Fluid Dynamics Characterization of Cerium Oxide Slurries in CMP Using Residence Time Distribution Modeling

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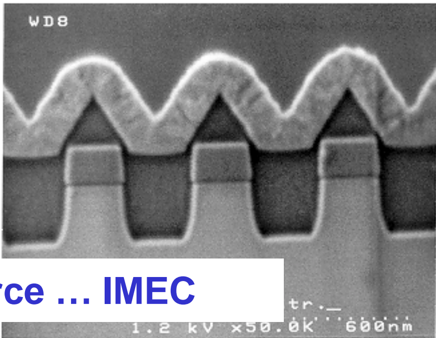
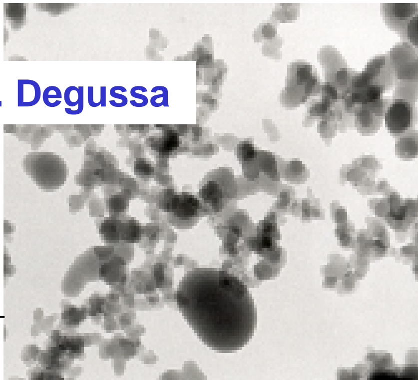
Generalized Schematic of CMP

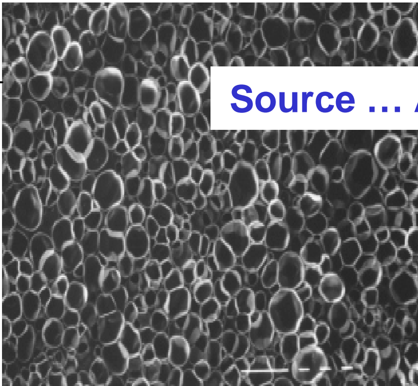
Rotating Patterned Wafer
(length scale: 100 ~ 200 nm)

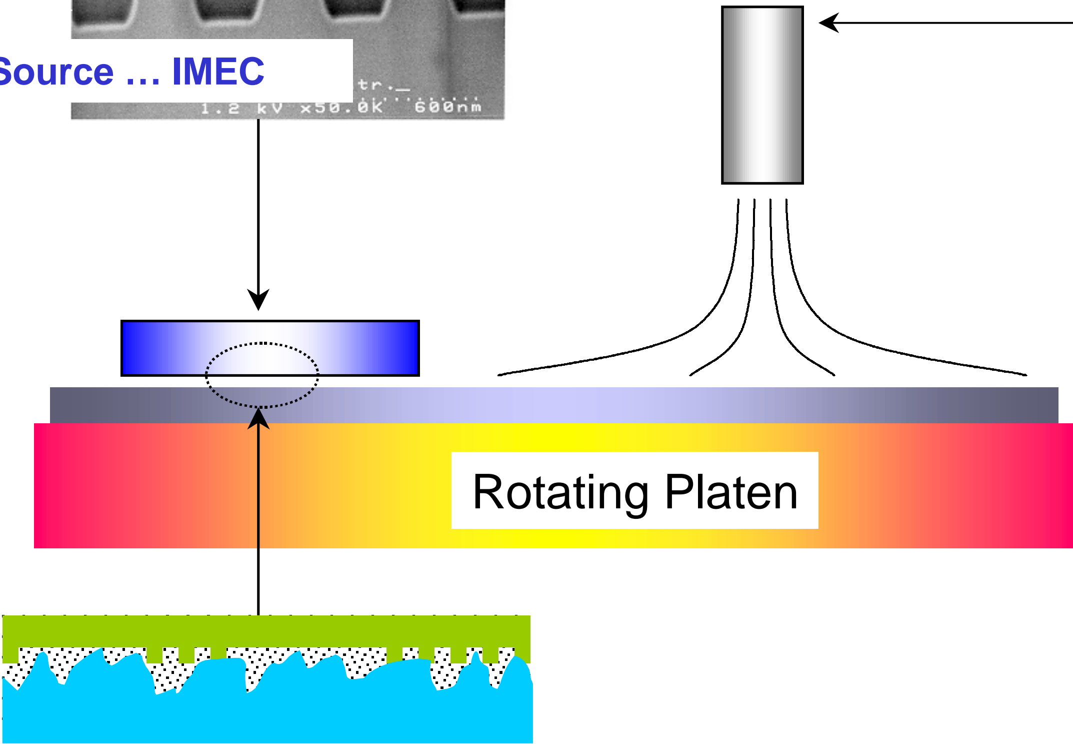


Slurry
(length scale: 50 ~ 200 nm)



Rotating Pad
(length scale: 2000 ~ 10000 nm)



