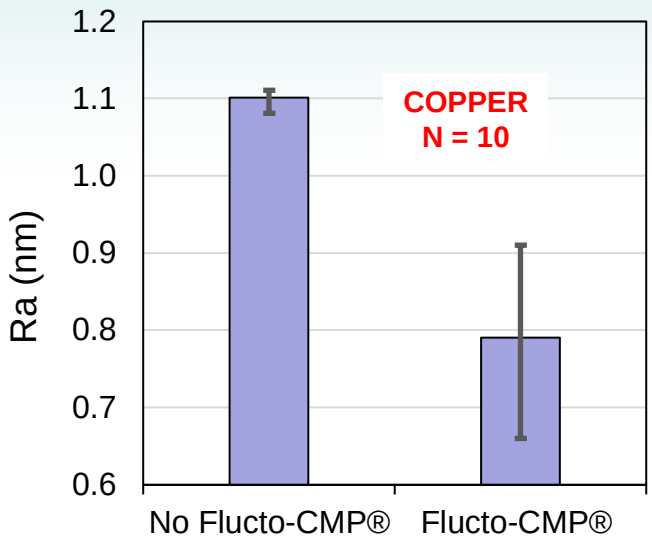
Our Rationale Regarding Defect Reduction

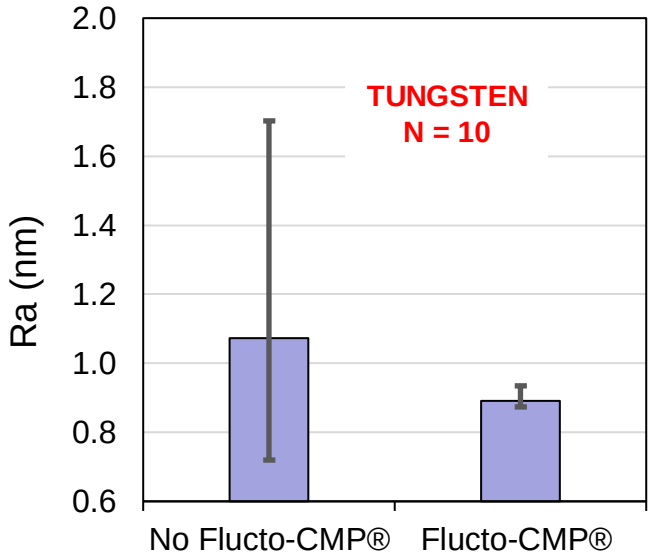
- **We believe that defect reduction – one of the main attractions of our technology – is due to three separate effects as follows:**

  - **Sonic waves break up agglomerates. Already proven and patented by Samsung and Micron more than 20 years ago with ultrasonic radiation. The next 2 slides demonstrate the effectiveness of Fluctо-CMP® on a modern-day copper slurry under megasonic waves.**

  - **Megasonic waves increase the concentration of the reactive oxidizing species and result in the formation of a softer passivation layer in which BTA and other molecules are non-covalently bonded on copper. This softer layer gets removed with greater ease compared to the dense covalently-bonded BTA-copper passivation layer in conventional CMP. Proven by AFM results on the penetration depth into the passivation layer under wet conditions. Dynamic electrochemical results also support our claim.**

  - **Lateral and normal vibrations of the carrier-wafer assembly are dramatically reduced (at times by as much as 80X) with Fluctо-CMP® as supported by our real-time shear force and normal force variance results.**

