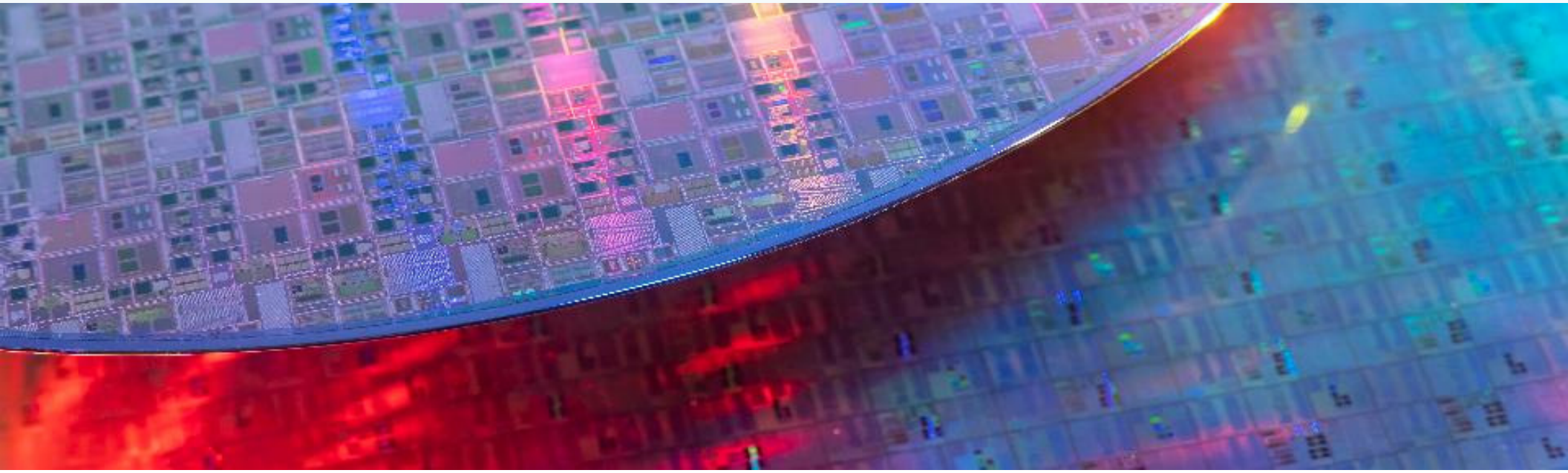
Fluctο-Clean® – A Novel Approach to Post-CMP Cleaning



Ara Philipossian and Yasa Sampurno, (Araca, Inc.)

Jason Keleher (Lewis University)

Traditional PVA Brush Scrubbing

- **PVA brush scrubbing continues to be the *de facto* method for advanced-node post-CMP cleans.**

- **Based on direct contact between a rotating spongy PVA brush and the wafer surface in the presence of certain chemically-active agents.**

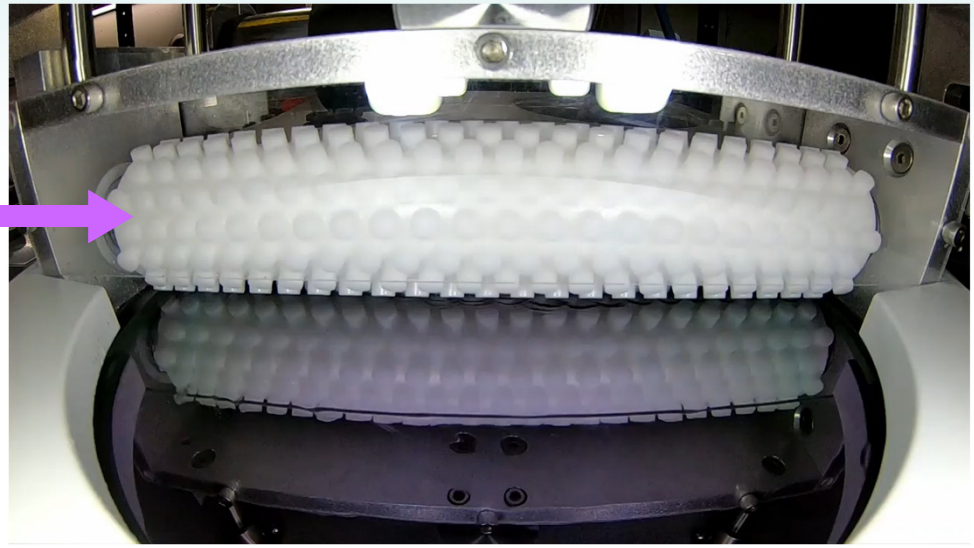
  - **Particle is first chemically "loosened up" from the wafer surface (via passivation layer formation, charge engineering, charge flipping, and shear force management)**
  - **Particle is then adsorbed on brush asperities**
  - **Wafer and brush rotations, and brush pressure, in the presence of a cleaning fluid dislodge and carry the particle away from the wafer surface**
  - **Megasonic agitation is often used for improved PRE – But at the wafer level**

- **Factors like megasonic power at the brush-wafer interface, pressure, tool kinematics, physical and chemical properties of the brush and the cleaning fluid, wafer surface condition, cleaning time, and magnitude of the shear forces are essential for high PRE.**

The NEW Idea Behind Our Patent-Pending Fluctо-Clean®

OPTIONAL
sono-activatable
additive

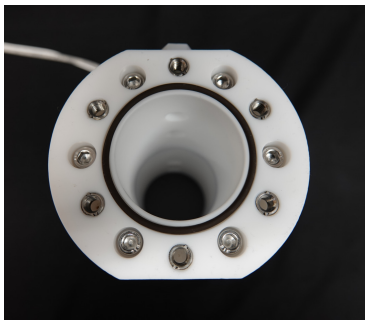
standard post-CMP
cleaning solution

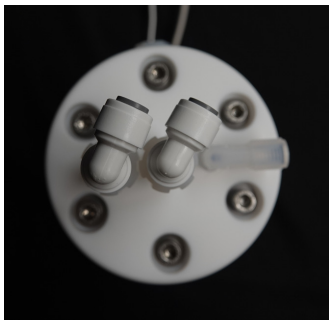


OFF-THE-SHELF
POST-CMP CLEANING
SOLUTION PLUS A
SONO-ACITIVATABLE
ADDITIVE FLOWS
INTO THE
FLUCTO-CLEAN®
REACTOR

MEGASONIC
TRANSDUCER

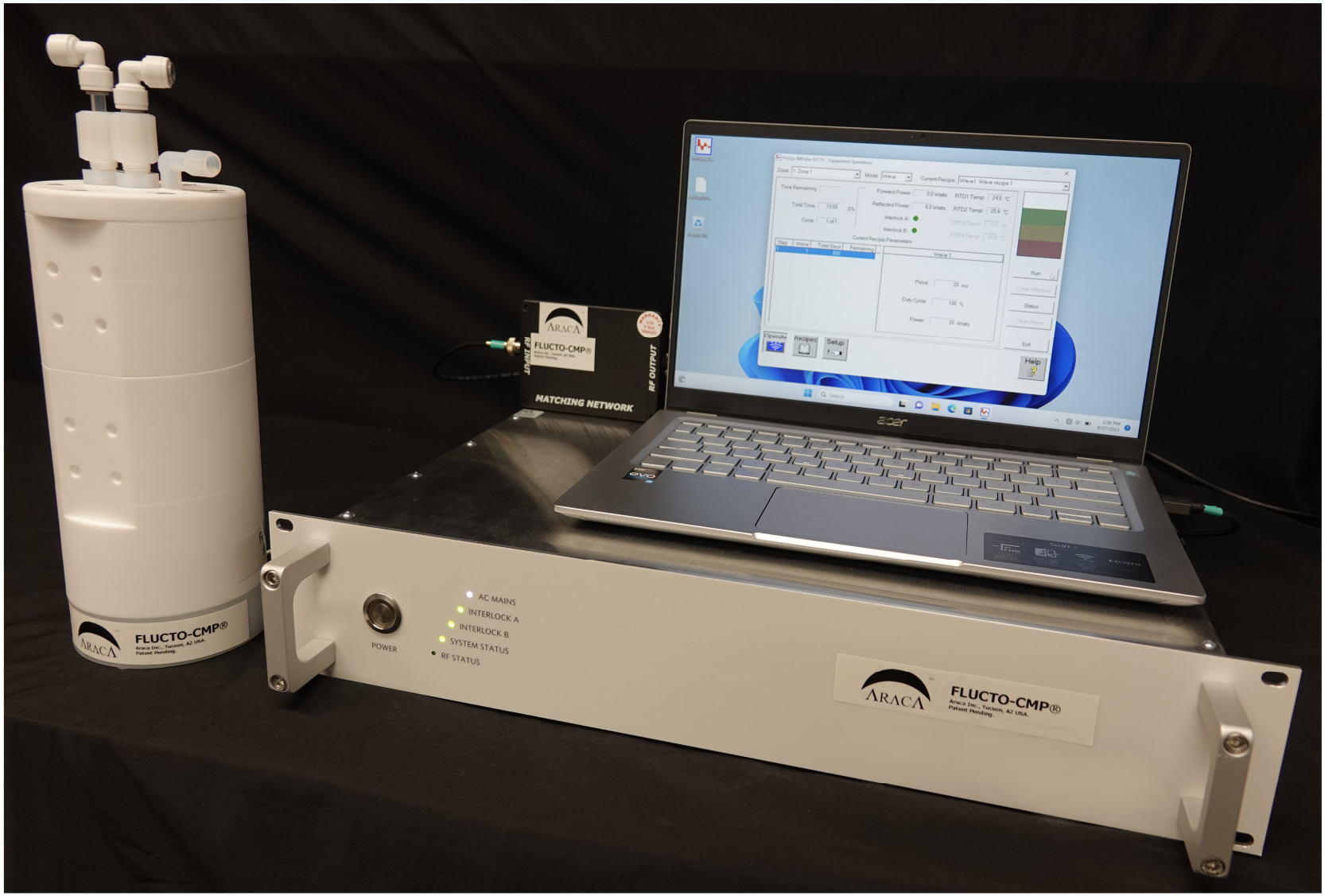
HIGHLY REACTIVE
AND
"JAZZED-UP"
POST-CMP CLEANING
SOLUTION GOES
TO THE
BRUSH SCRUBBER