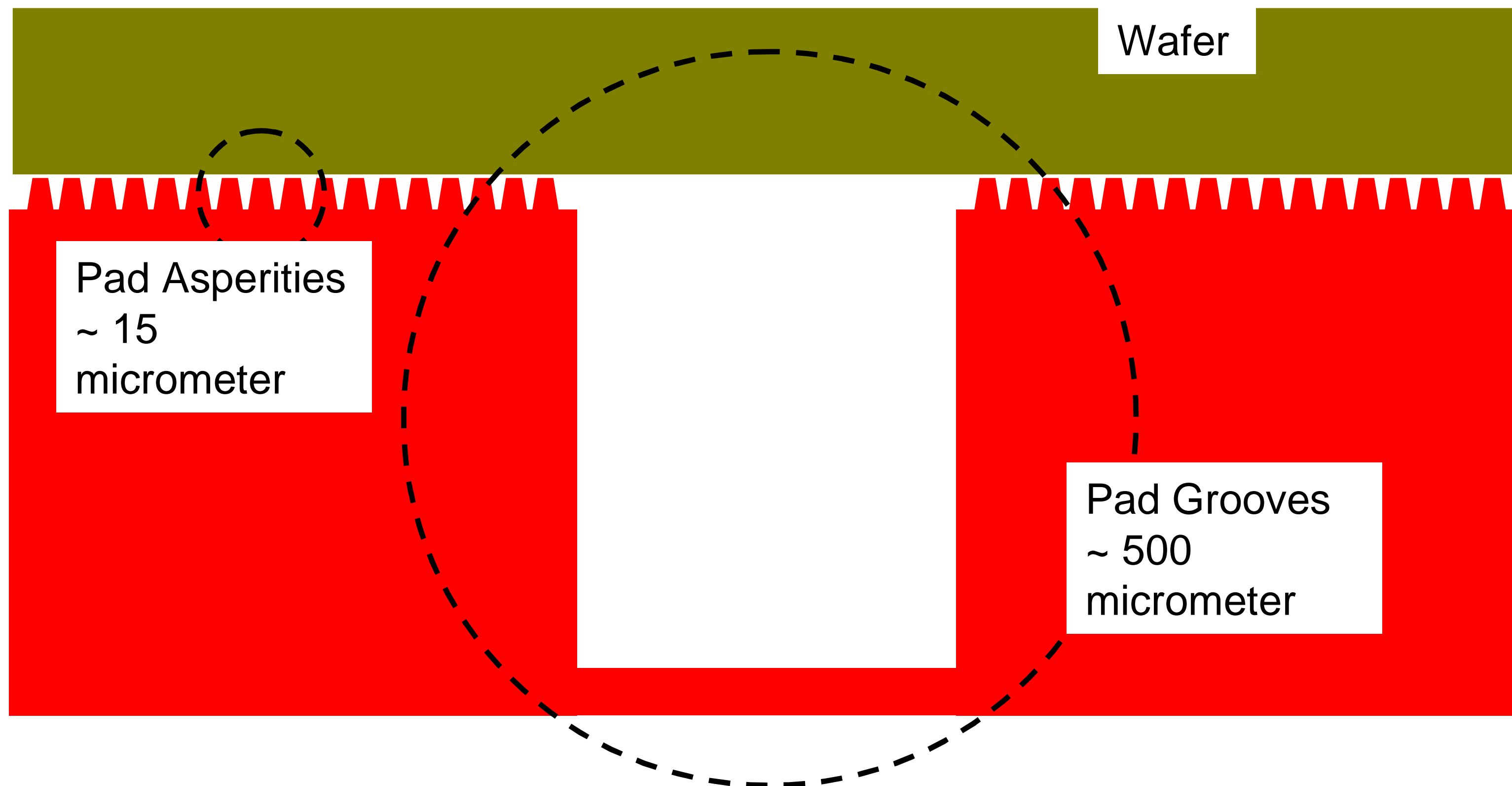


Outline

- Apparatus for real-time measurement of slurry mean residence time (τ)
  - Effect of various key parameters on (τ)
    - Slurry flow rate
    - Cerium oxide concentration in slurry
    - Additives
    - Pad grooving
  - Preliminary fluid dynamics model
- Conclusions