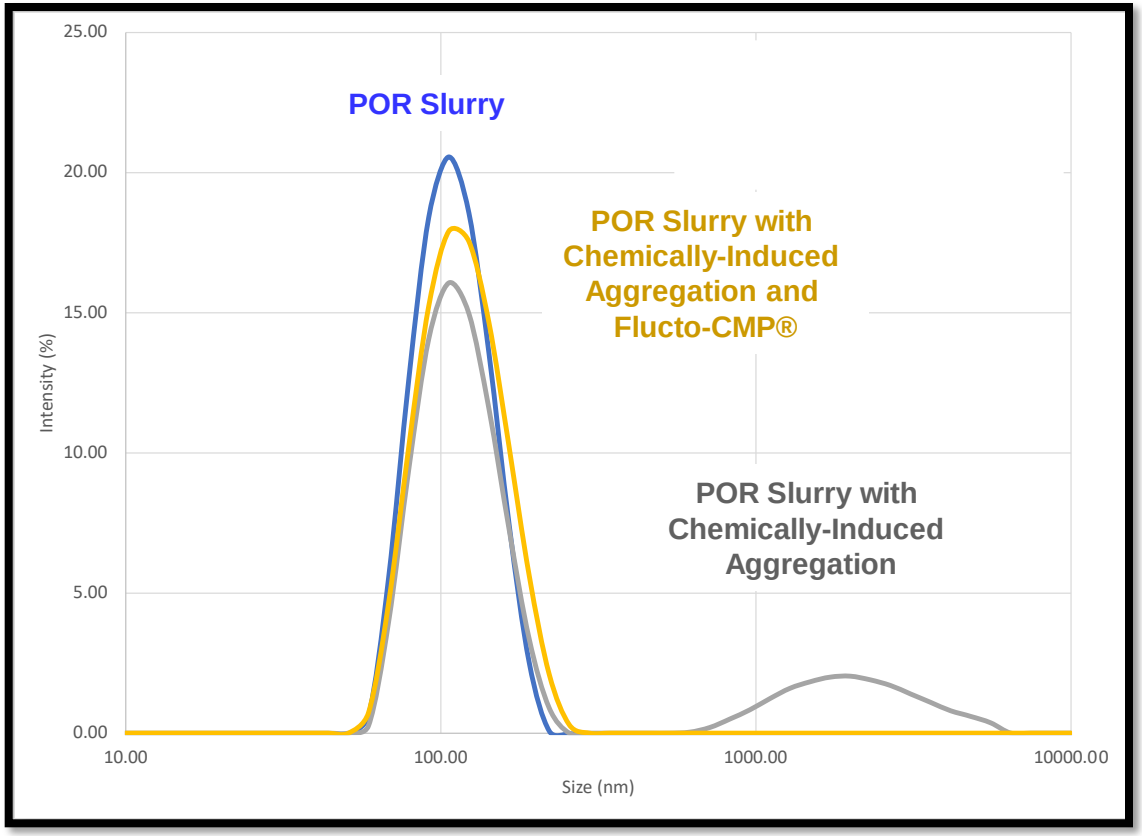




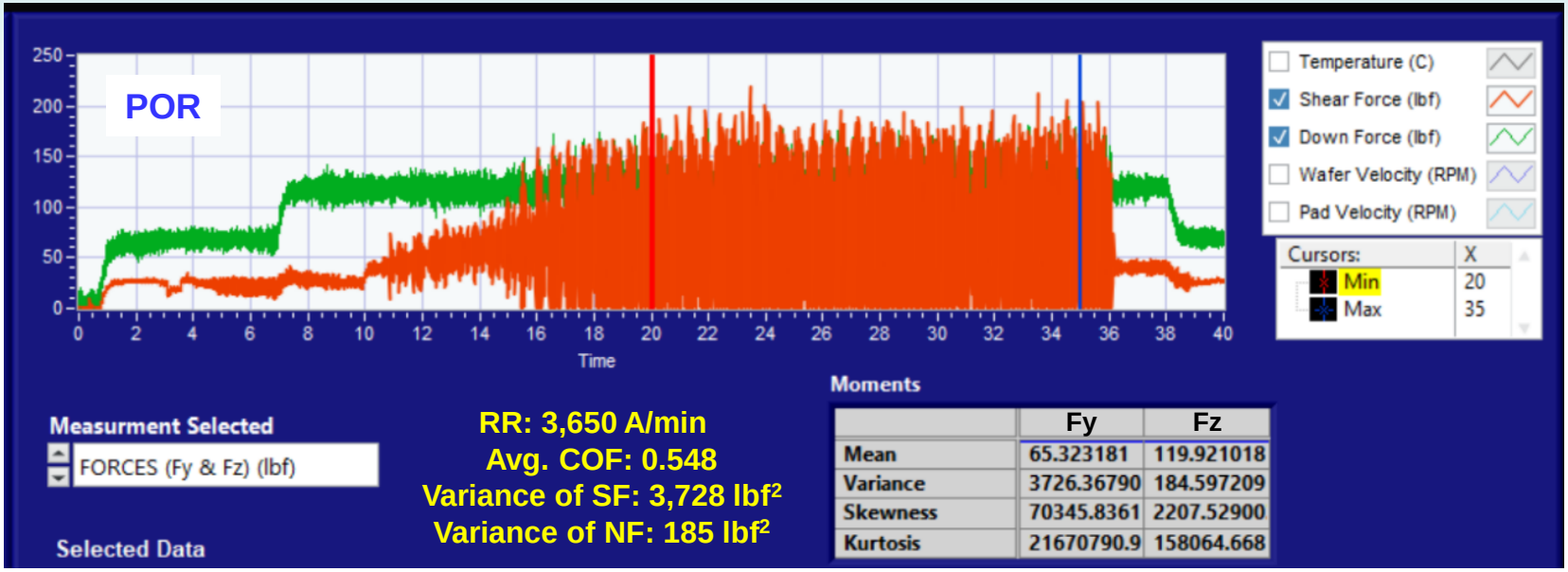
Preliminary Results on Deagglomeration

- **Effect of Flucto-CMP® technology on slurry nano-particle (NP) health in the case of Cu Slurry Supplier A is shown below. We used a Malvern Zetasizer Nano ZS® particle sizing system.**

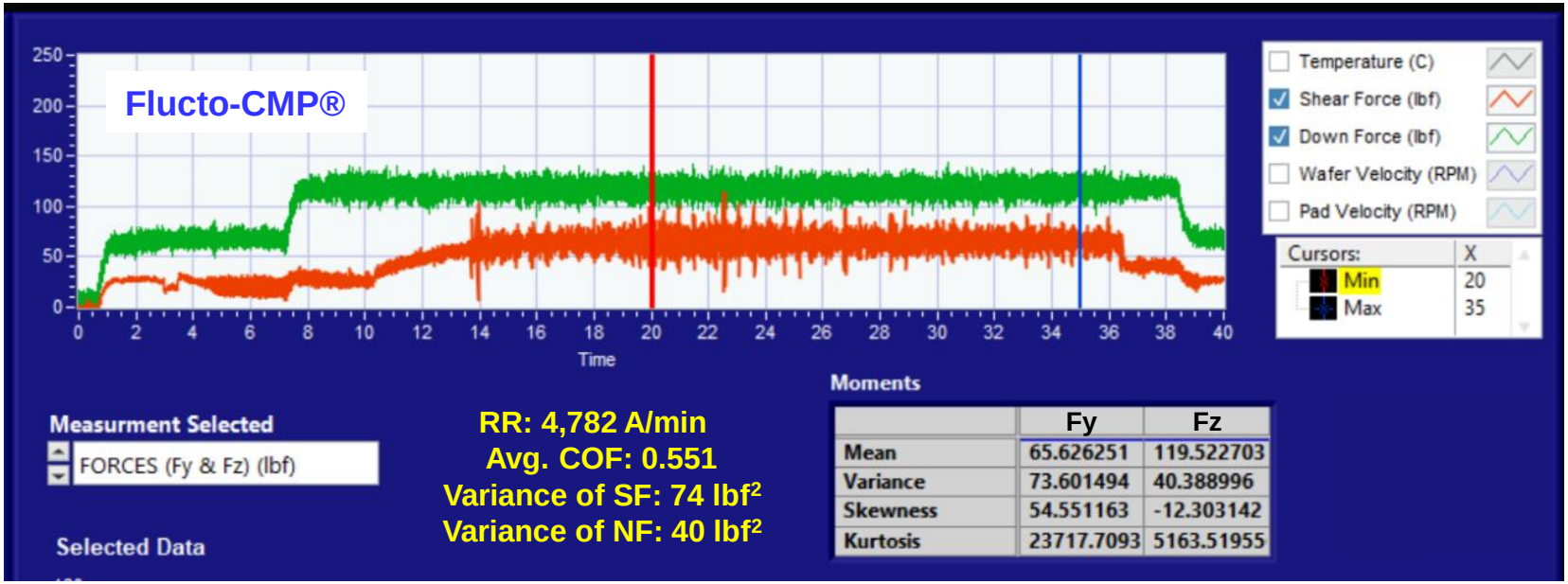
- **Results show that:**
  - ❖ **Our salt-induced NP aggregation method works as many large aggregates are generated in the copper slurry. An average size of 2 microns!**
  - ❖ **Only after 1 minute of exposure to sound waves, Flucto-CMP® restores the highly-aggregated slurry to its original state.**