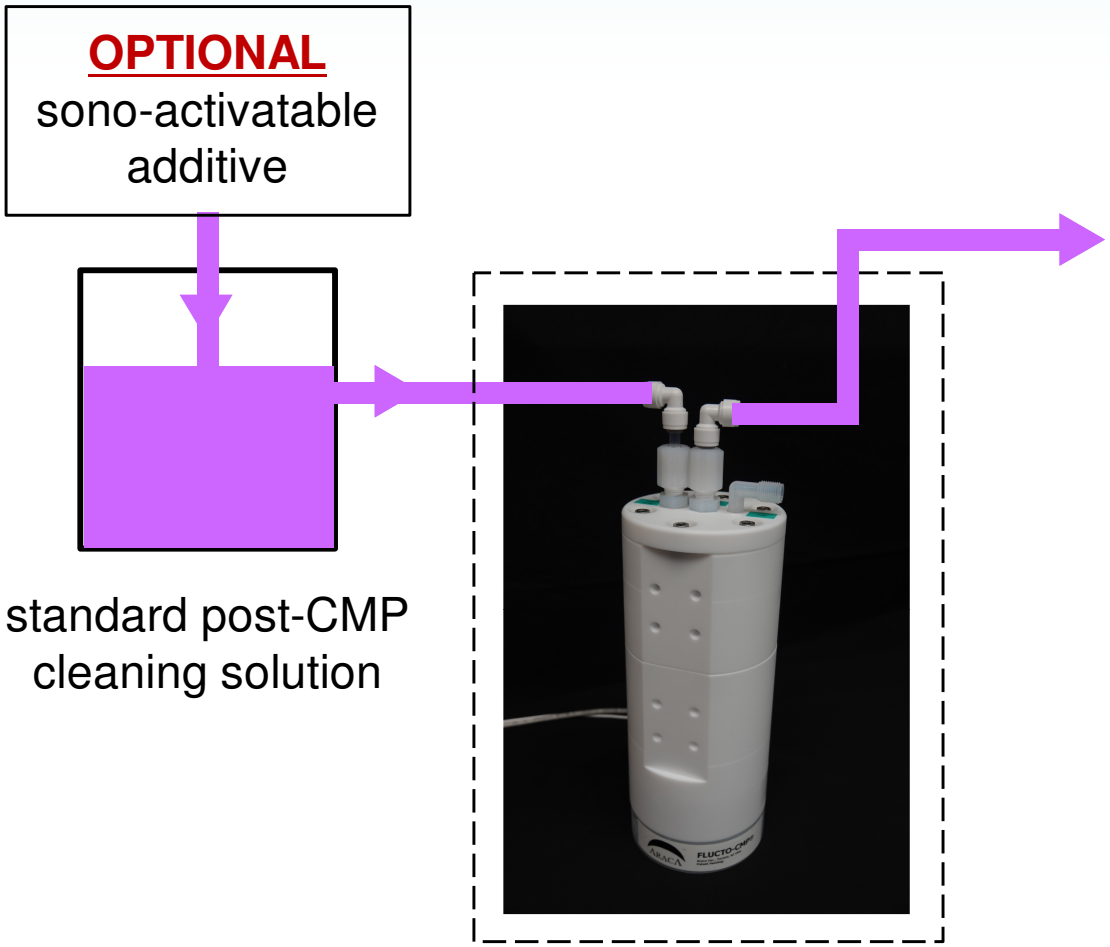


The Patent-Pending Flucto-Clean® System by Araca, Inc.

This system, as well as Flucto-CMP®, are co-developed by ProSys (Campbell, CA USA)



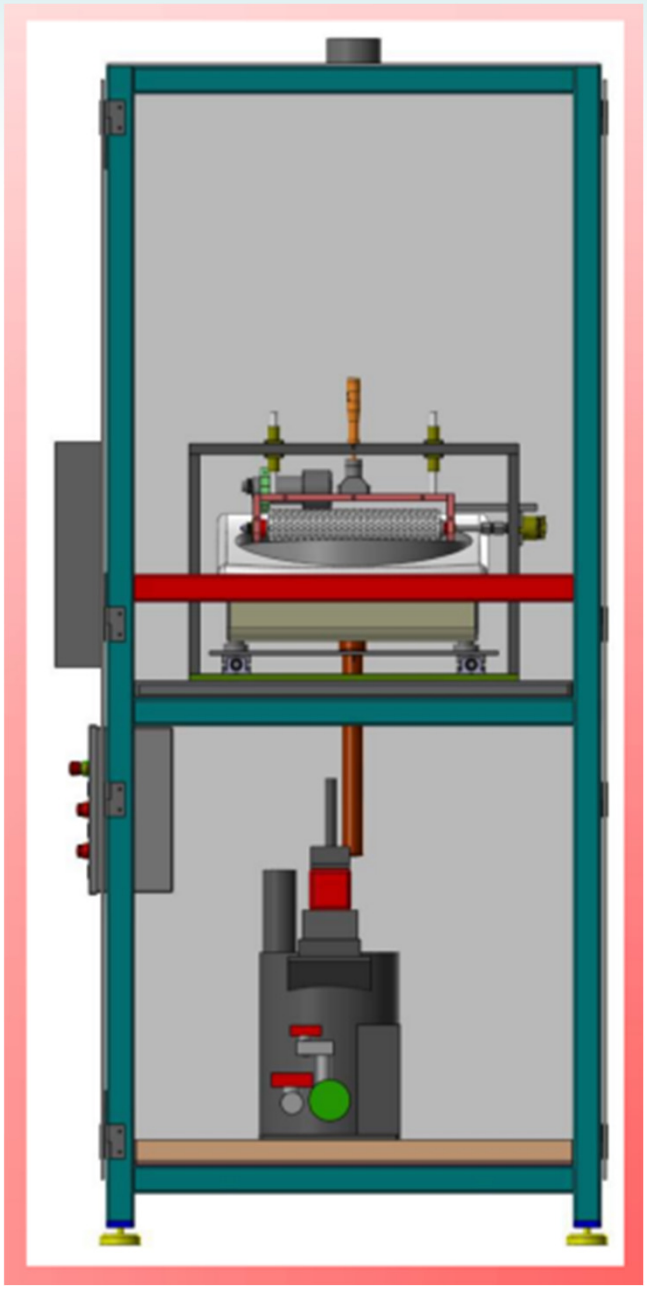
The Idea Behind Fluct-Clean®

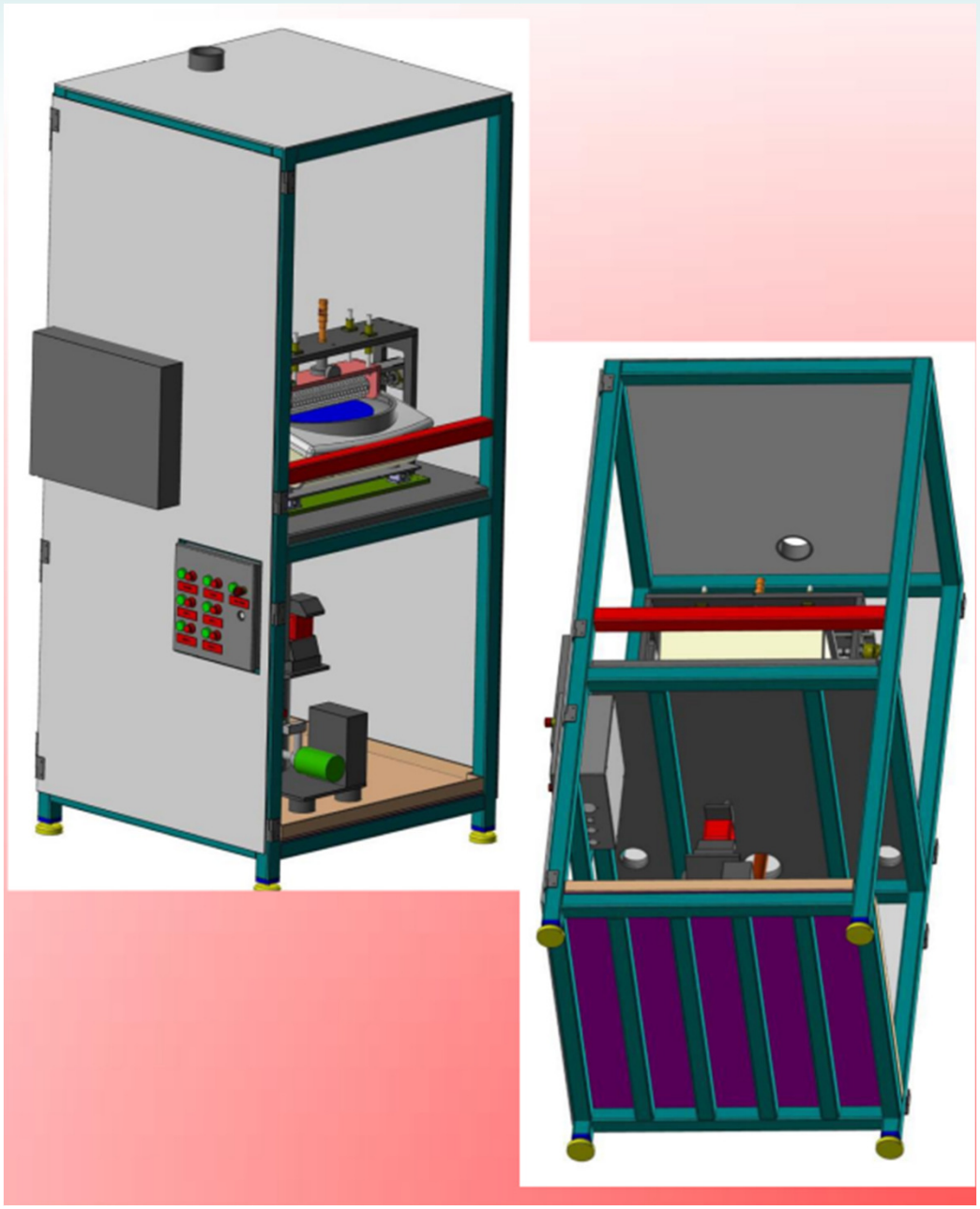


- **Sonication further activates the chemistry of the cleaning solution and helps create myriad reactive oxidizing species (ROS).**
- **Dissolved oxygen (DO) in the cleaning solution is enough to initiate the reaction.**
- **See proposed mechanism – Slides 12 and 13.**