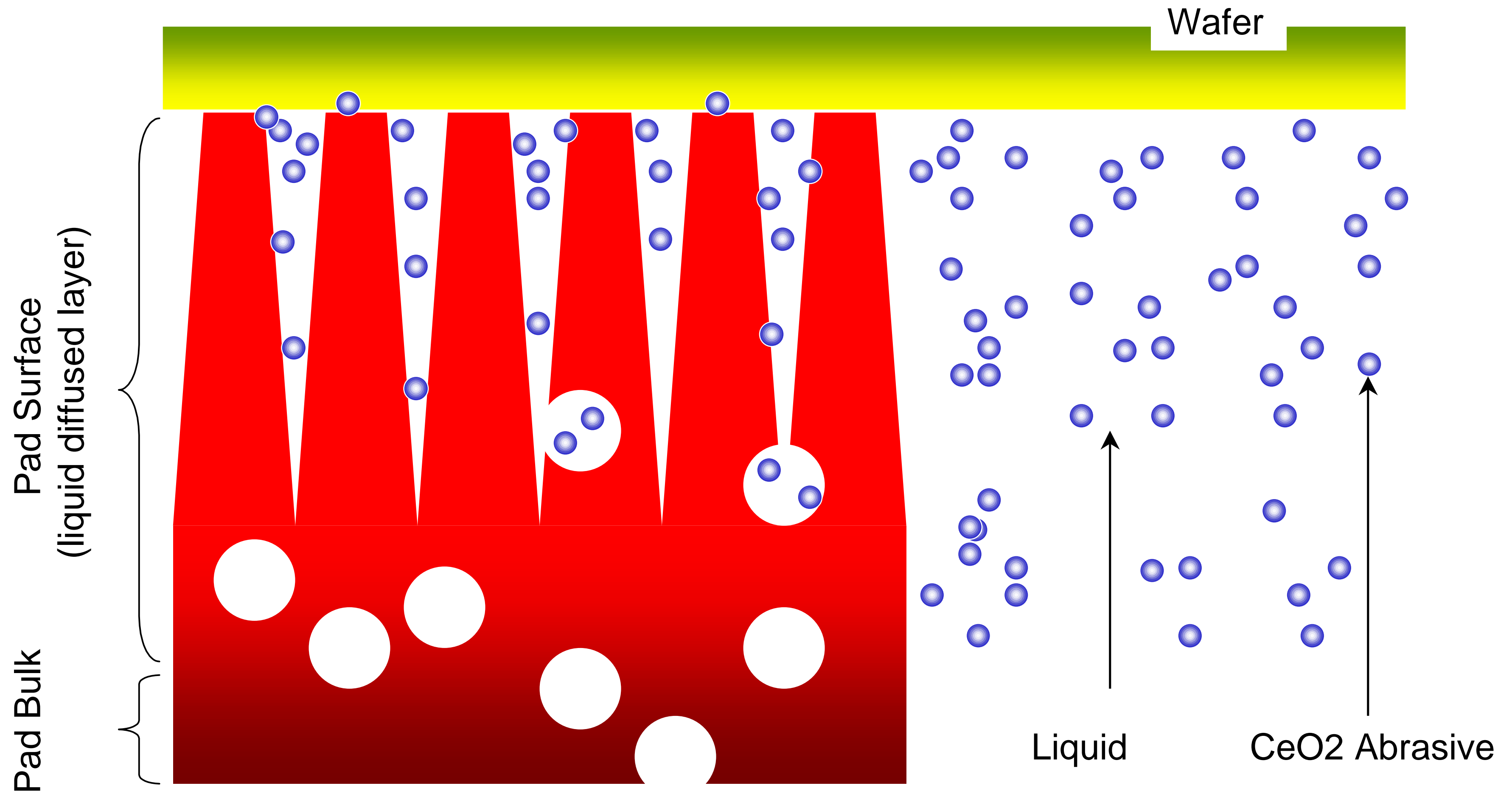
Note of Caution

Extending The Stribeck Curve to the CMP System

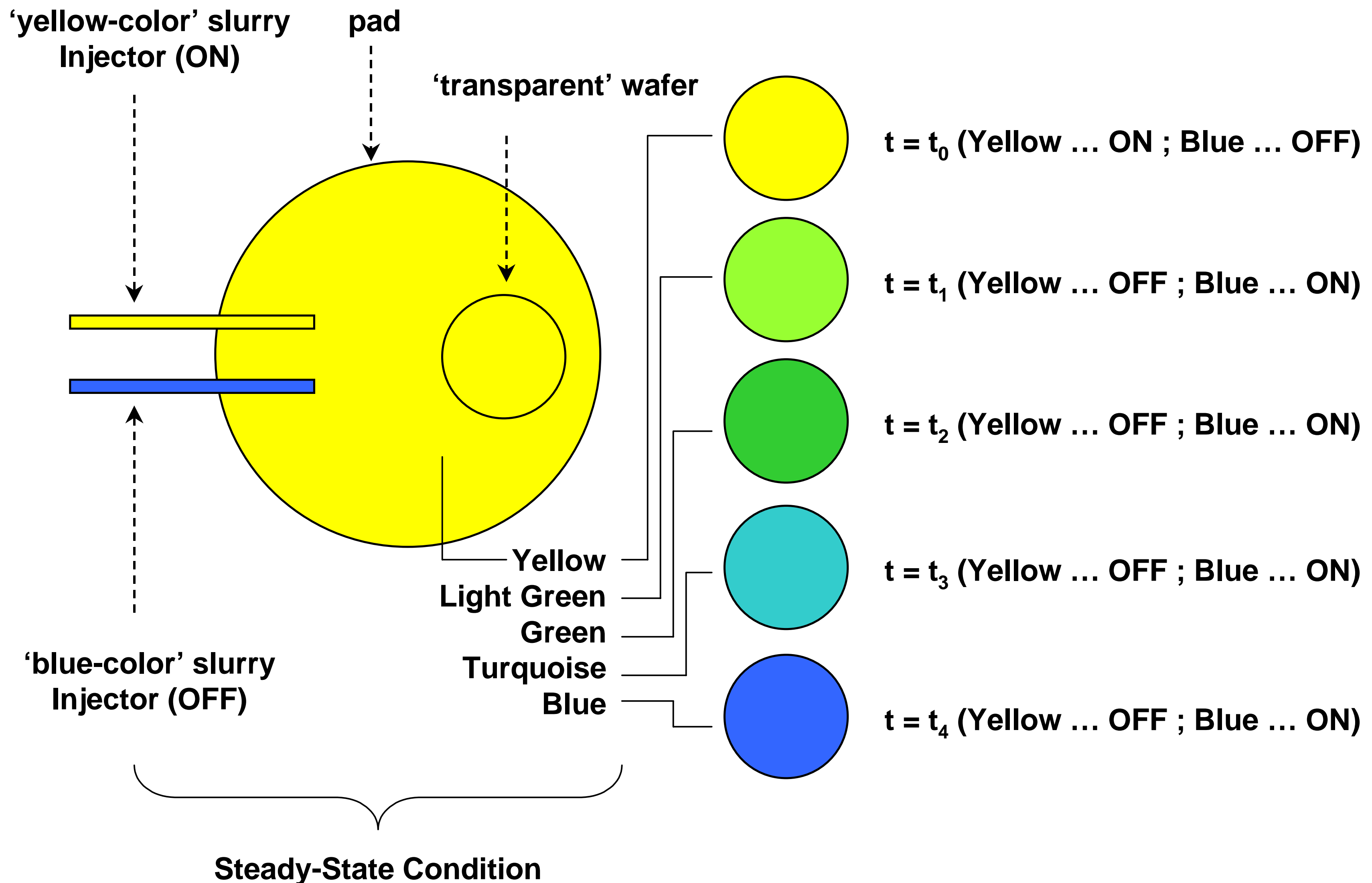


Note of Caution (continued)

