New Method for Determining Reactor Mean Residence Time and Extent of Dispersion in CMP Processes

Erin Mitchell, Scott Olsen & Ara Philipossian

University of Arizona
Department of Chemical & Environmental Engineering
Tucson, AZ USA

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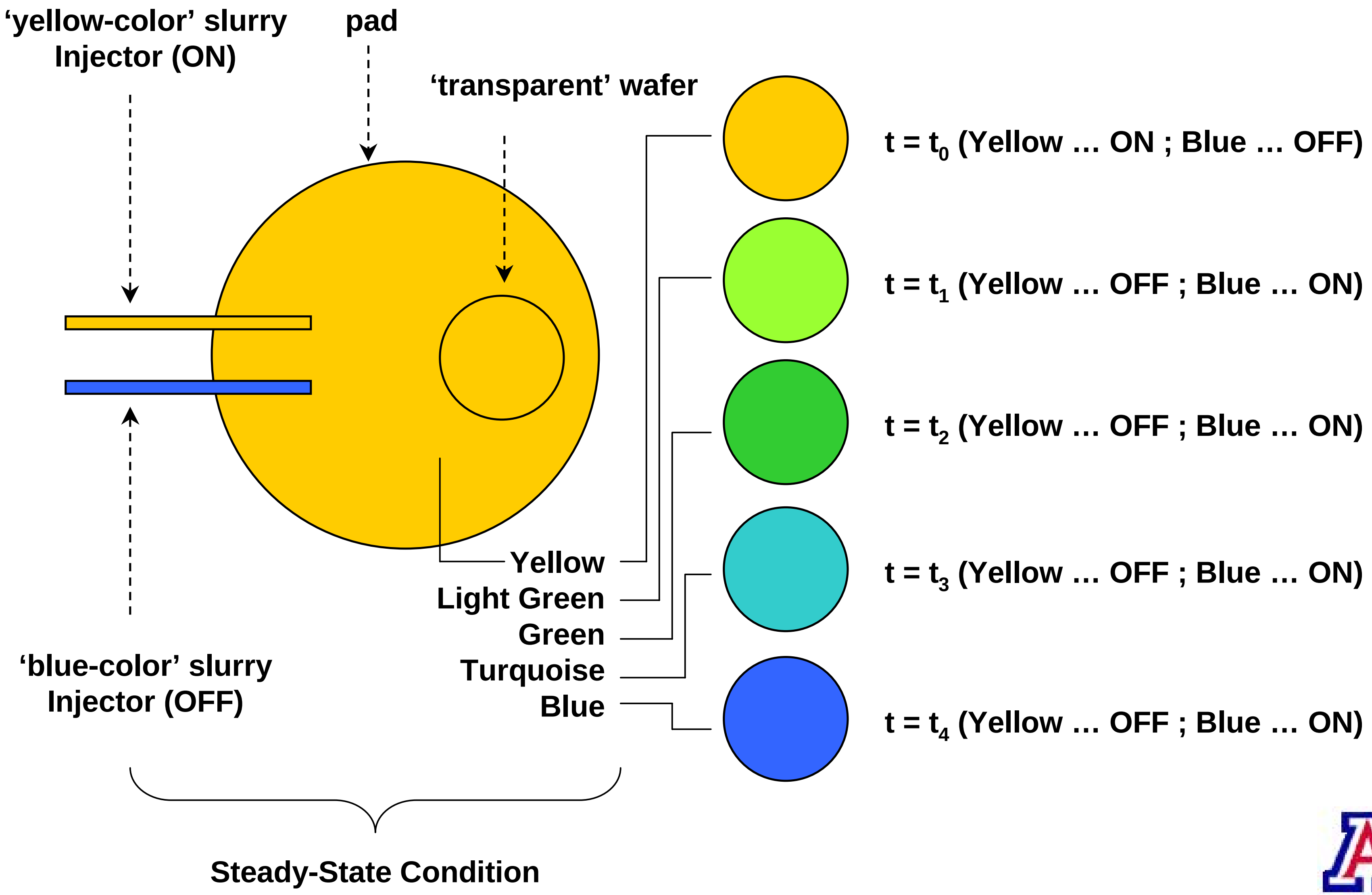
Driving Force