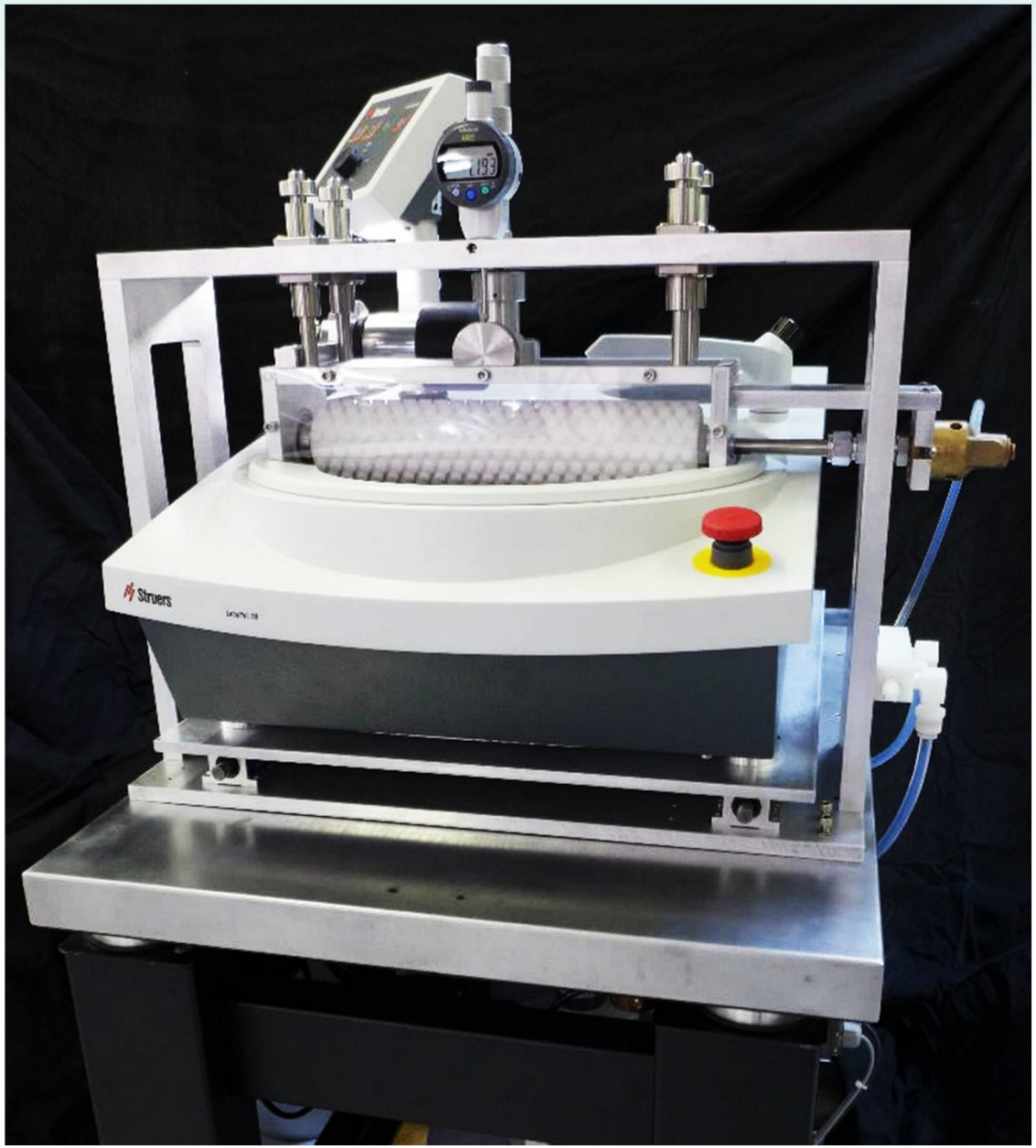
- **With optional sono-activatable additives, one can control the release of more reactive species which will enhance interfacial kinetics and thermodynamics.**
- **This results in lower shear forces and an improved particle removal efficiency (PRE).**
- **See proposed mechanism – Slides 16 to 18.**

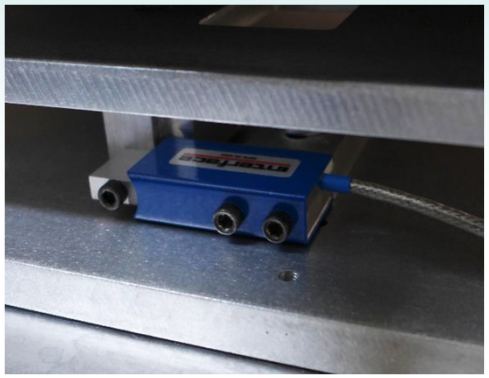
The Araca PCC-300® PVA Scrubber and Tribometer