Time Traces – 1.5 PSI – 1.5 m/s – 1% H2O2

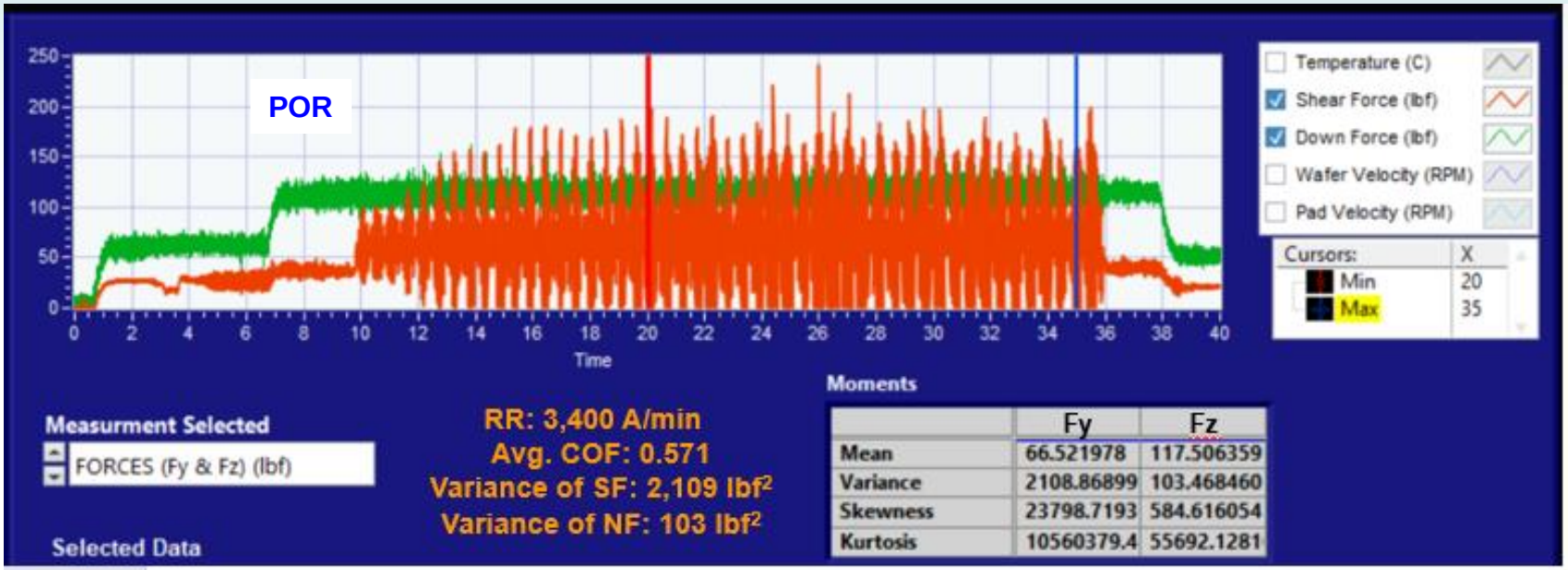


	Fy	Fz
Mean	65.323181	119.921018
Variance	3726.36790	184.597209
Skewness	70345.8361	2207.52900
Kurtosis	21670790.9	158064.668

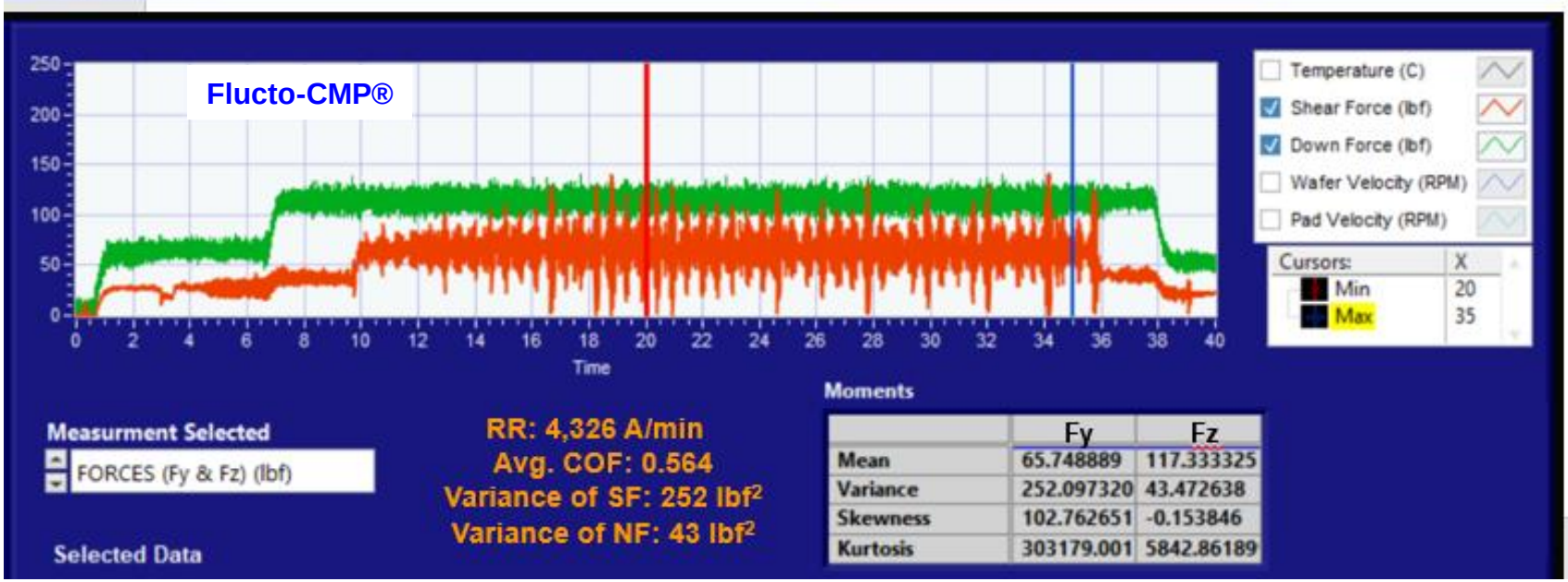


	Fy	Fz
Mean	65.626251	119.522703
Variance	73.601494	40.388996
Skewness	54.551163	-12.303142
Kurtosis	23717.7093	5163.51955