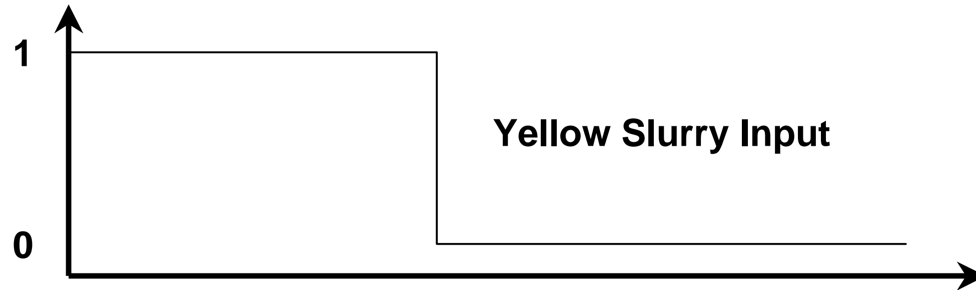
Extending The Stribeck Curve to the CMP System

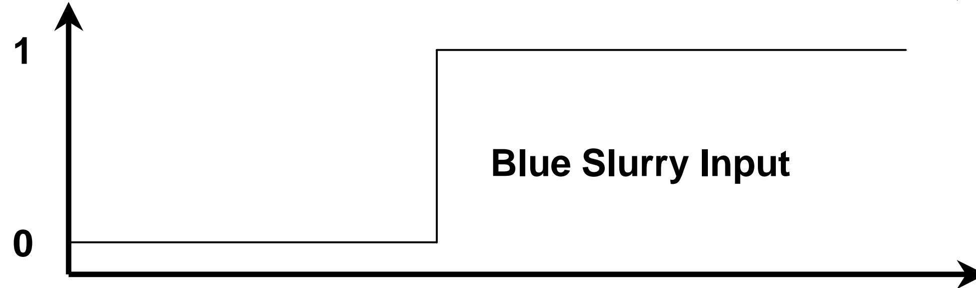


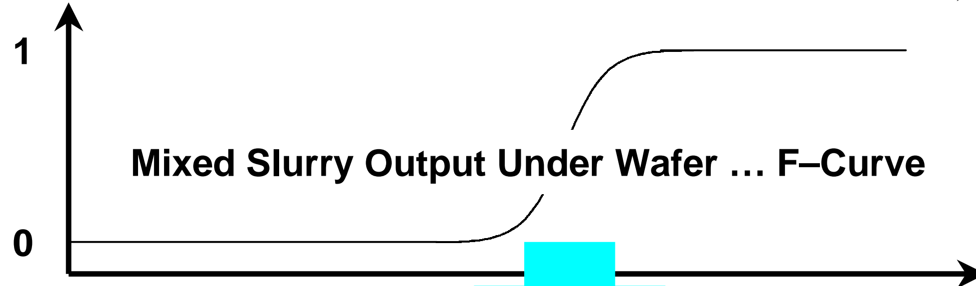
The Residence Time Distribution Technique