Characterization and fundamental understanding
of the fluid dynamics of the CMP process
will lead to the development of
environmentally benign processes & equipment
and reduced slurry usage

Outline

- Generic Residence Time Distribution (RTD) technique
- Equations describing Mean Residence Time (τ) & Dispersion (D)
- Current Best Known Method (BKM) for determining τ & D in CMP
- Proposed method for determining τ & D in CMP
  - Experimental procedure
  - Preliminary data
- Methods comparison
- Future plans

The Residence Time Distribution Technique



‘yellow-color’ slurry Injector (ON)

pad

‘transparent’ wafer

‘blue-color’ slurry Injector (OFF)

Yellow

Light Green

Green

Turquoise

Blue

Steady-State Condition

t = t_0 (Yellow … ON ; Blue … OFF)

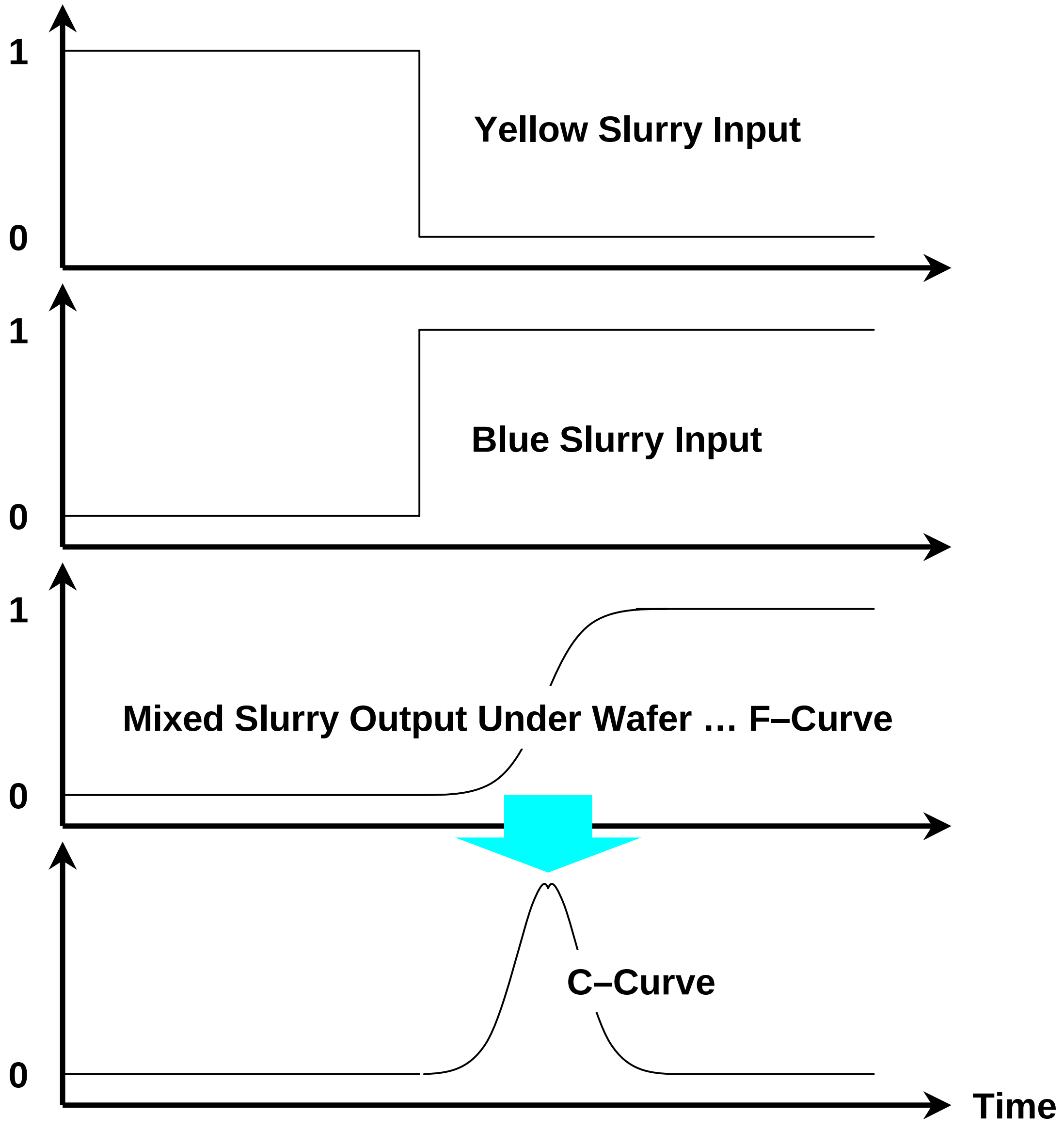
t = t_1 (Yellow … OFF ; Blue … ON)

t = t_2 (Yellow … OFF ; Blue … ON)

t = t_3 (Yellow … OFF ; Blue … ON)

t = t_4 (Yellow … OFF ; Blue … ON)