Time Traces – 1.5 PSI – 1.5 m/s – 1.5% H2O2 – Copper Supplier A

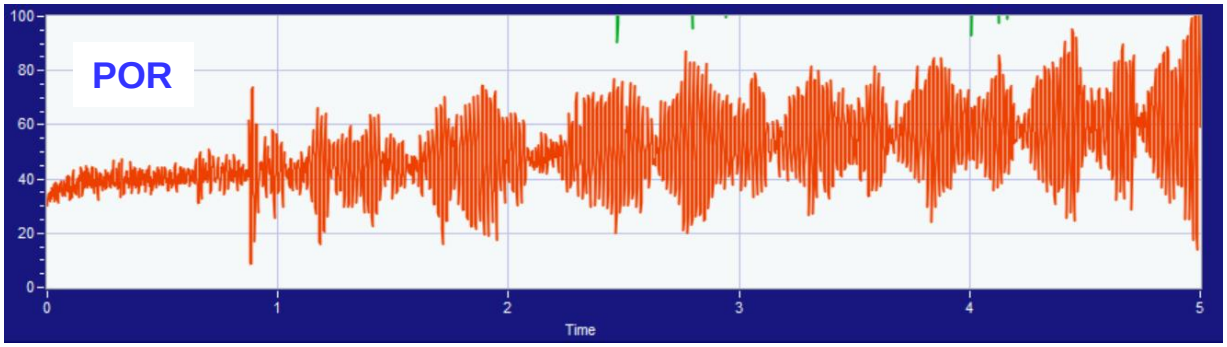


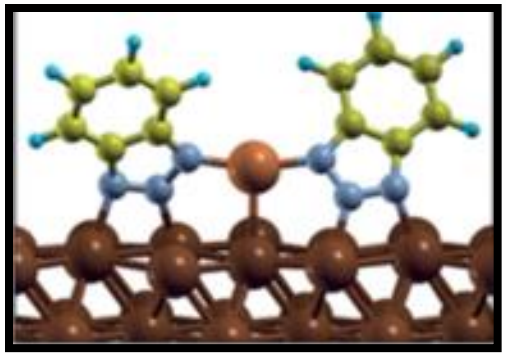
	Fy	Fz
Mean	66.521978	117.506359
Variance	2108.86899	103.468460
Skewness	23798.7193	584.616054
Kurtosis	10560379.4	55692.1281

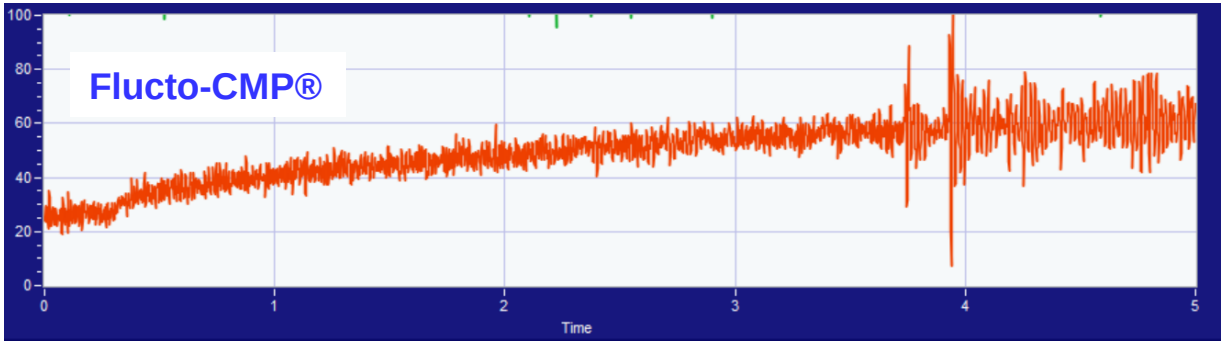


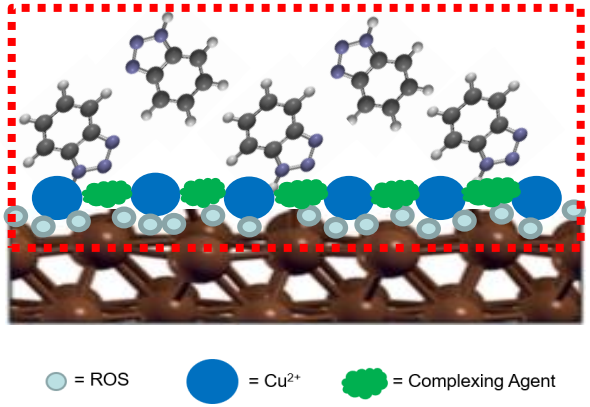
	Fy	Fz
Mean	65.748889	117.333325
Variance	252.097320	43.472638
Skewness	102.762651	-0.153846
Kurtosis	303179.001	5842.86189

Interfacial Effects with Cu^{+} – Coordinated Dense BTA Passivation Film?