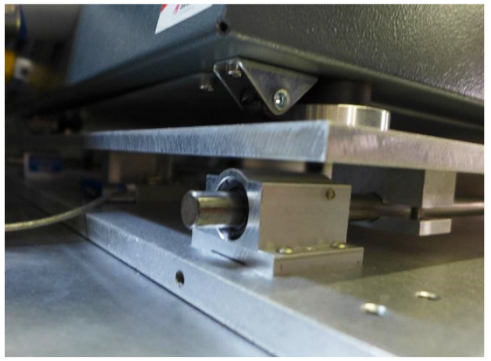


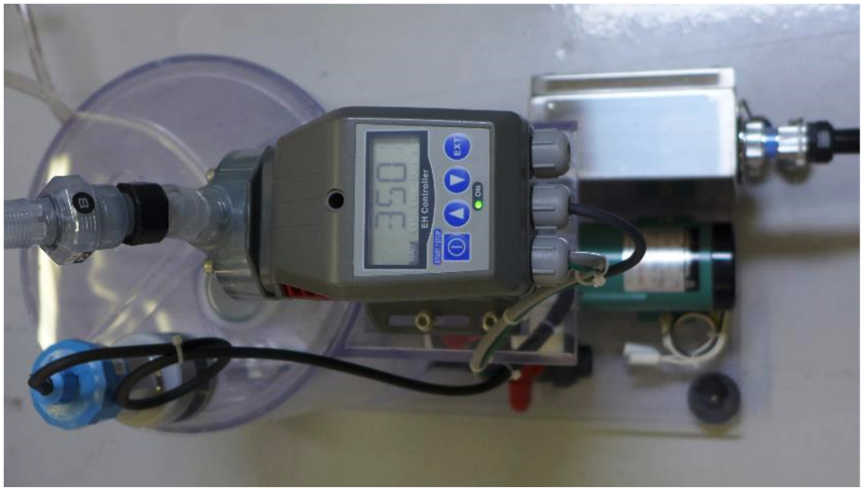


The Araca PCC-300® PVA Scrubber and Tribometer

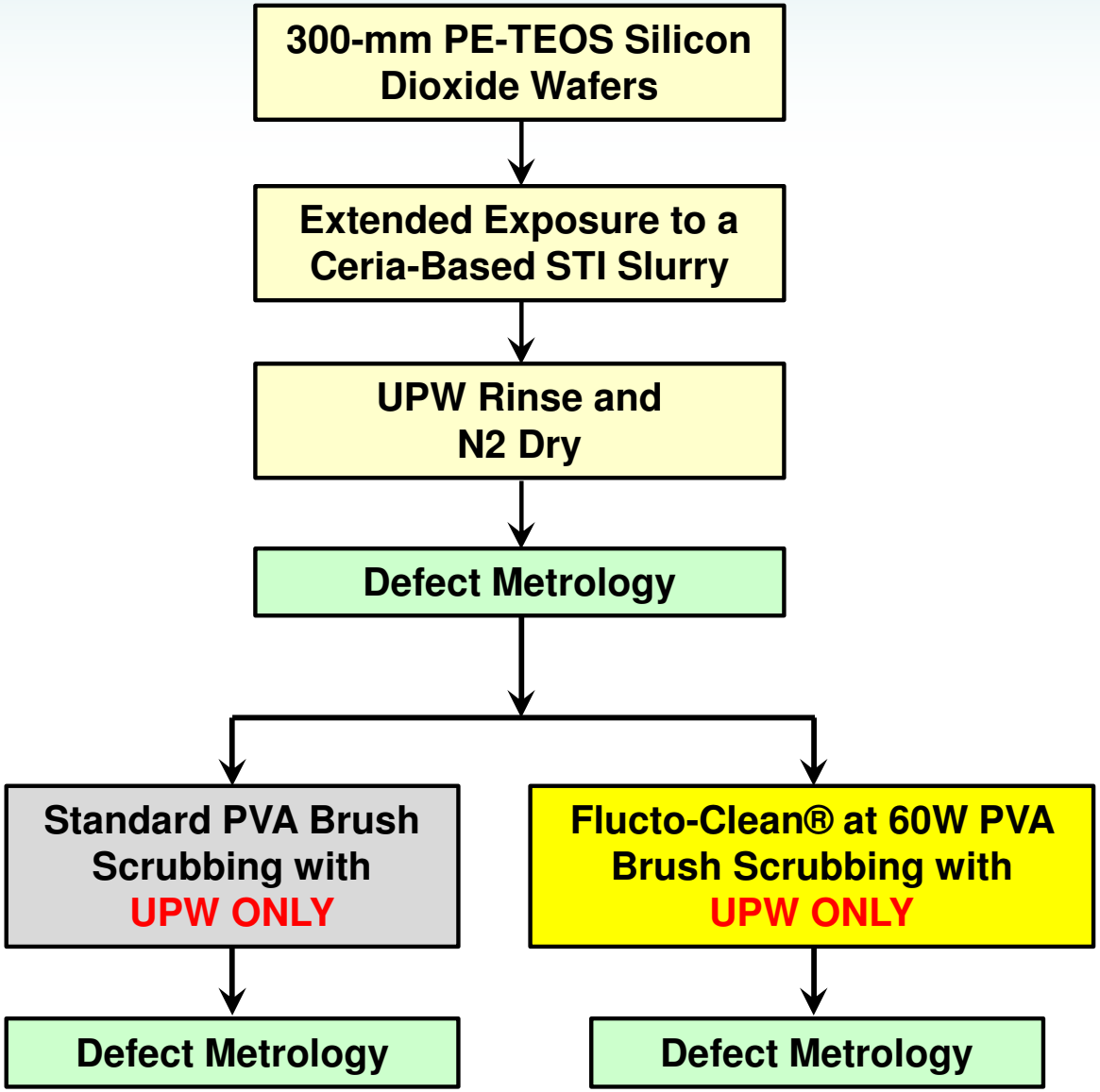




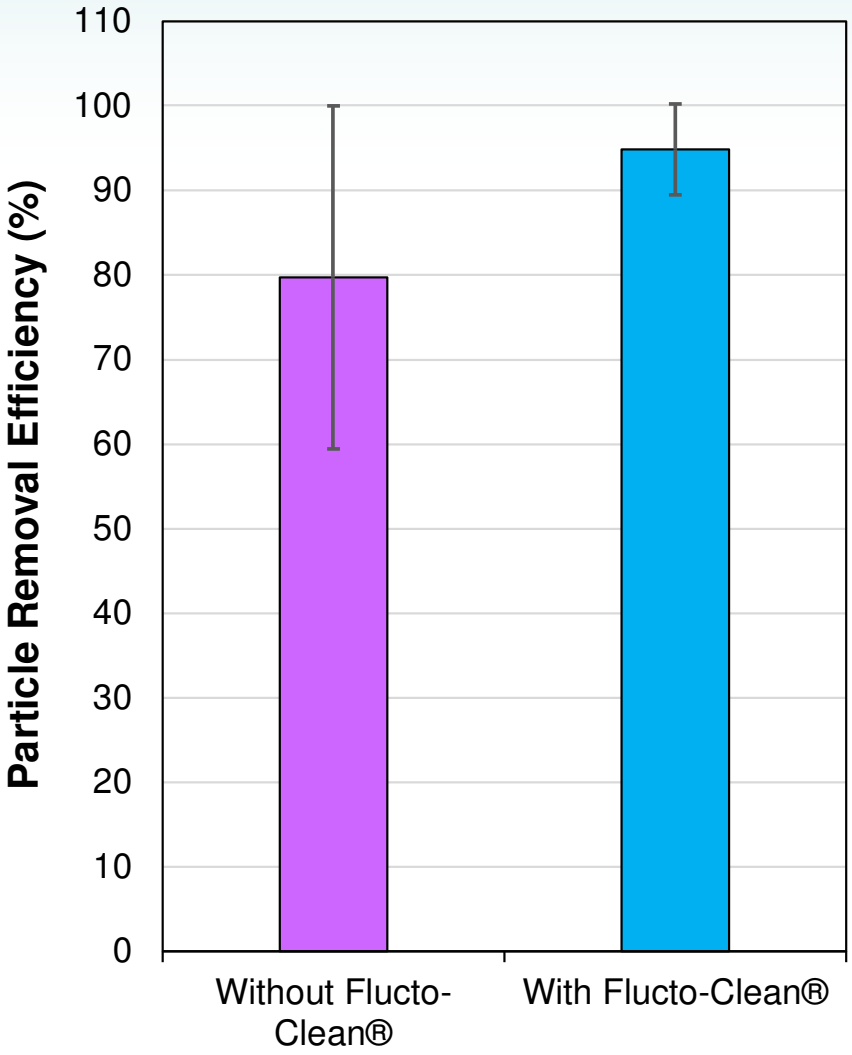


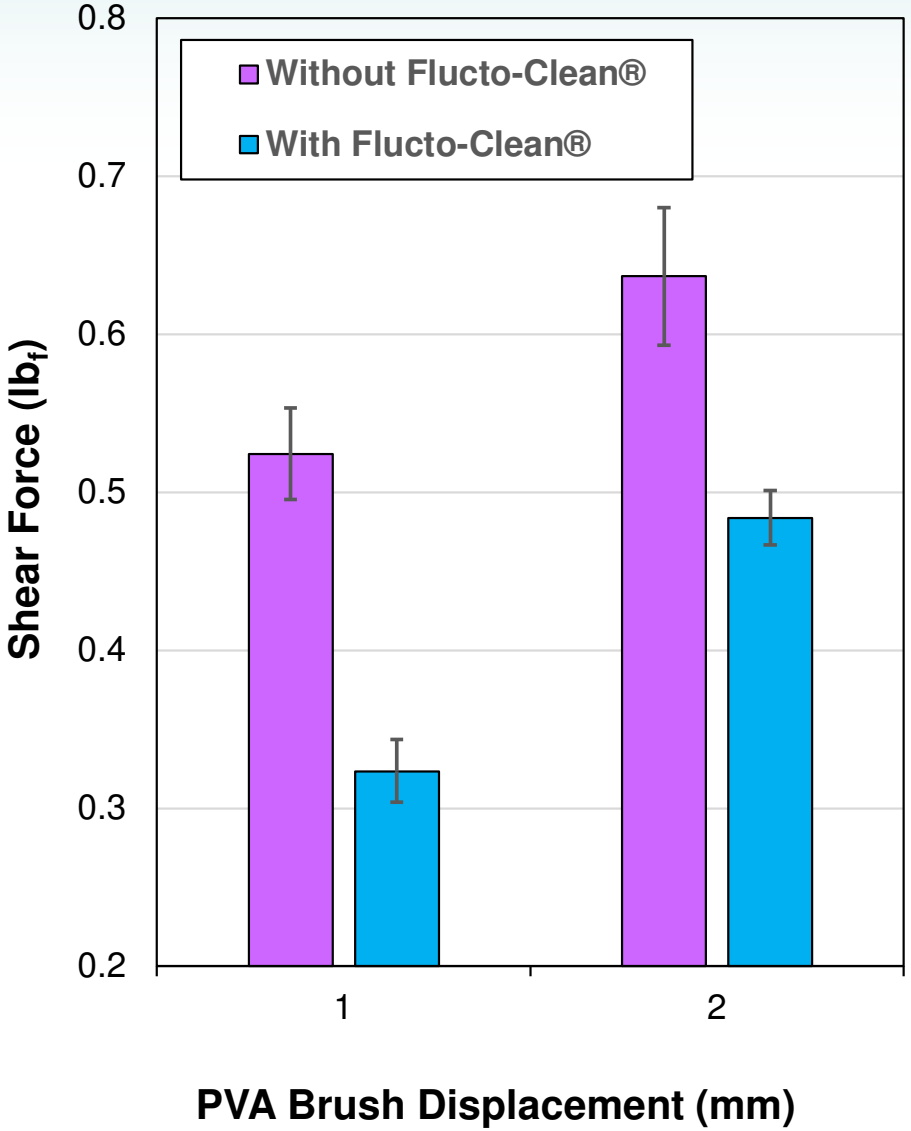


Example 1 – post-STI-CMP Ceria NP Removal

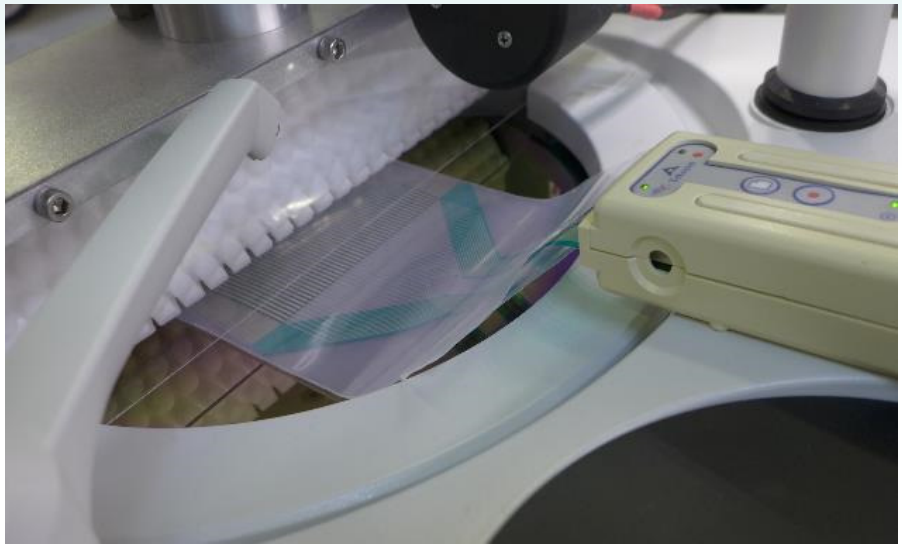


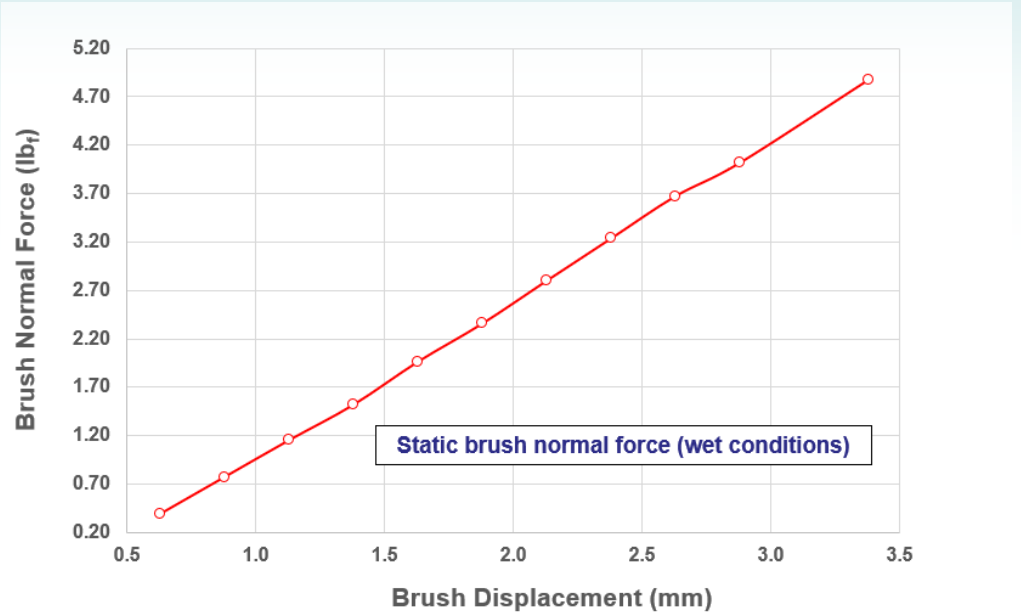
Example 1 – Ceria NP Removal Efficiency and Shear Forces