The Residence Time Distribution Technique



Governing Equations

$$\tau = \int_0^t t \times C(t)\,dt$$

$$\theta = \frac{t}{\tau}$$

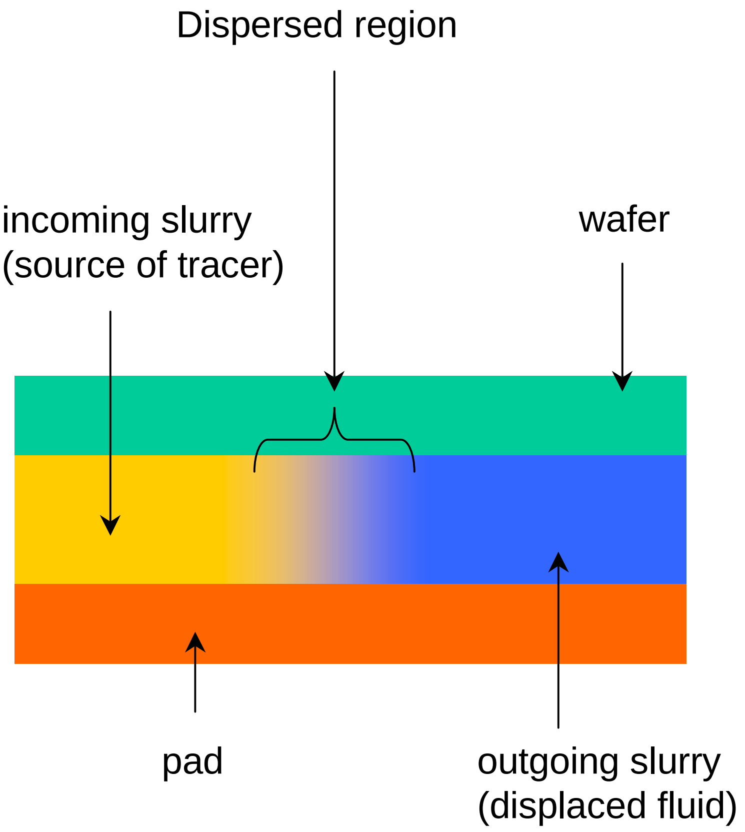
$$\sigma^2 = \int_0^\infty (\theta - 1)^2 \times C(\theta)\,d\theta$$

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} = D\frac{\partial^2 C}{\partial x^2}$$