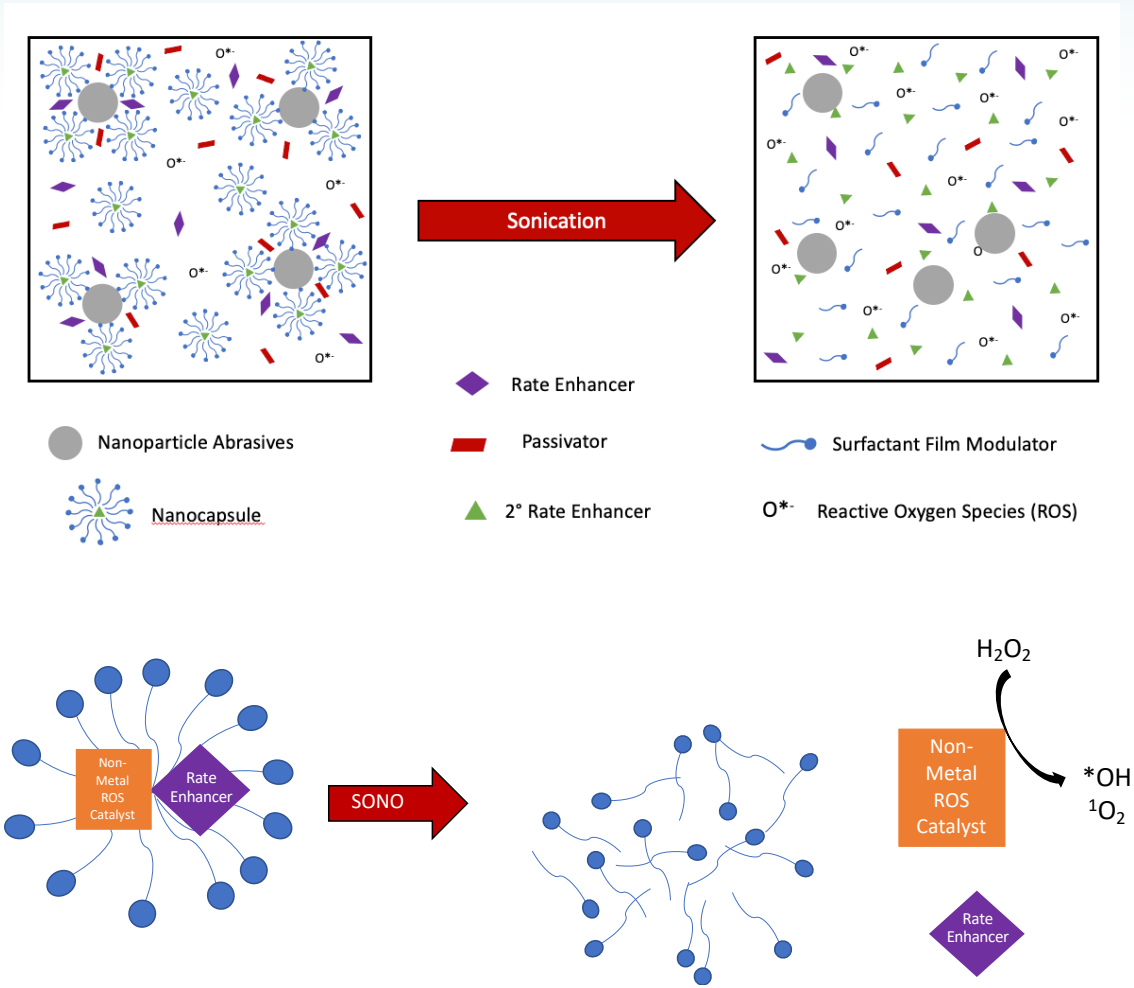






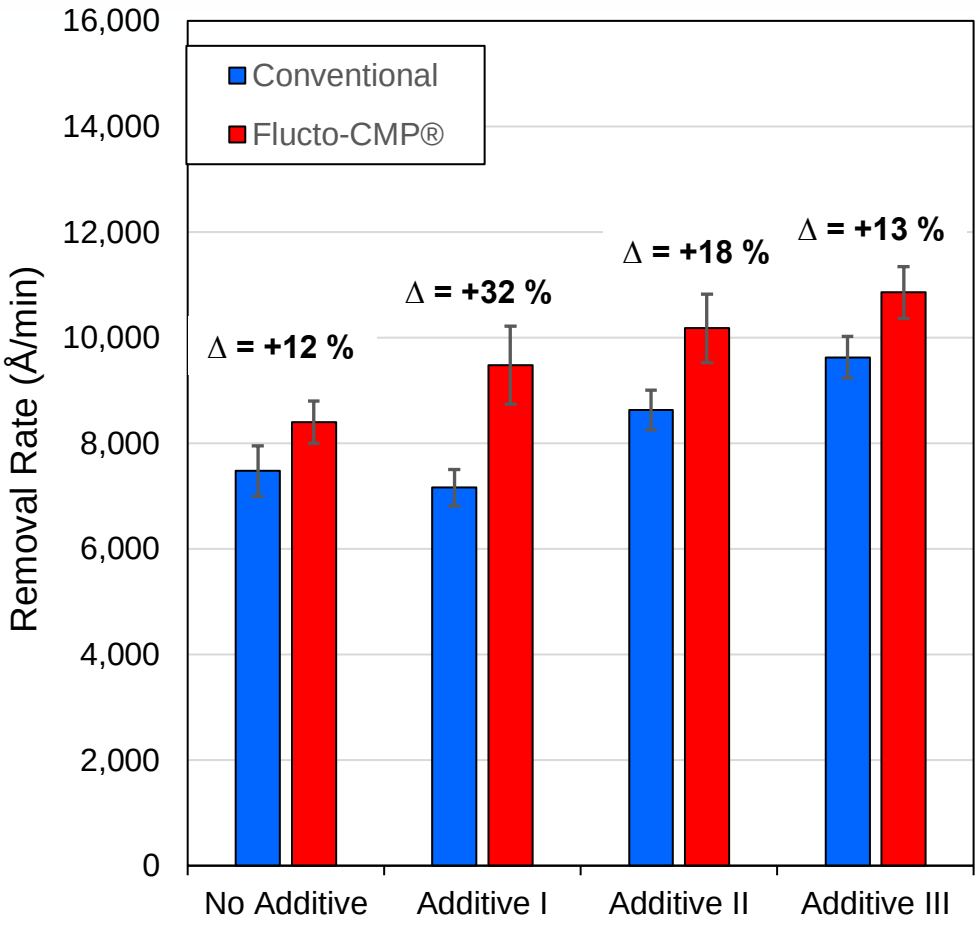
Development of Sono-Activated® Additives