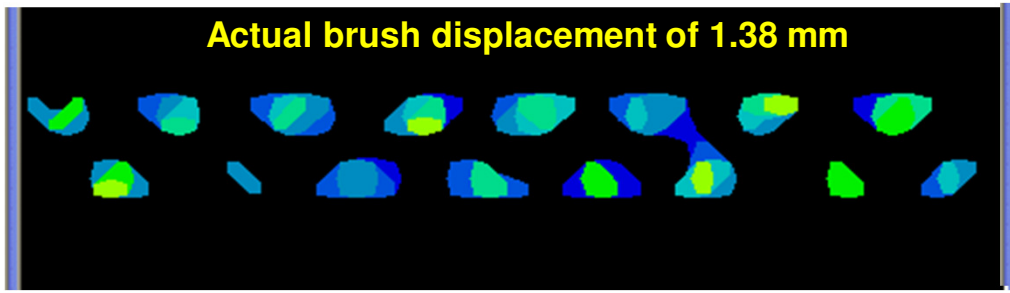


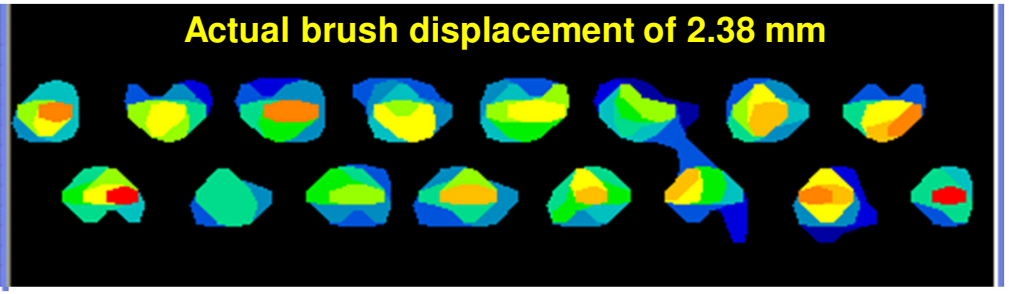


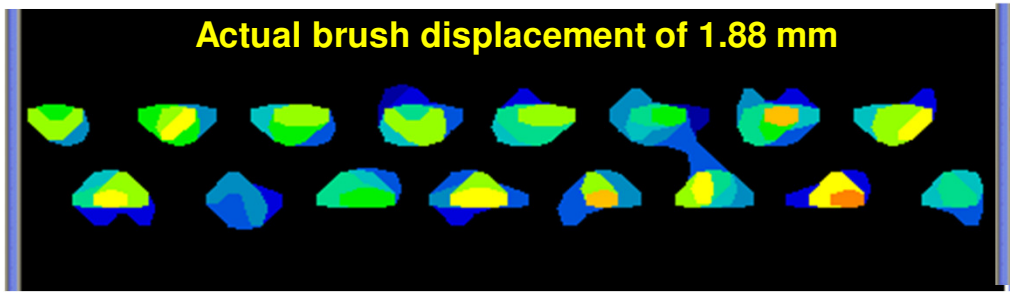
The Tekscan® Pressure Sensor

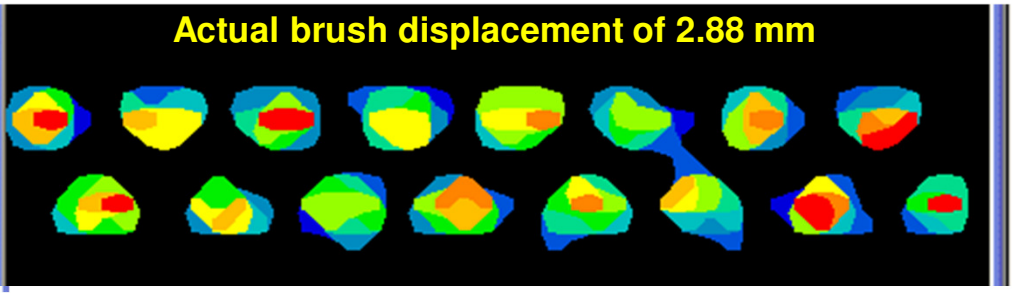






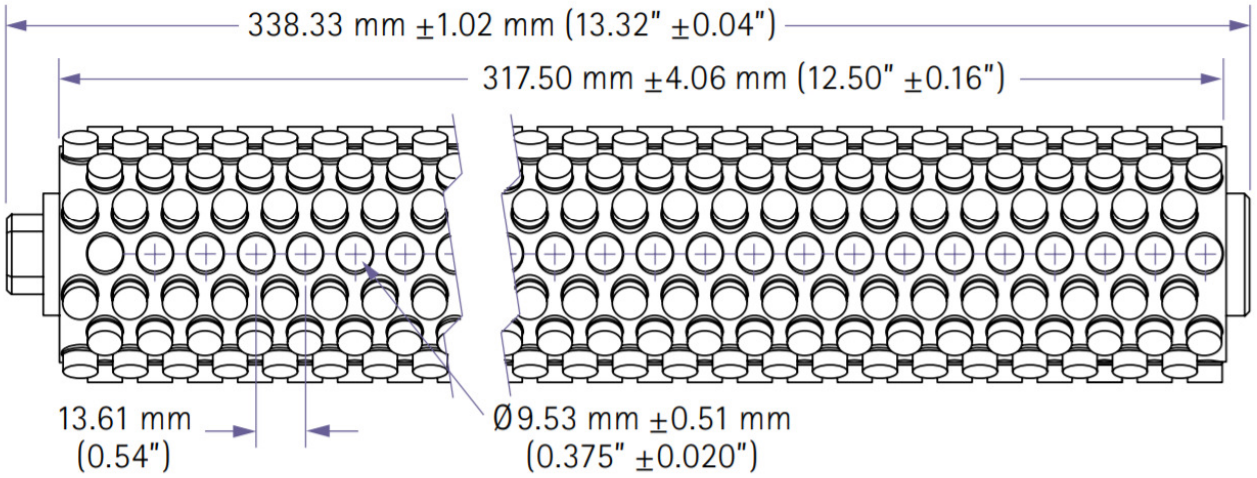


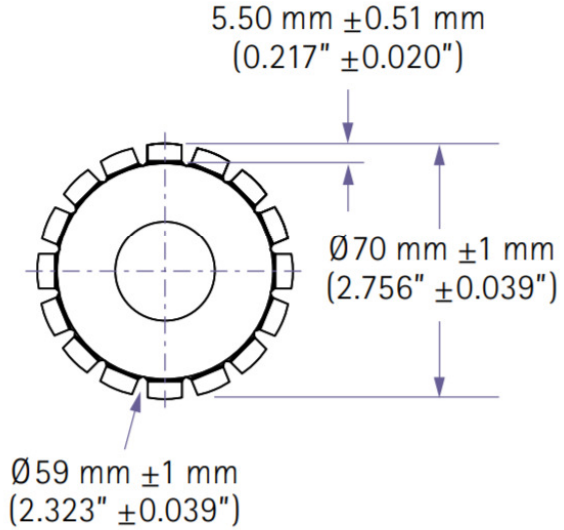


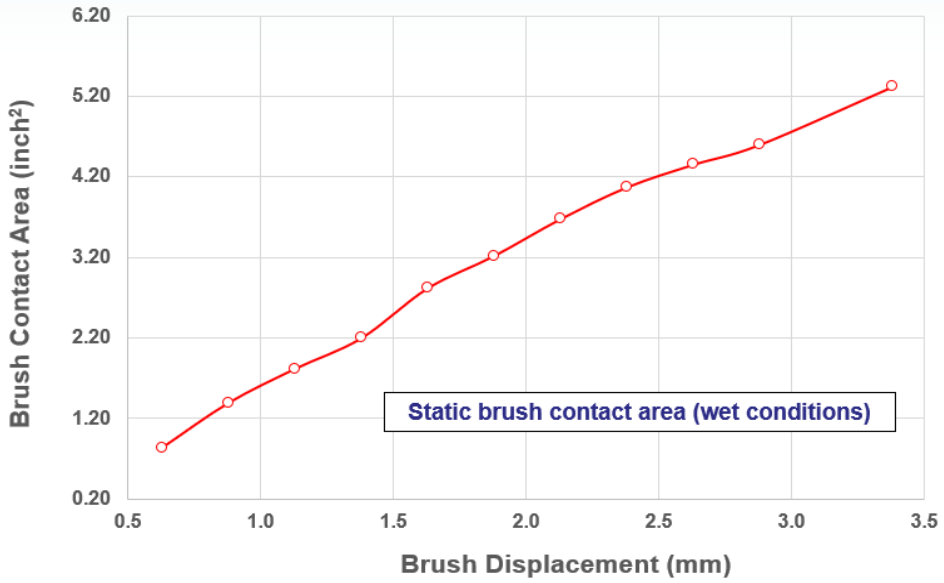


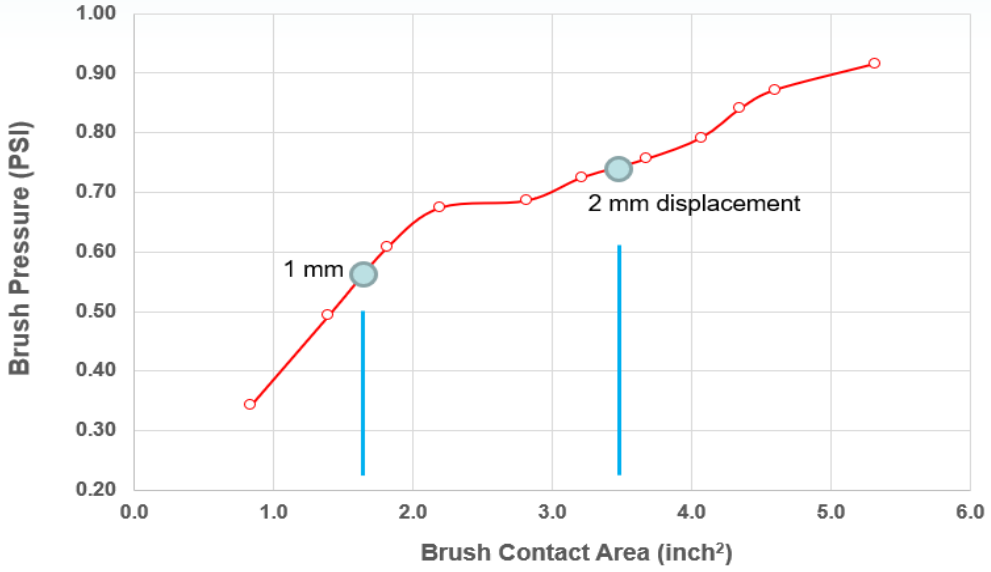
Area – Pressure – Displacement Relationships