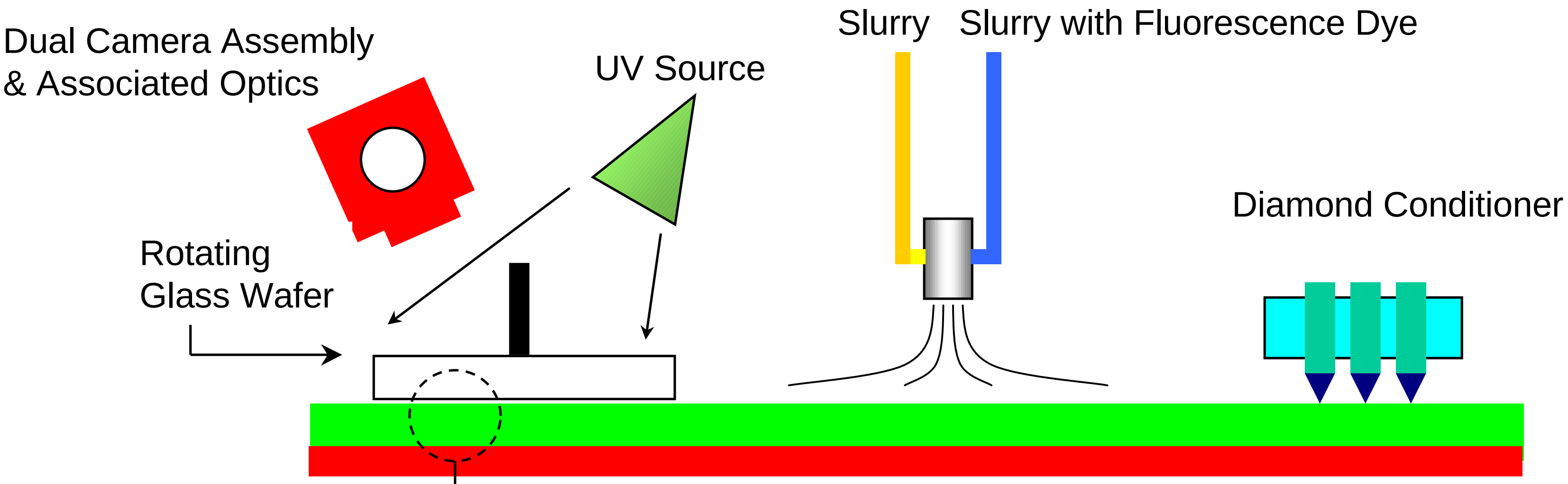
$$\sigma^2 = D^2\left[\frac{2}{D} + 8\right]$$ *(open system)*