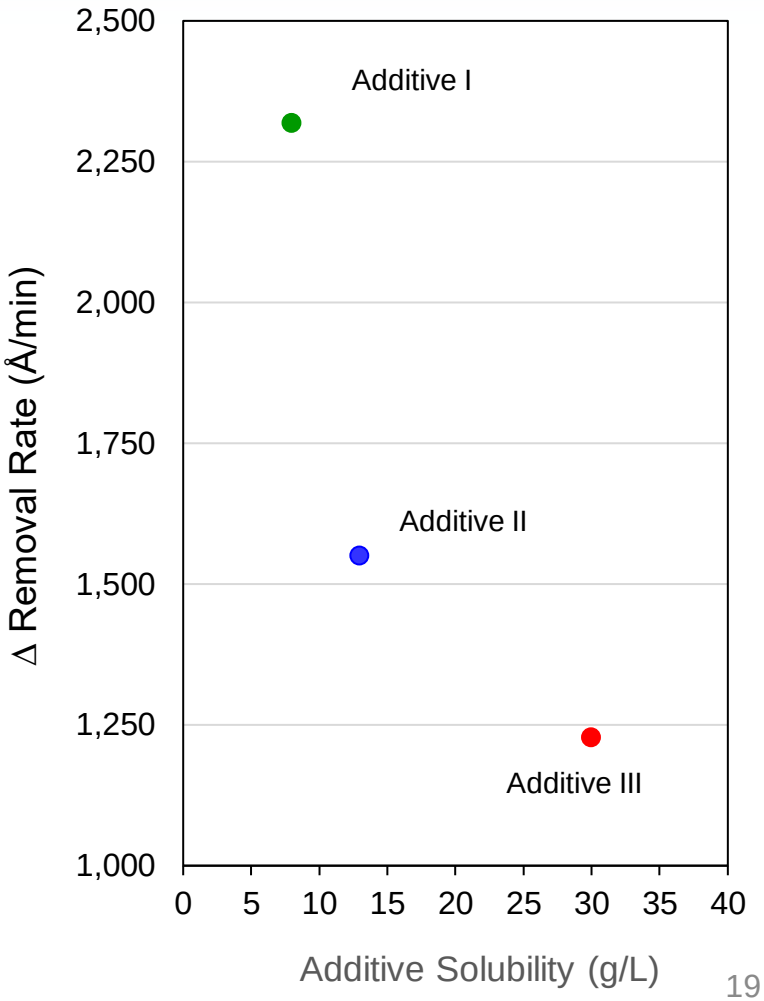
- **DROP-IN and RE-FORMULATION approaches will be employed to modulate passivation film density (i.e., nature, hardness, and chemical activity).**
- **While some PV and temperature response is likely, the chemical activity and film formation mechanism will be initiated by the release of the additives from sonication, and not from slurry heating or shear force at the pad-wafer interface.**
- **While controlling or modulating ROS is one factor, it is the synergy between the redox and complexation mechanisms that will alter the nature of the surface film resulting in SOFTER and more productive CMP processes.**



Addition of Sono-Activated® Additives to Cu Supplier A Slurry

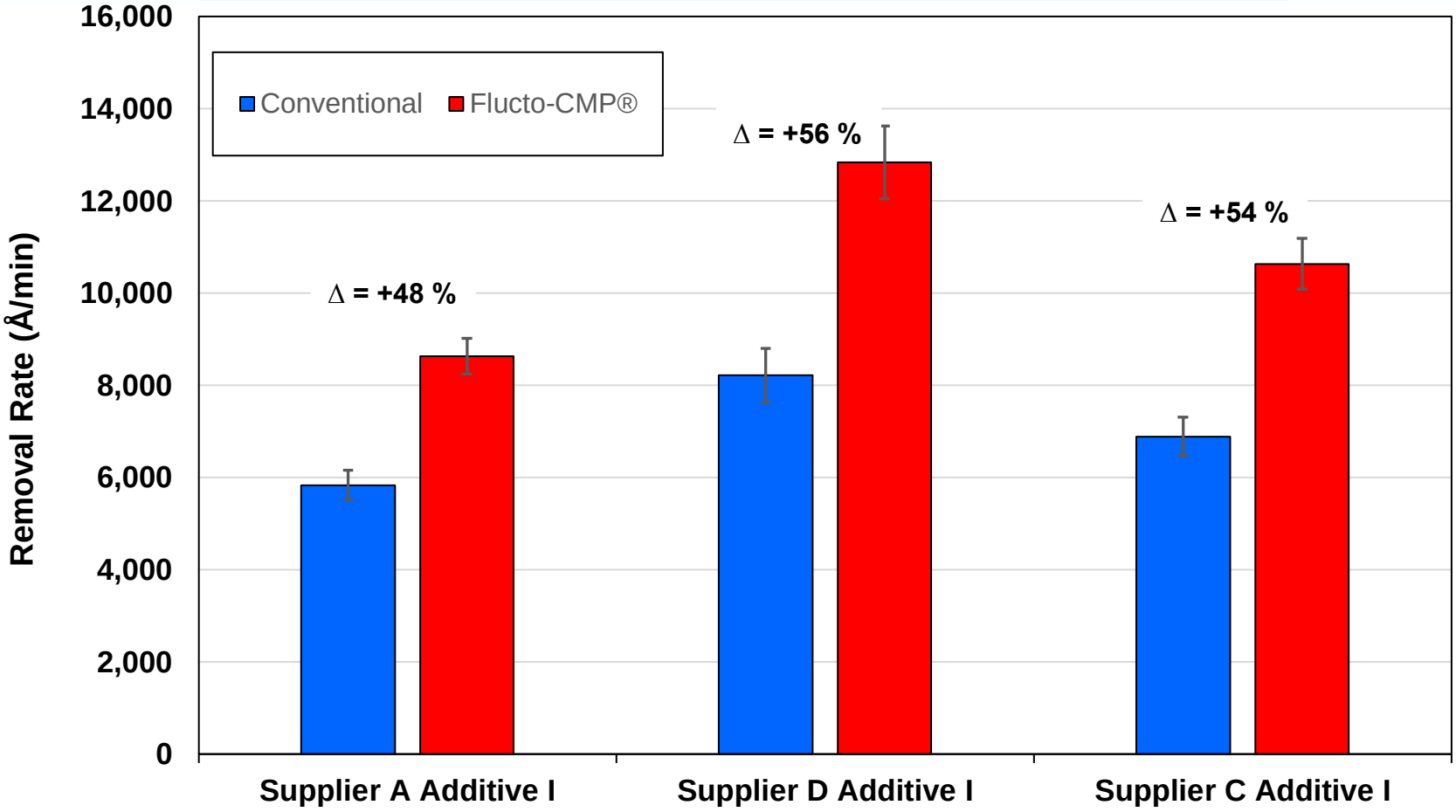
N = 8 wafers
Polishing Pressure= 3.0 PSI
Cu Supplier A
Flucto-CMP® at 1 W/cm²