PVP1ARXR1 and PVP0ARXR1 Planarcore Brush

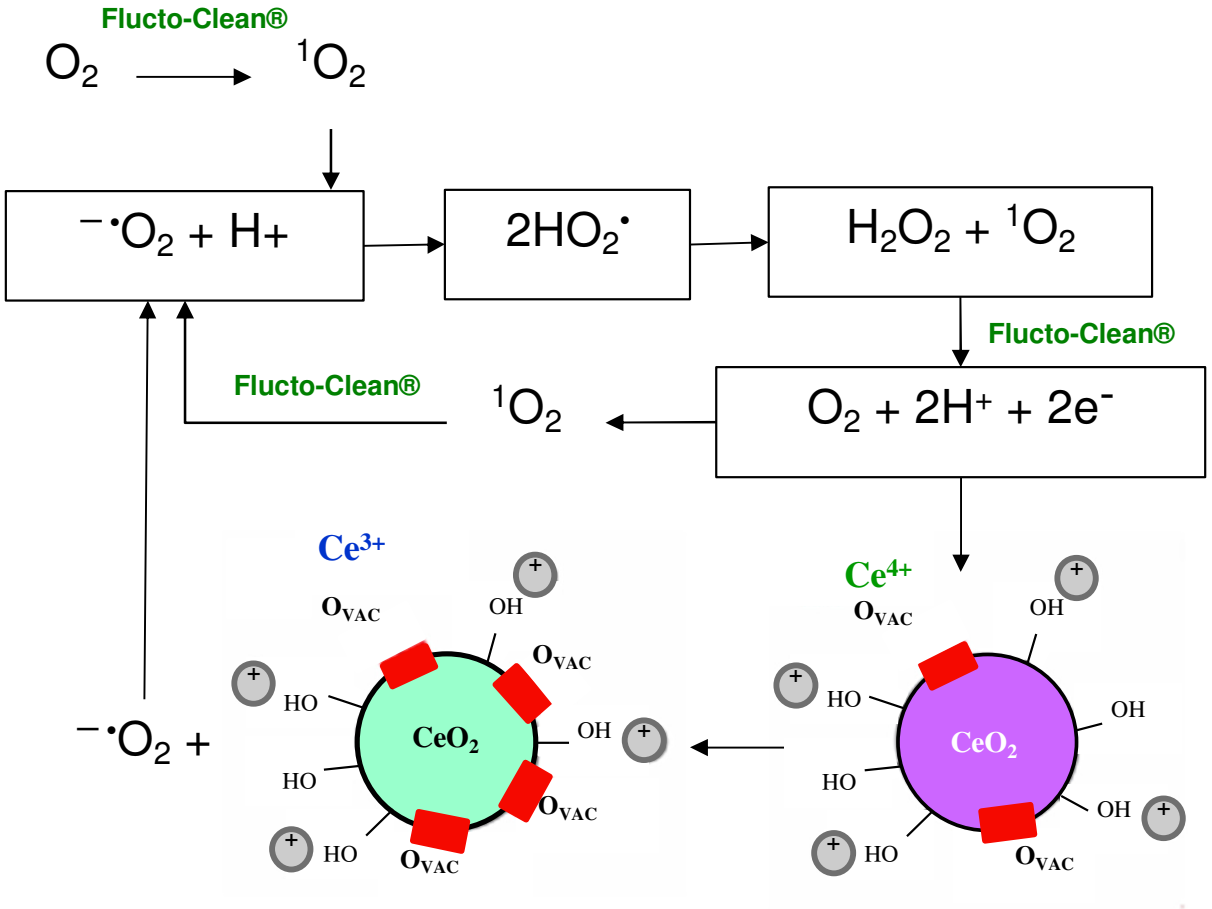






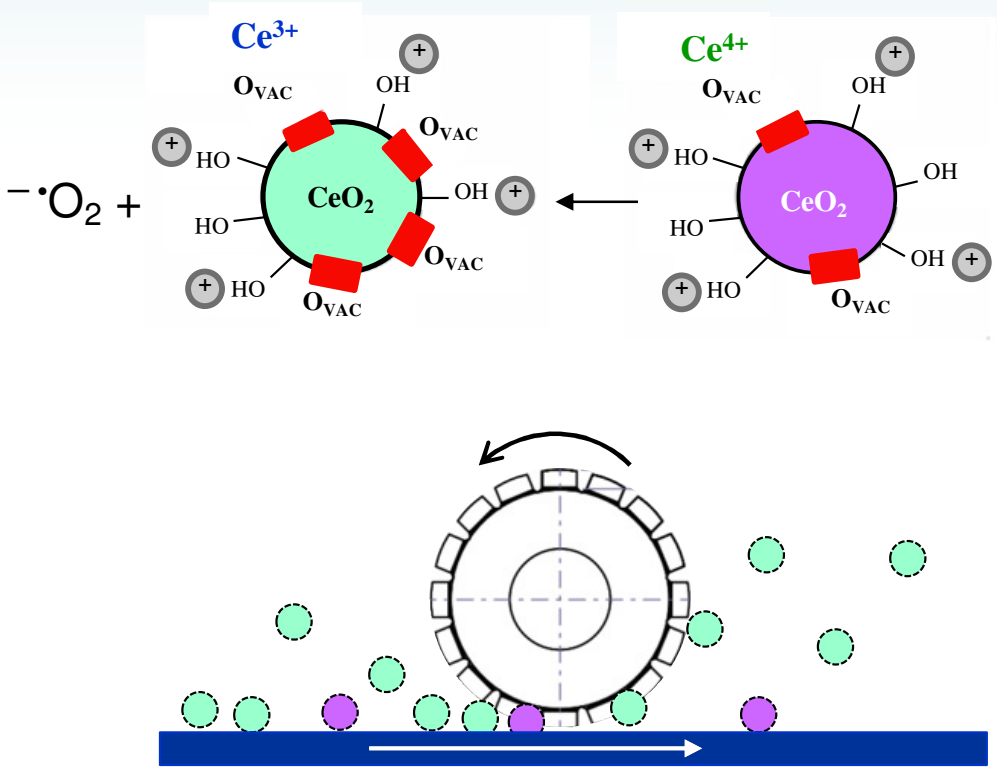


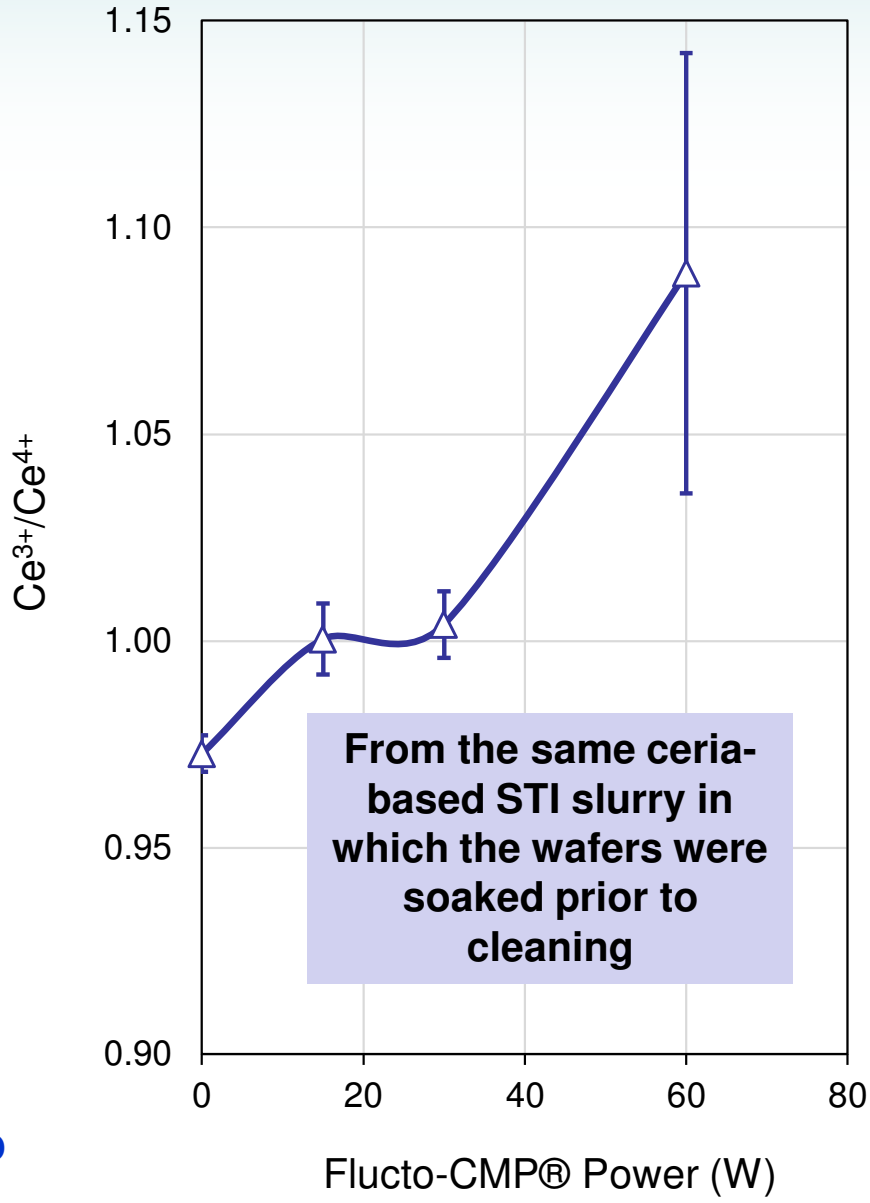
Example 1 – Proposed Ceria NP Removal Mechanism



- ✓ **With Flucto-Clean® protonation occurs in the presence of DO. This leads to the formation of "peroxo" species (H_2O_2).**
- ✓ **"Peroxo" species degrade in the presence of megasonic energy to form two electrons.**
- ✓ **The resulting concentration is not significantly high, but the continuously flowing reactor will provide an environment for effective surface reduction of ceria NPs that are present on the wafer.**

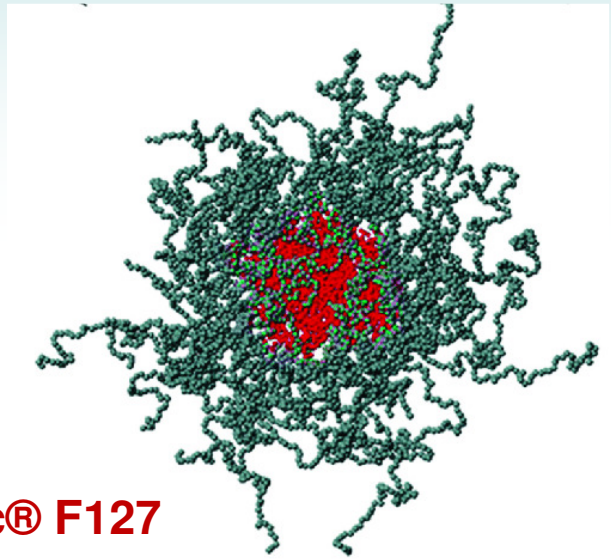
Example 1 – Proposed Ceria NP Removal Mechanism



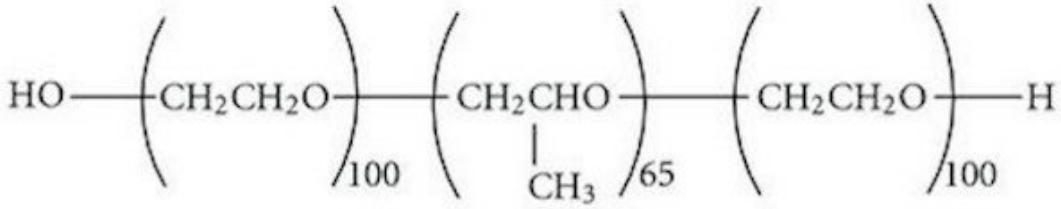


The Ce^{4+} to Ce^{3+} redox reaction weakens the interfacial Ce-O-Si bond.
This promotes particle removal.
This "looser" and "softer" interfacial layer also helps lower the COF.

Example 2 – SiC post-CMP Alumina NP Removal



Pluronic® F127



100-mm Research Grade Silicon Carbide Wafers

5-minute Polish with KMnO4 and Alumina NP Slurry

UPW Rinse and N2 Dry

Defect Metrology

Standard PVA Brush Scrubbing with UPW ONLY

Defect Metrology

Standard PVA Brush Scrubbing with UPW and F127

Defect Metrology

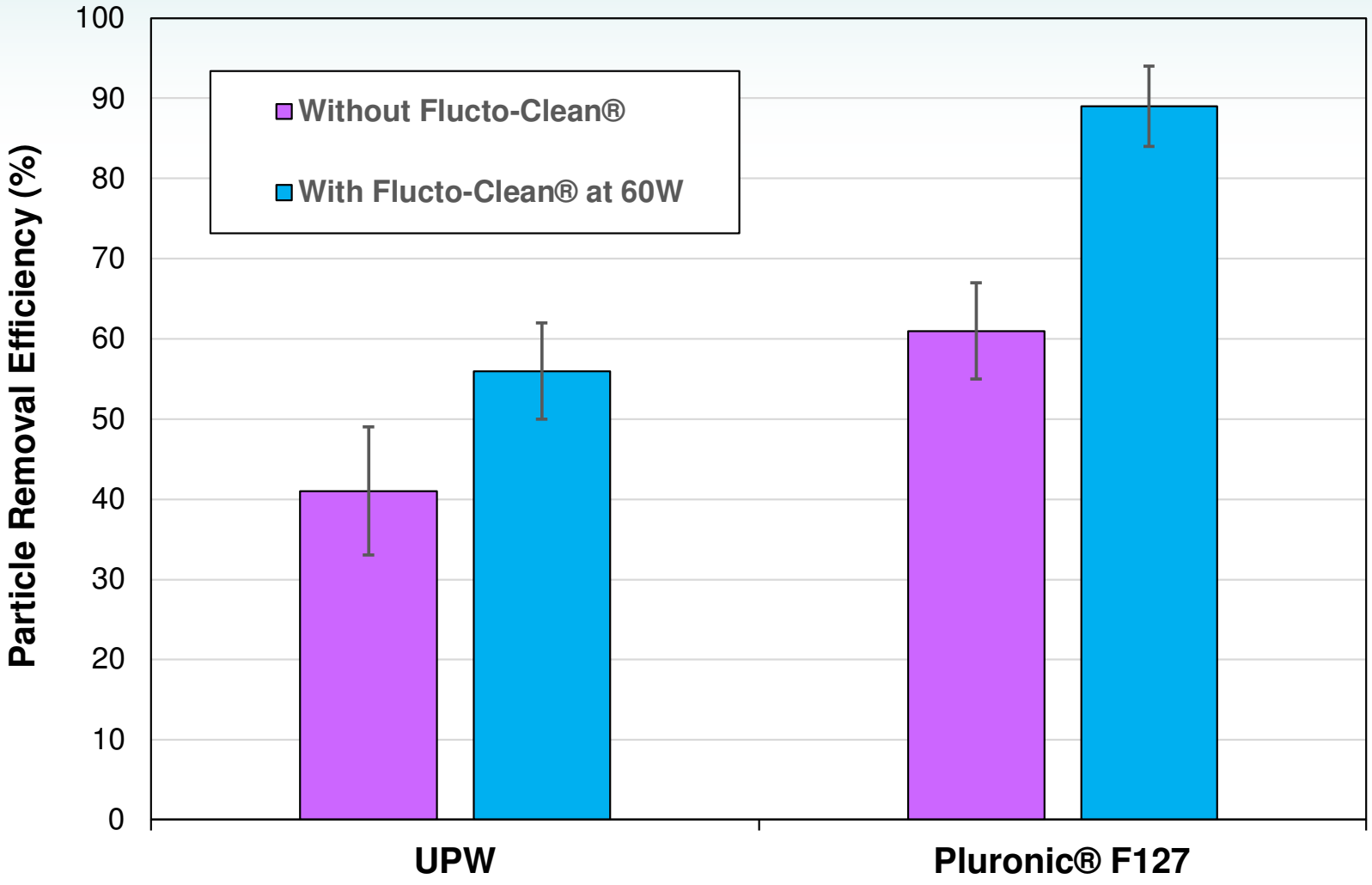
Flucto-Clean® at 60W PVA Brush Scrubbing with UPW ONLY