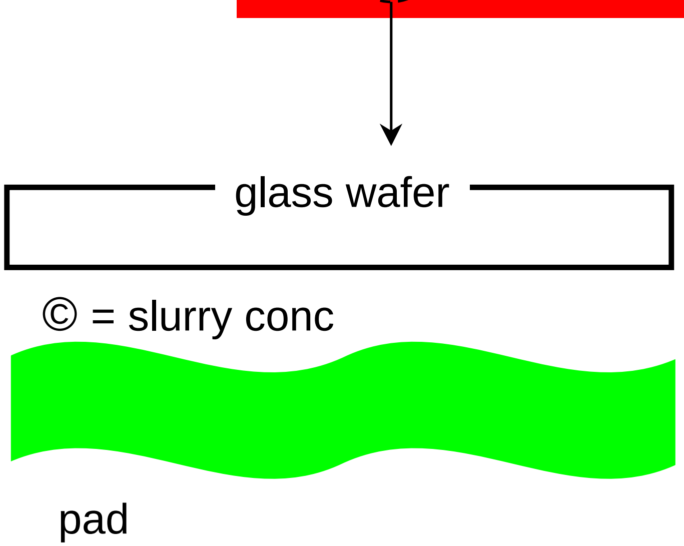
$D \to \infty (CSTR)$

$D \to 0 (PFR)$

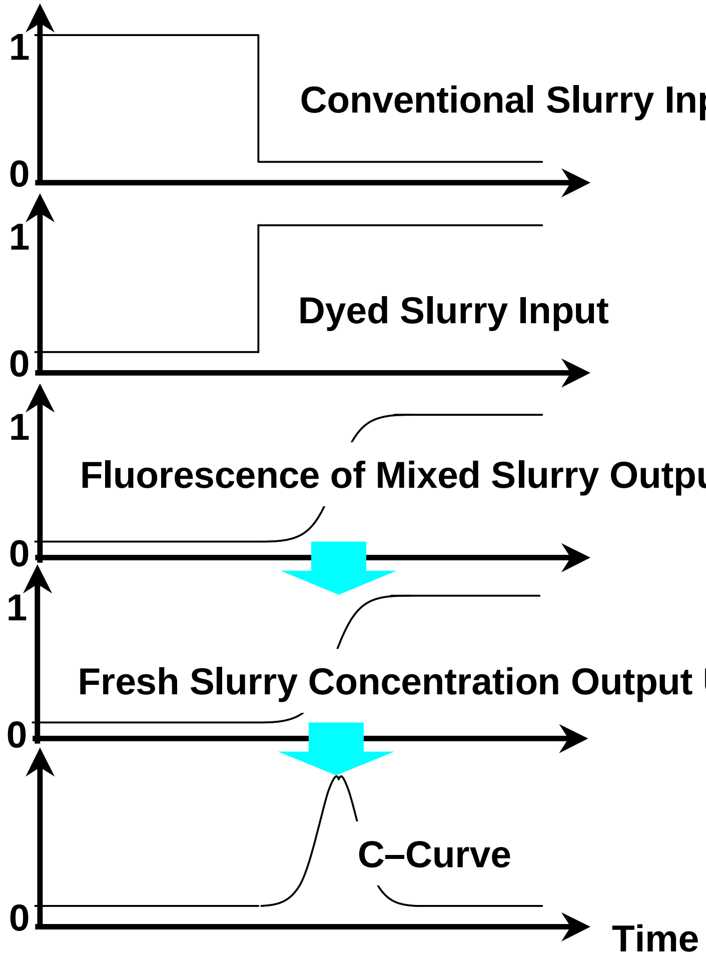


Dual-Emission UV-Enhanced Fluorescence Imaging for CMP RTD





Current BKM for CMP RTD



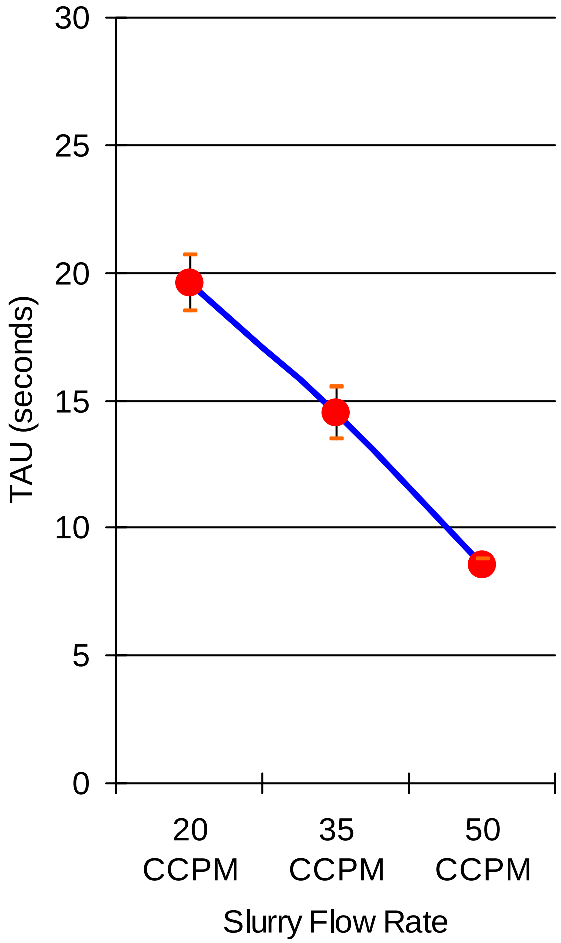
Conventional Slurry Input

Dyed Slurry Input

Fluorescence of Mixed Slurry Output Under Wafer … F–Curve

Fresh Slurry Concentration Output Under Wafer … F–Curve

C–Curve

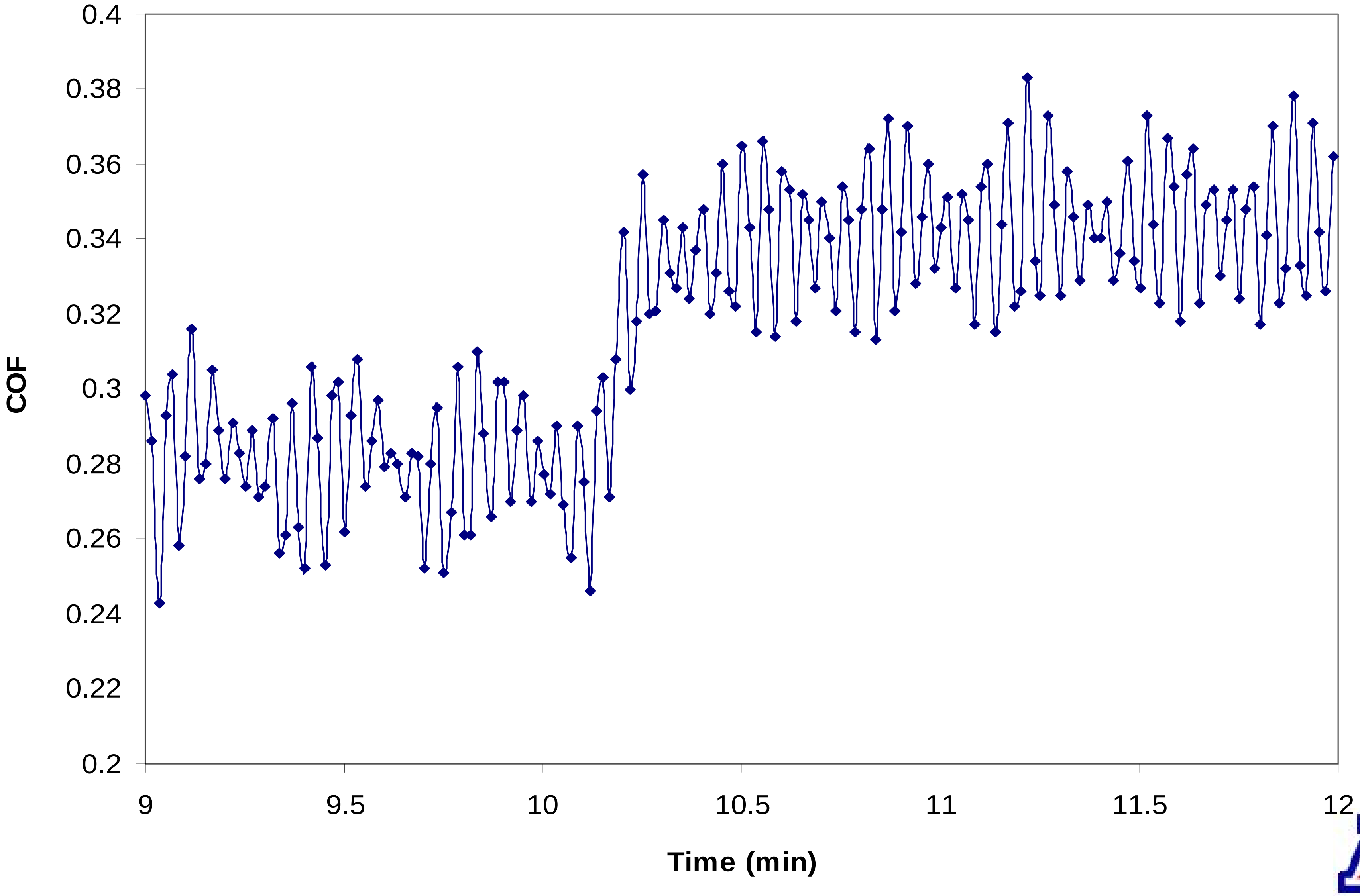


Experimental Procedure

- Pad:
  - Rodel IC-1000 perforated (no sub-pad)
  - 30 minute conditioning followed by 1 minute wafer break-in
- Conditioning:
  - In-situ conditioning with 100 grit diamond disk
  - Disk speed … 30 rpm
  - Sweep frequency 20 times per minute
- Polisher conditions:
  - Platen speed … 40 & 80 rpm (matched to wafer speed)
  - Wafer pressure … 2 psi
  - Slurry flow rate … 40 & 80 cc per minute
- Slurries:
  - Conventional 25% silica slurry for ILD polish
  - Conventional 2.5% silica slurry for ILD polish