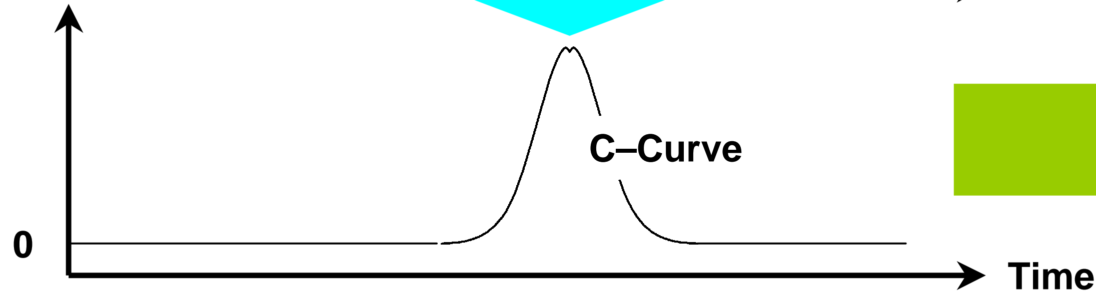


The Residence Time Distribution Technique









$$\tau = \frac{\int C(t) \times t \times dt}{\int C(t) \times dt}$$

Dual-Emission UV-Induced Fluorescence

Dual Camera Assembly & Associated Optics

UV Source

Slurry

Slurry & Fluorescence Dye

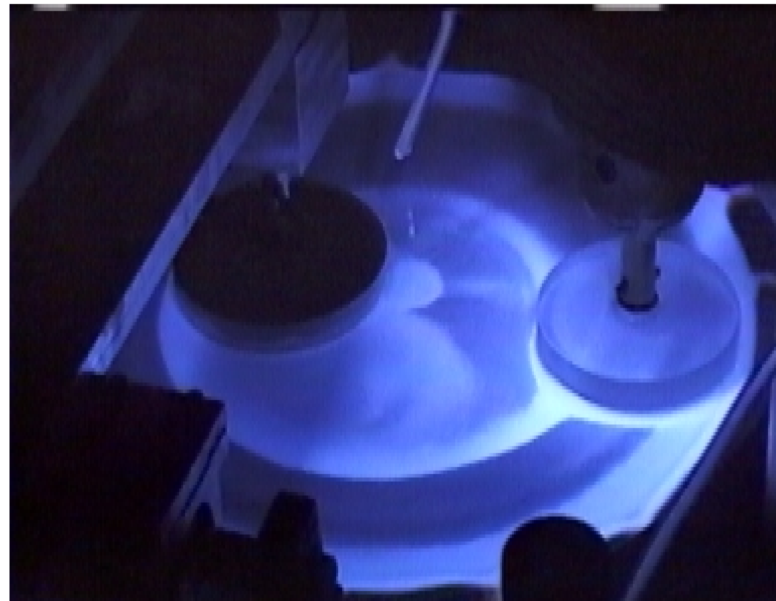
Rotating Glass Wafer

Diamond Conditioner