Defect Metrology

Flucto-Clean® at 60W PVA Brush Scrubbing with UPW and F127

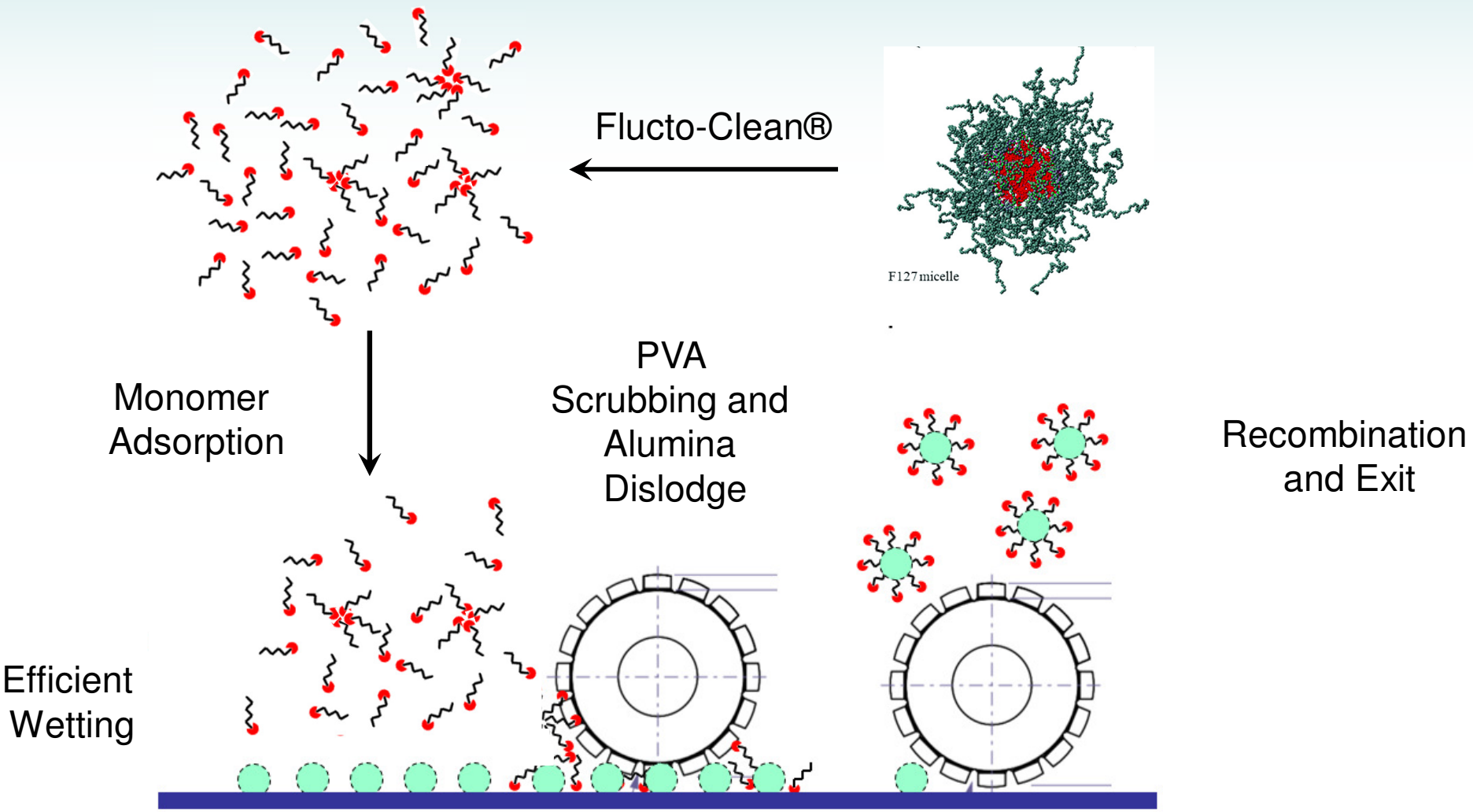
Defect Metrology

Example 2 – Post-SiC-CMP Alumina NP Removal Data with F127



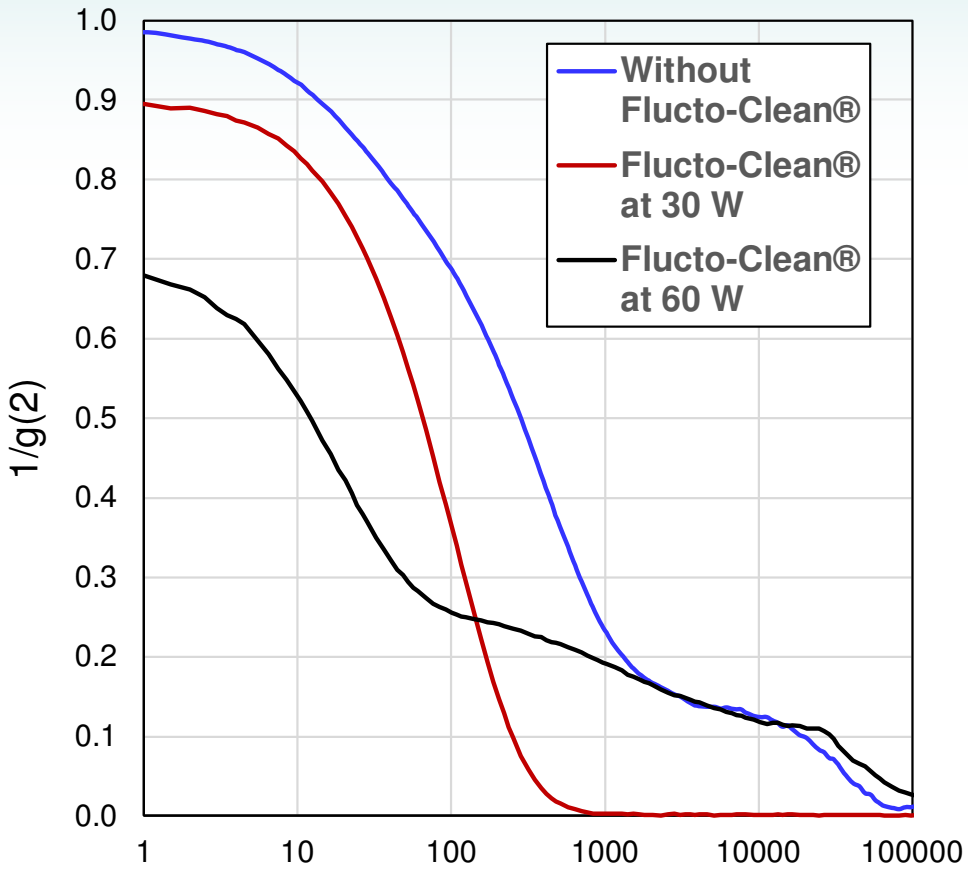
In all 4 cases, EDX analysis of carbon residue on the SiC wafers showed no change in carbon levels compared to the reference wafer (essentially below detection limits).

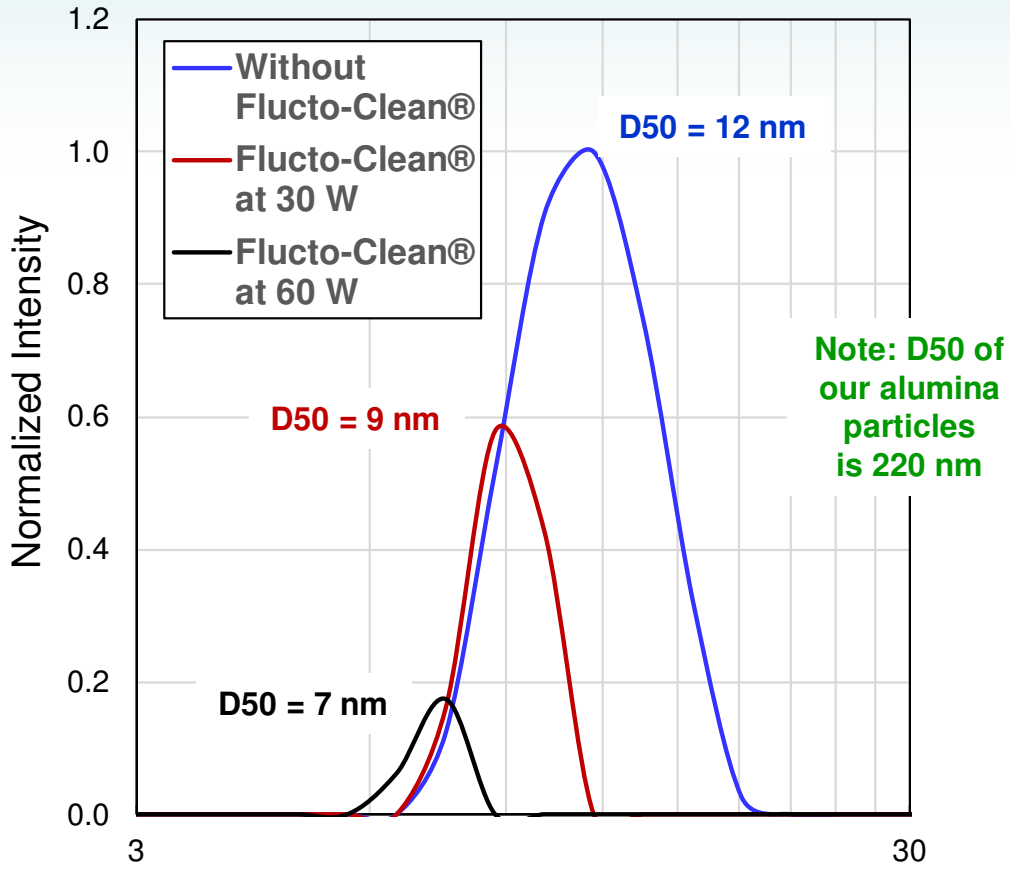
Proposed Mechanism – Pluronic® F127 with Flucto-Clean®



F127 is a micellar surfactant. We postulate that there is breaking of micelles into monomers due to sonic waves prompted by Flucto-Clean®. At the wafer-brush interface, the removal of dislodged alumina particles is facilitated via recombination with the F127 monomers that also promote wetting.