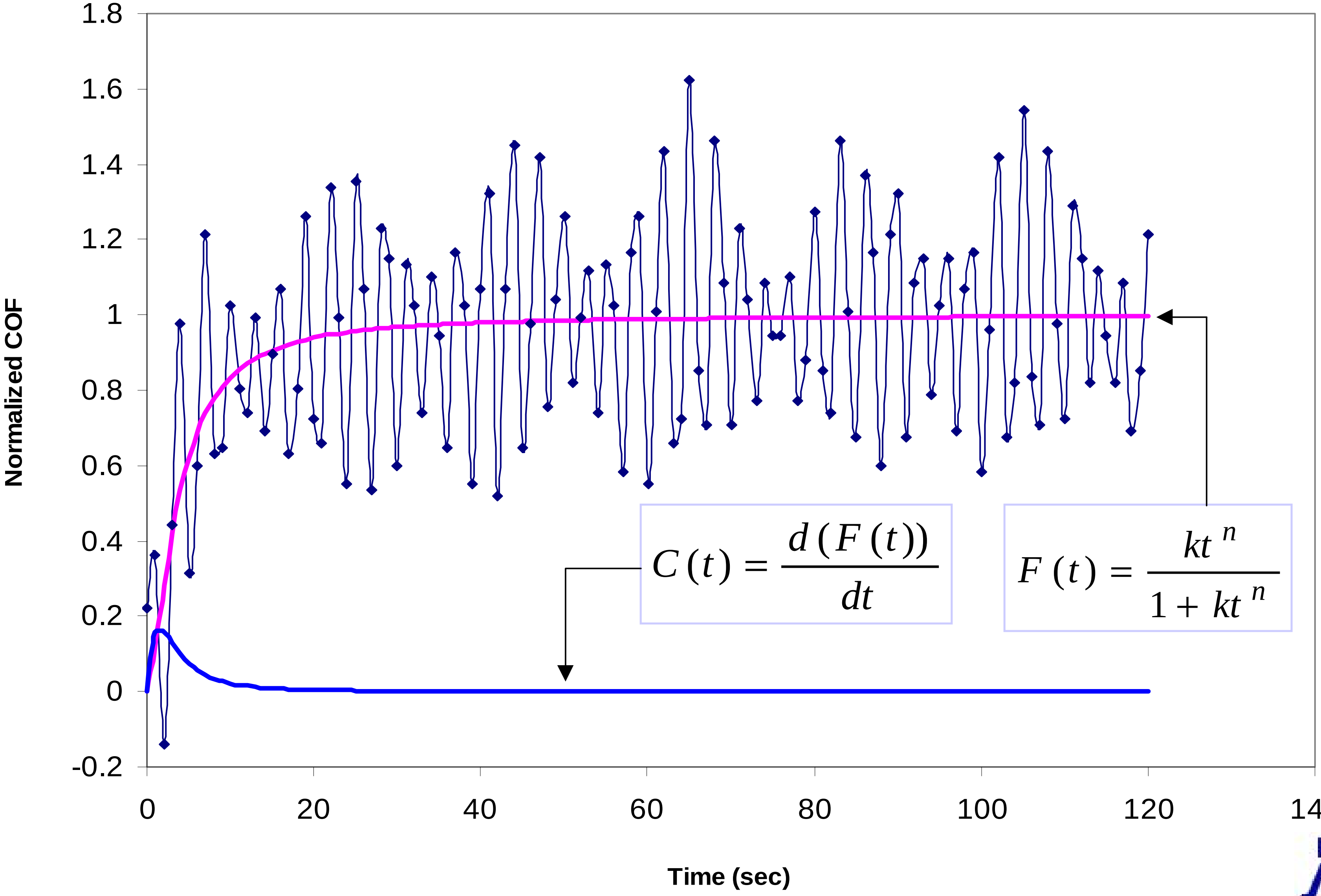
COF-RTD

(Raw Data)



COF-RTD

(Fitted & Normalized Data)



$$C(t) = \frac{d(F(t))}{dt}$$

$$F(t) = \frac{kt^{n}}{1 + kt^{n}}$$

COF-RTD Results

Flow Rate (CCPM)	**Platen Speed (RPM)**	**Pressure (PSI)**	**τ_1 (sec)**	**τ_2 (sec)**
40	40	2	7.21	7.07
80	40	2	5.22	4.85
40	80	2	9.28	7.21
80	80	2	5.90	5.06

Methods Comparison

	DEUVIF-RTD	COF-RTD
Need for image acquisition hardware & software	Y	N
Compatible with actual silicon wafer substrate	N	Y
Compatible with actual retaining ring	N	Y
Compatible with carrier film	N	Y
Need for a dark room	Y	N
Data obtained from entire substrate	N	Y
Need for dyed pad *	Y	N
Data skewed due to wafer substrate shape change during polish **	Y	N
Accurate & precise	Y	TBD

* Dyed pads may have different mechanical characteristics compared to conventional pads

** Wafer shape change leads to hysterisis which in turn leads to uneven load distribution

Future Plans

- Determine accuracy and precision of COF-RTD technique
- Determine how the following parameters affect mean residence time and dispersion:
  - Slurries
  - Pads
  - Pad groove shapes
  - Diamond grit sizes
  - Conditioning recipes
  - Slurry flow rates
  - Wafer pressures
  - Wafer and platen rotational speeds
- Develop comprehensive fluid dynamics model which describes the above observations