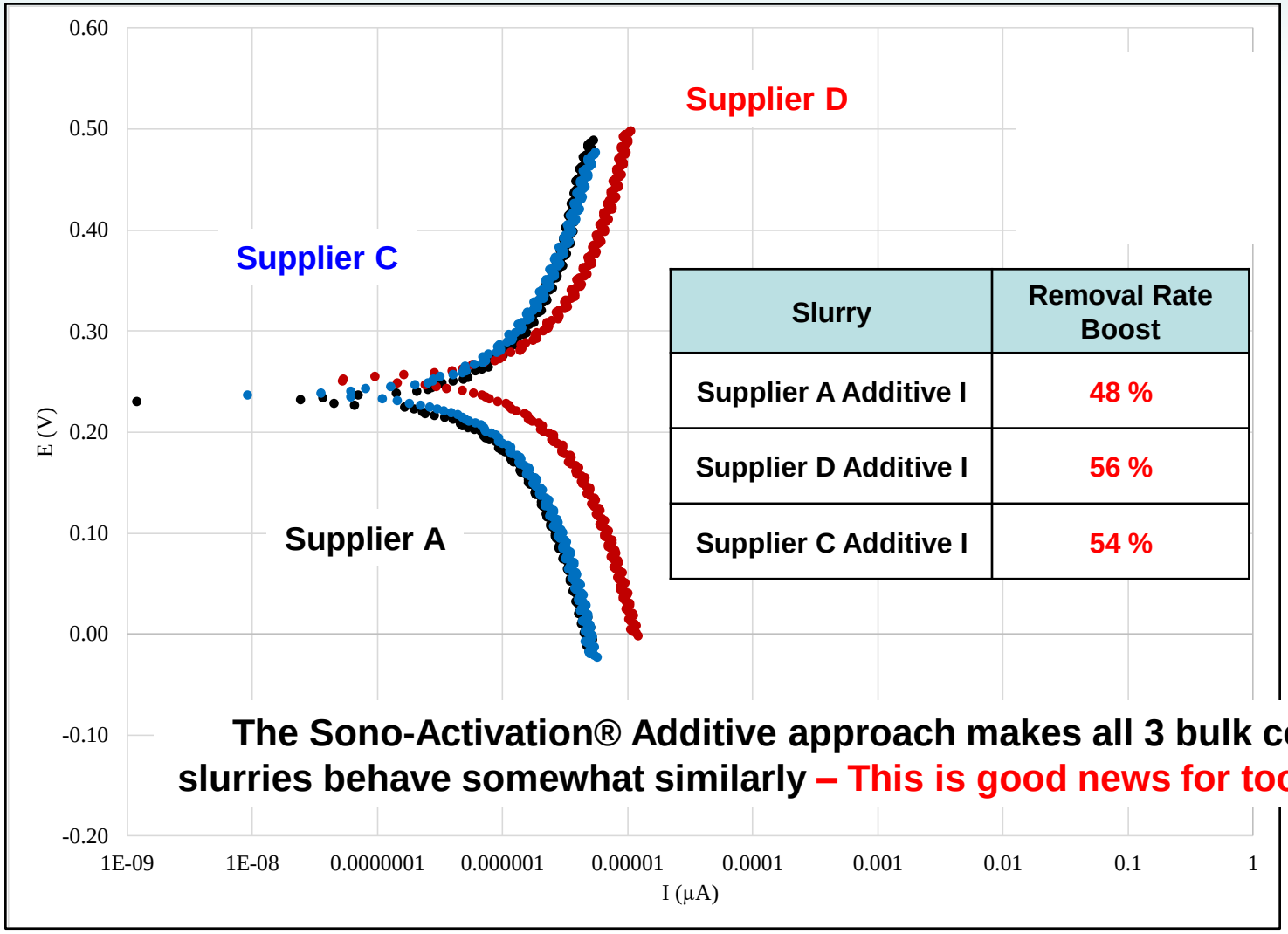


Effect of Sono-Activated® Additive on 3 Slurries

N = 8 wafers
Polishing Pressure = 3.0 PSI
All slurries were diluted as per manufacturer's specification
Flucto-CMP® at 1 W/cm²



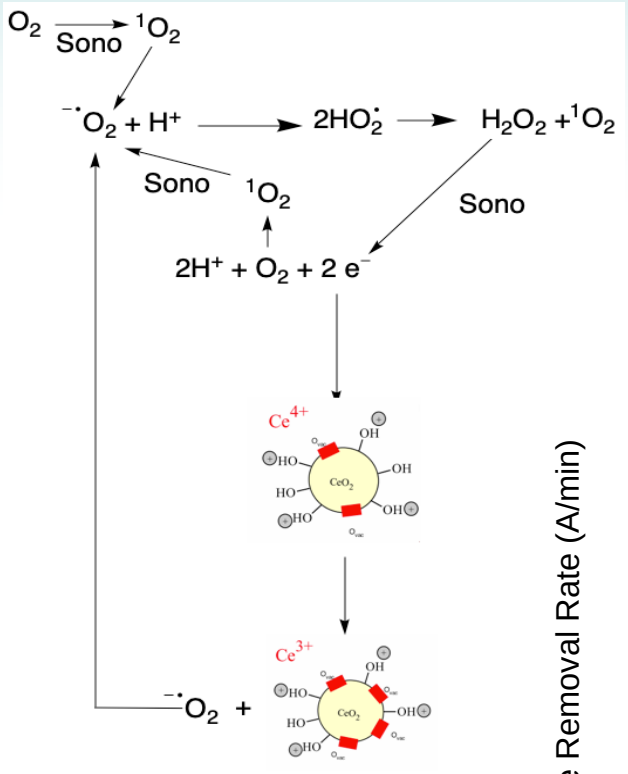
Film Formation Kinetics with Sono-Activated® Additive Approach