Proof of Micellar Fracture into Smaller Micelles and Monomers

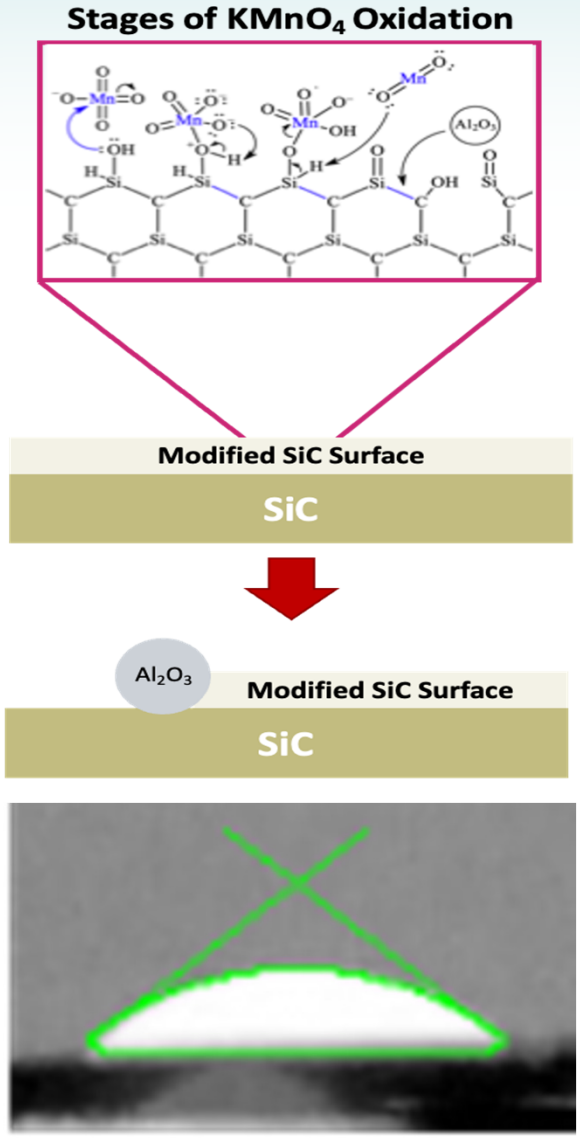


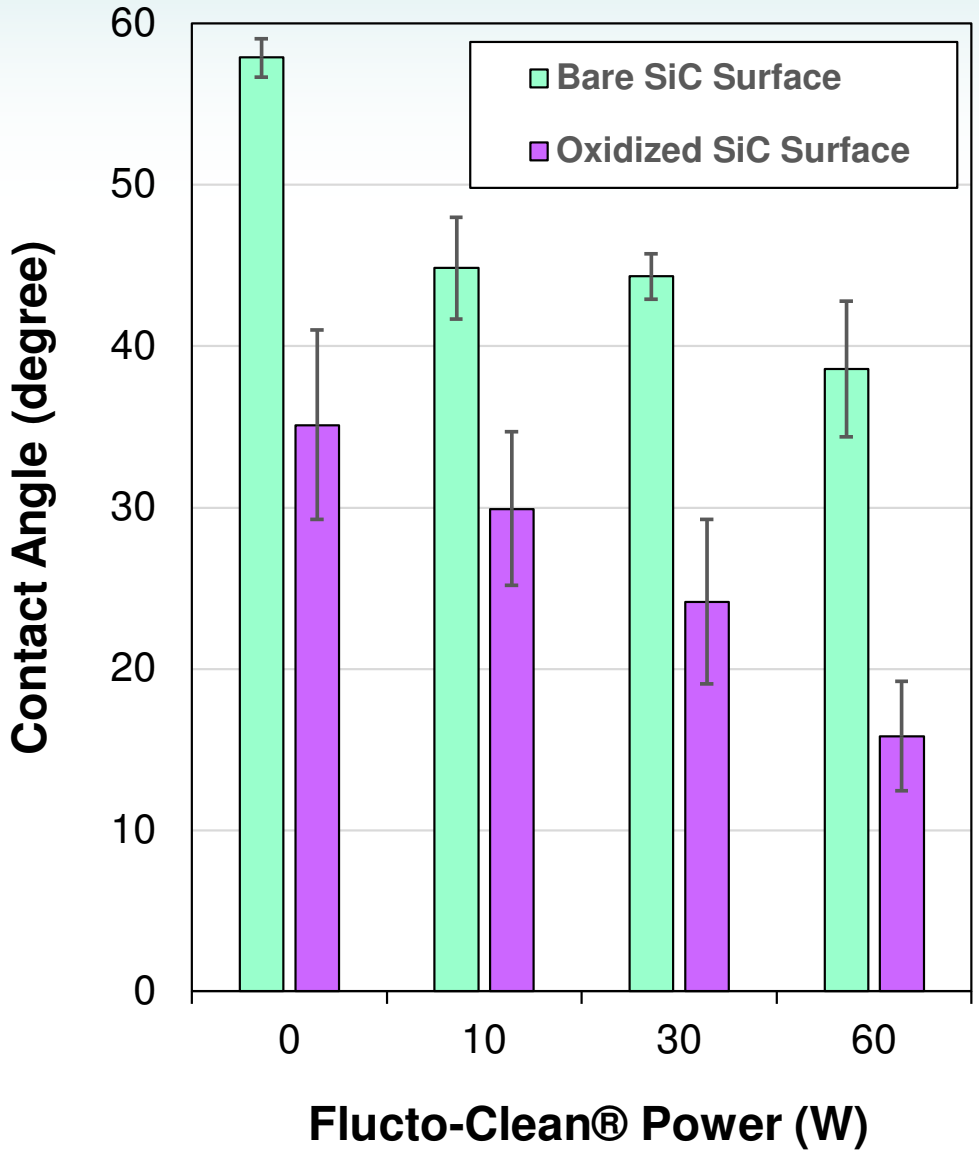


Photon Correlation Spectra re: F127 – Malvern Zetasizer Nano ZS

Stokes – Einstein Equation

Wetting Characteristics of F127 Micelles and Monomers

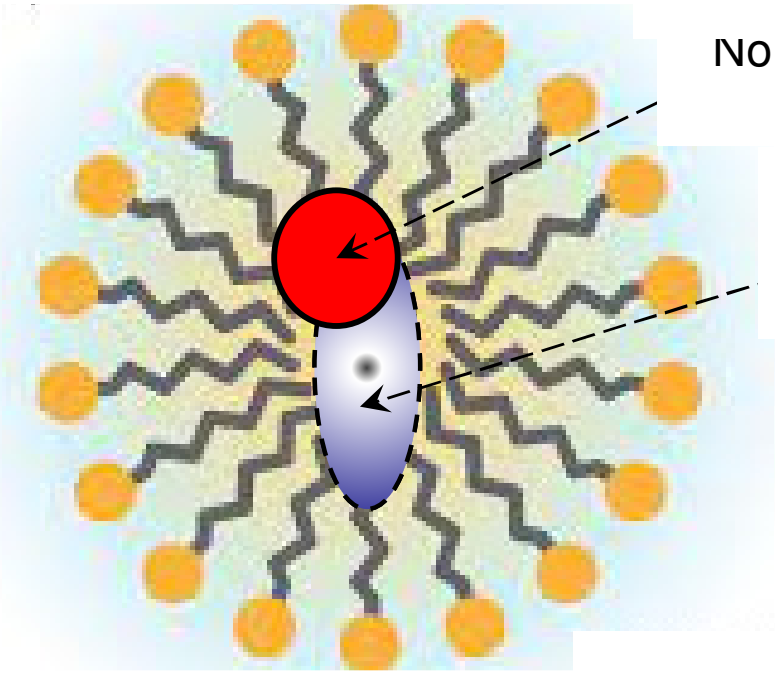




Analyzing the Air – SiC – F127 contact angle on bare and oxidized wafers

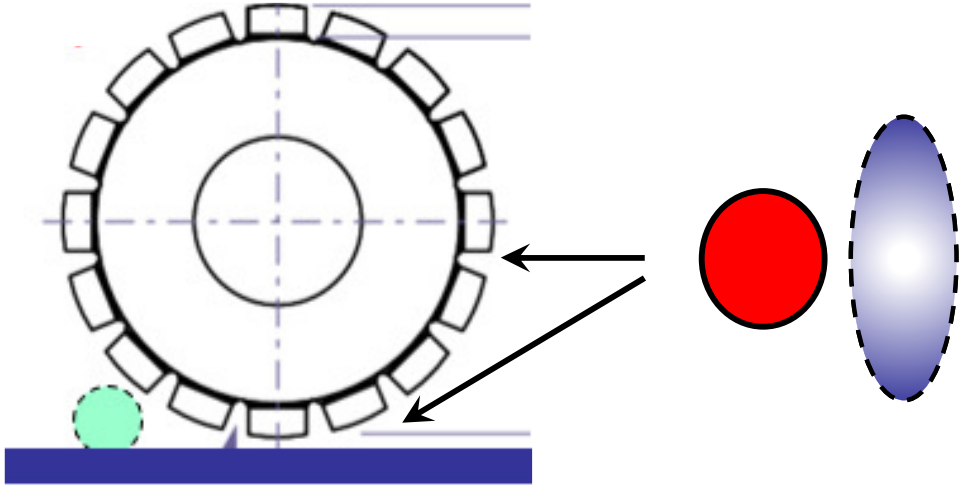
Another Approach – Looking for a JDP Partner

Supramolecular shell surfactants allow one to introduce non-soluble chemicals into the solution



Non-soluble cleaning rate enhancer

Non-soluble Non-metallic ROS catalyst



Flucto-Clean® will break apart the micellar supramolecule and release the active chemicals

Summary

- **The patent-pending Flucto-Clean® system is showing promise.**
- **With up-stream sonication in post-STI-cleaning, we can activate the chemistry of the cleaning solution. This creates myriad reactive oxygen species (ROS):**
  - ❖ **Improved PRE and results in tighter distributions.**
  - ❖ **Lowers shear forces (we don't yet know how this has come about, but are working to understand its fundamentals).**
  - ❖ **Lowers surface tension.**
- **In the case of post-SiC-clean, with sono-activatable additives (Pluronic® F127), we can enhance interfacial kinetics and thermodynamics to improve PRE.**
- **We are starting to use Flucto-Clean® to break apart new additives inside the cleaning solutions (such as micellar supramolecules) to release the active chemicals that we have embedded inside them.**

We are looking for a JDP partner who can make and sell post-CMP cleaning chemicals. Please contact me offline!

ARACA SM

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

Thank You!