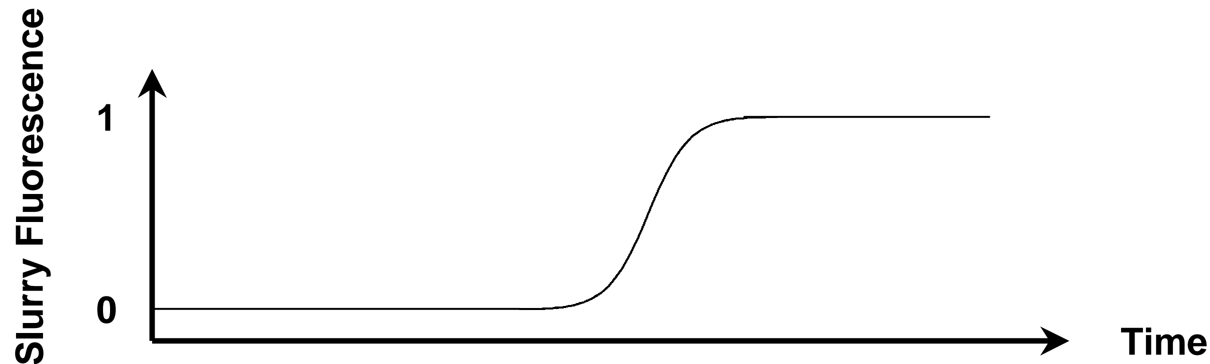
glass wafer

© = slurry conc

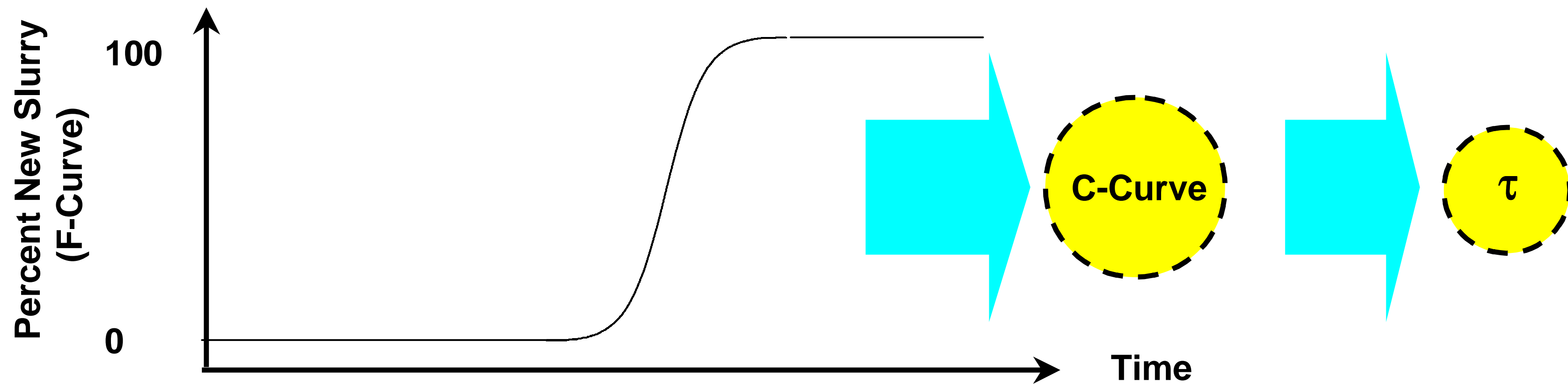
pad



The Residence Time Distribution Technique

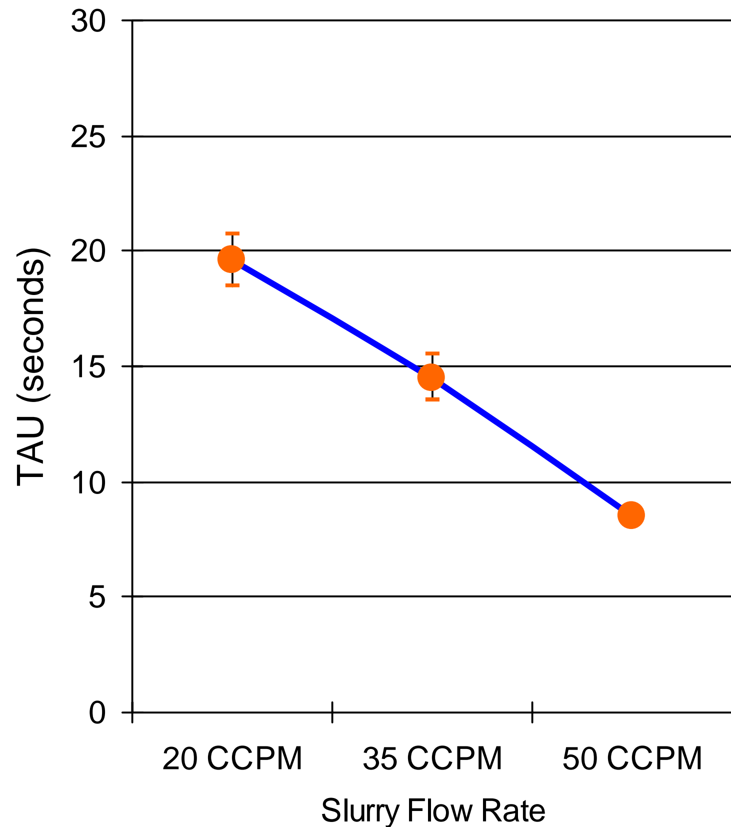


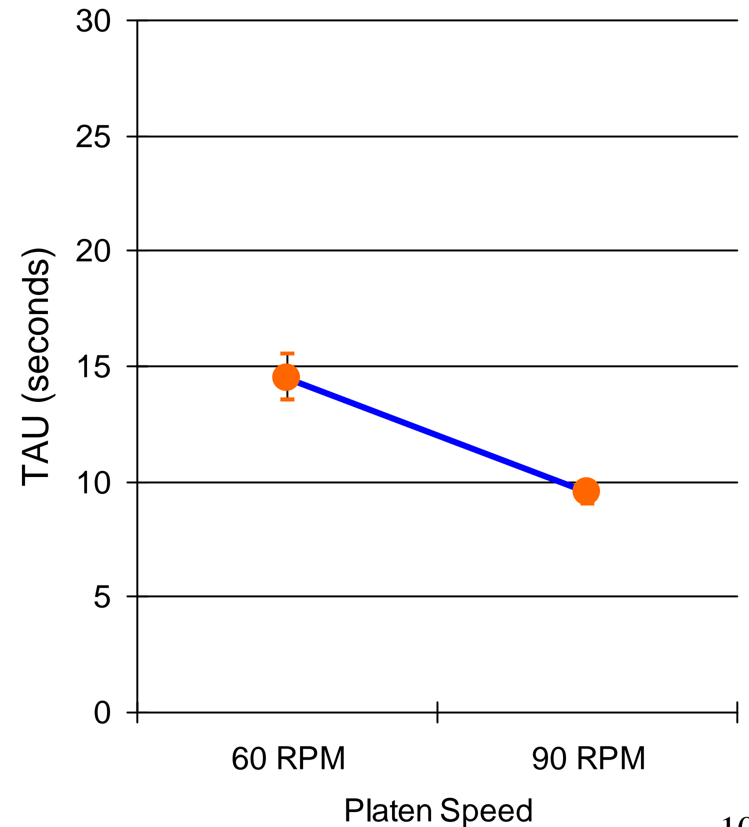
Calibration With Known Standards



Effect of Cerium Oxide Slurry Flow Rate and Platen Speed on τ

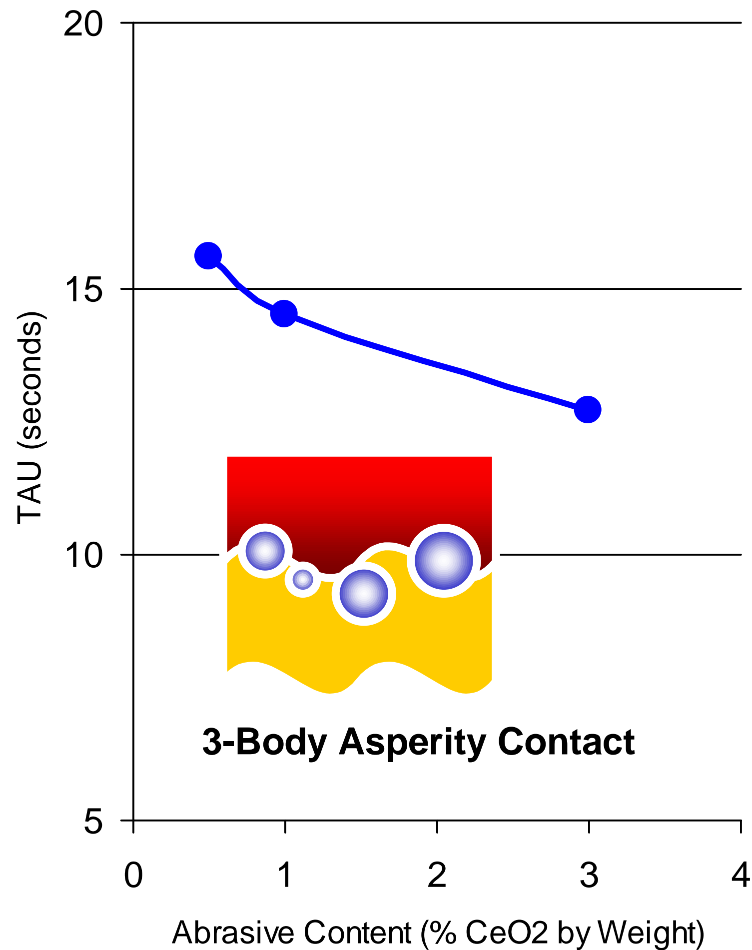
Pad : **IC-1000 Perforated**
Conditioning : **Ex-Situ**
Platen & Wafer Speeds : **60 rpm**
Wafer Pressure : **28,000 N per square meter (4 PSI)**

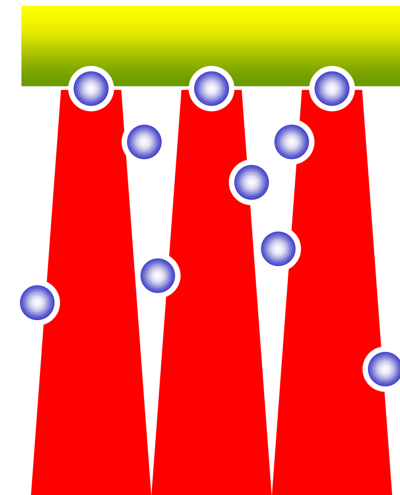




Effect of Cerium Oxide Abrasive Concentration on τ

Pad : **IC-1000 Perforated**
Conditioning : **Ex-Situ**
Platen & Wafer Speeds : **60 rpm**
Wafer Pressure : **28,000 N per square meter (4 PSI)**
Wafer : **SiO2**