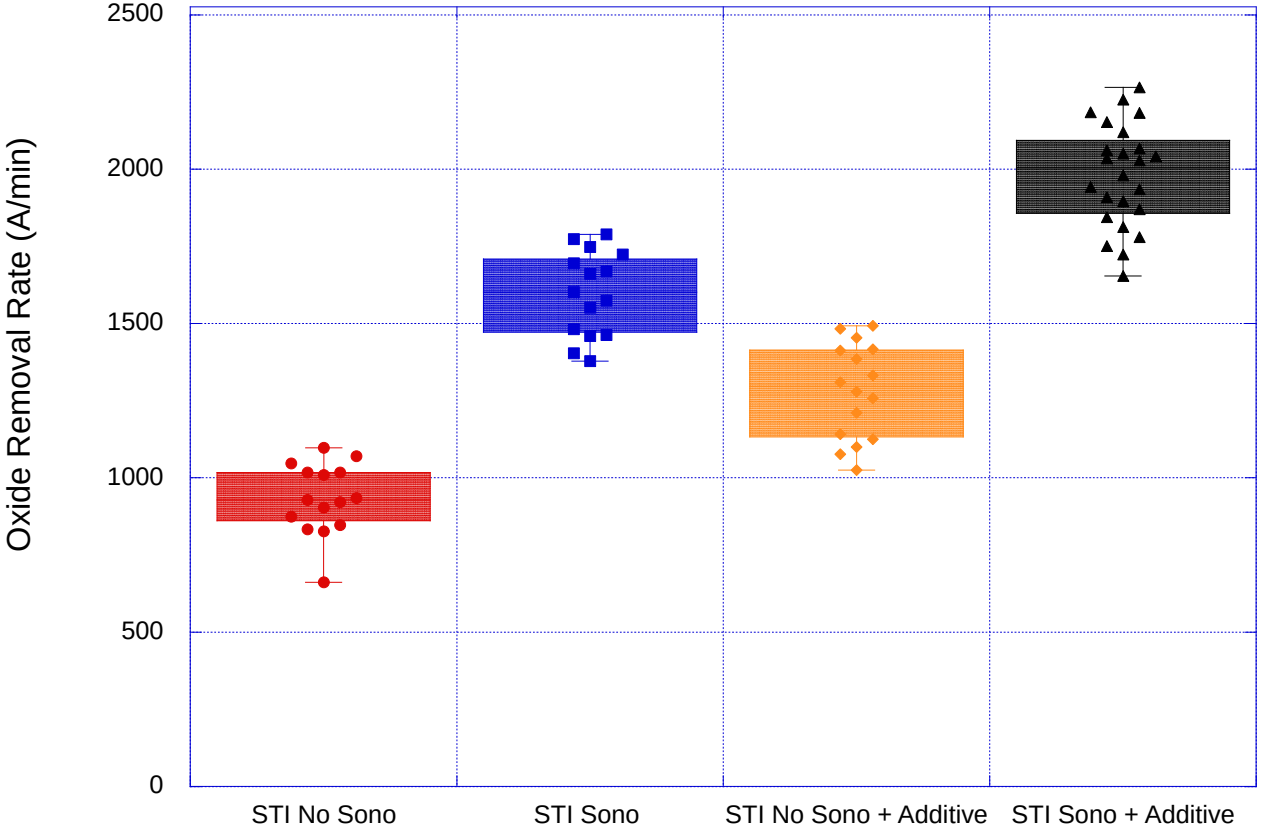


Slurry	Removal Rate Boost
Supplier A Additive I	48 %
Supplier D Additive I	56 %
Supplier C Additive I	54 %

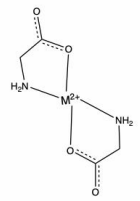
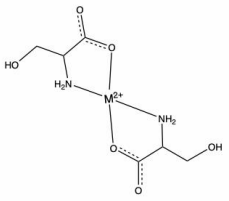
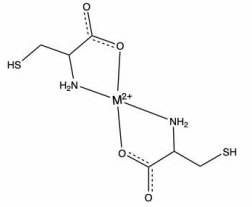
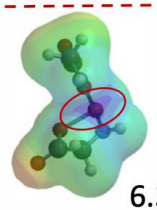
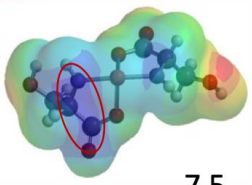
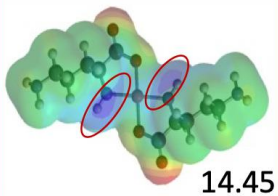
The Sono-Activation® Additive approach makes all 3 bulk copper slurries behave somewhat similarly – This is good news for toolmakers!

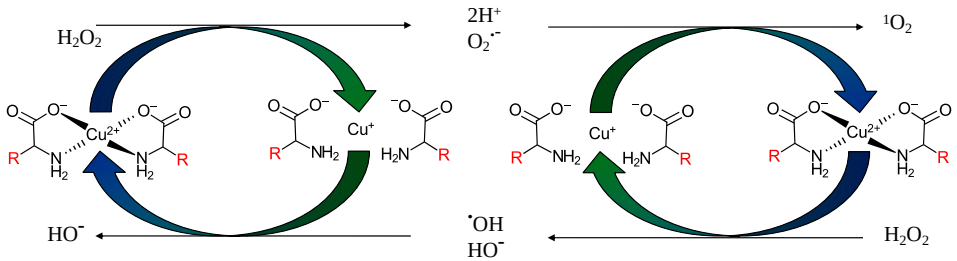
Flucto-CMP® Range of Applications – STI

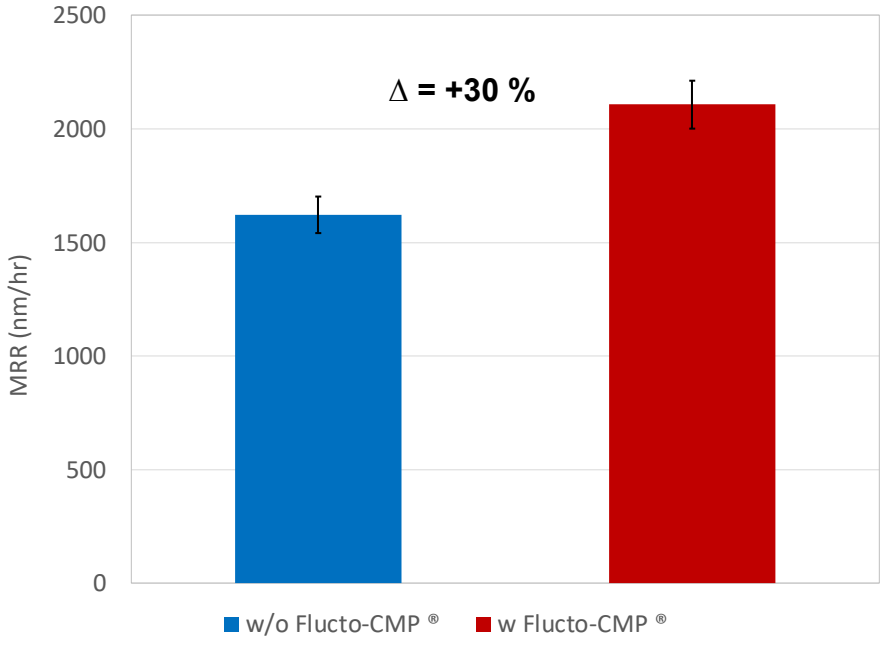




Flucto-CMP® Range of Applications – Non-$KMnO_4$ SiC CMP

			
log β	14.9	15.2	22.4
[ROS](x 10^{-14} M)	1.84	2.0	3.4
Potential Map E^+ Area (Å^2)	 6.35	 7.5	 14.45





Thank You!