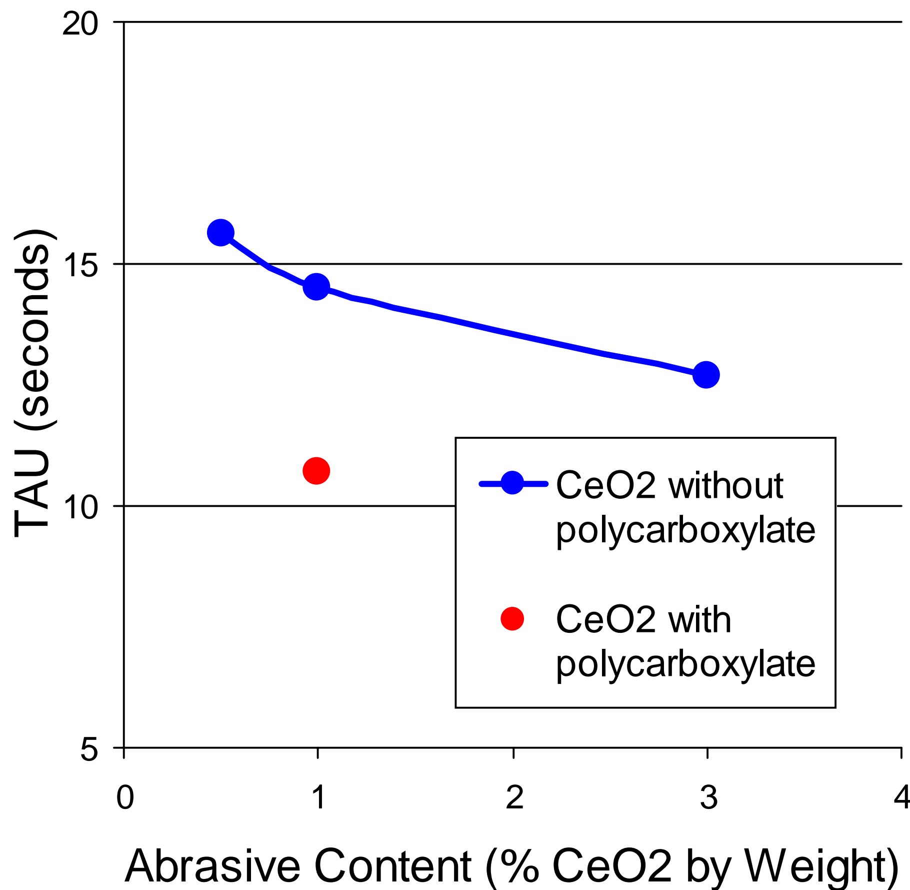


Abrasive particles act as ‘rollers’ and speed up the movement of the wafer relative to the pad

They enhance fluid flow in the wafer-pad region

Effect of Anionic Organic Additive on τ

Pad : **IC-1000 Perforated**
Conditioning : **Ex-Situ**
Platen & Wafer Speeds : **60 rpm**
Wafer Pressure : **28,000 N per square meter (4 PSI)**
Wafer : **SiO2**



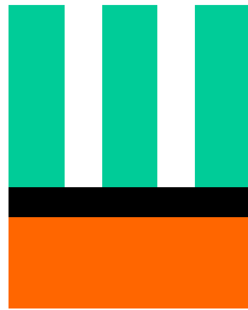
The anionic organic additive adsorbs on the cerium oxide abrasive and further promotes the movement of the wafer relative to the pad

This enhances fluid flow in the wafer-pad region

The additive does not adsorb on SiO2

This model is consistent with coefficient of friction studies

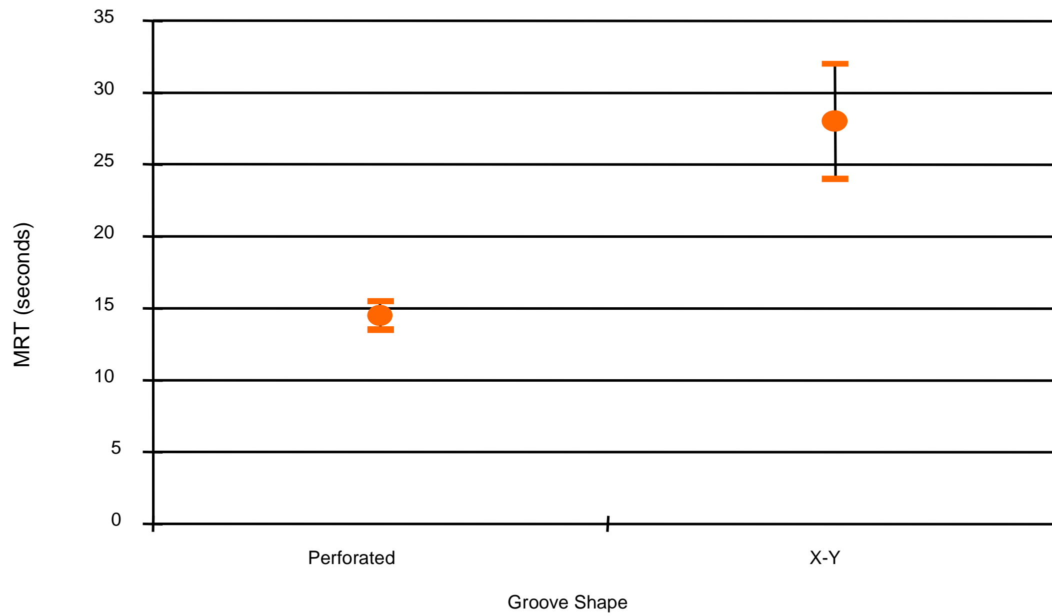
Effect of Pad Grooving on τ



Perforated Pad (side or front view)

X-Y Grooved Pad (front view)

X-Y Grooved Pad (side view)



$$\frac{void_{x-y}}{void_{perforated}} = \frac{1.05}{.65} = 1.6$$

$$\frac{\tau_{x-y}}{\tau_{perforated}} = 1.9$$

Conclusion

- Showed that (τ) varied with slurry flow rate and platen speed in a manner consistent will well-established chemical engineering reactor design theories
- Showed that (τ) was a strong function of CeO2 abrasive concentration as well as anionic organic additive content
- Showed that pad surface treatment such as grooving or perforation significantly affected (τ)
- Developed a preliminary fluid dynamics model which explained these trends and supported earlier findings on additives and COF