Effect of Concentric Slanted Groove Patterns on Slurry Flow during Copper CMP

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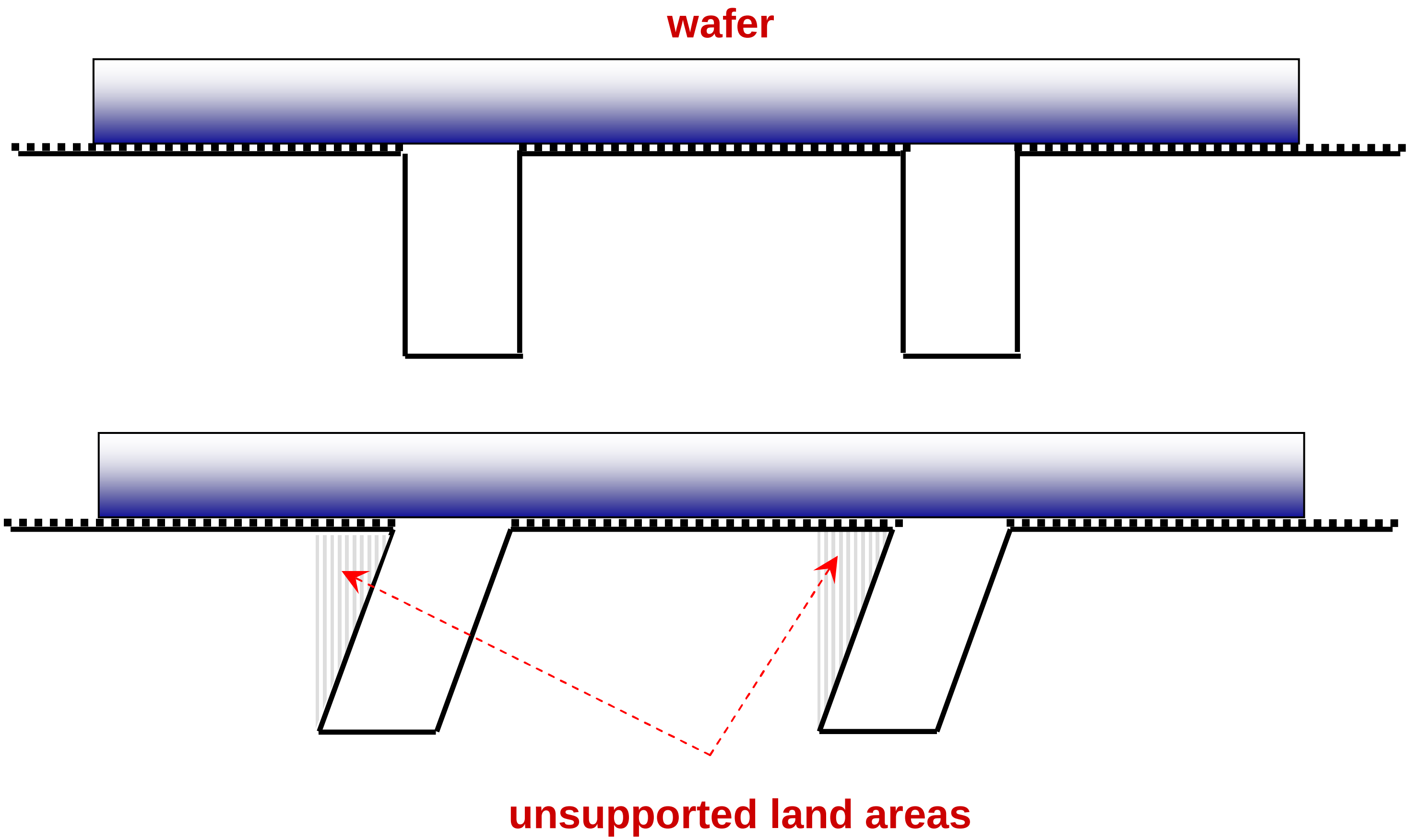
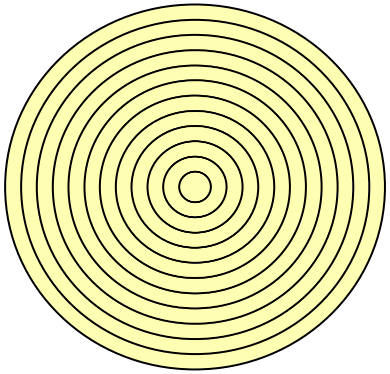
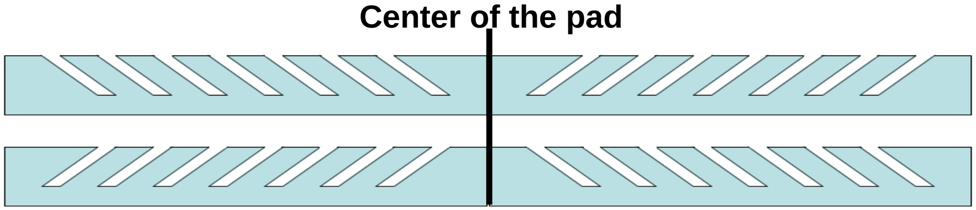
The Idea



Concentric Slanted Grooves

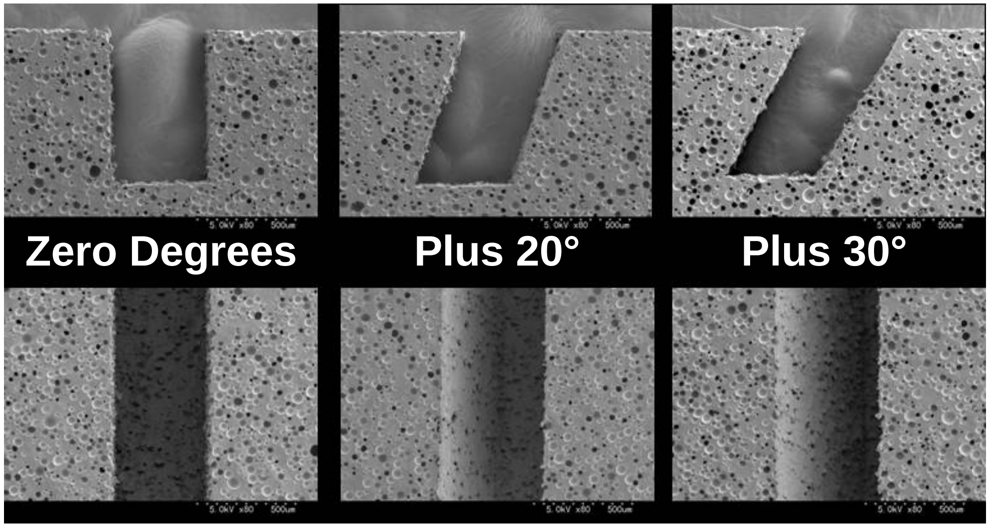


Wafer and pad rotate
counter – clockwise



Positive Direction

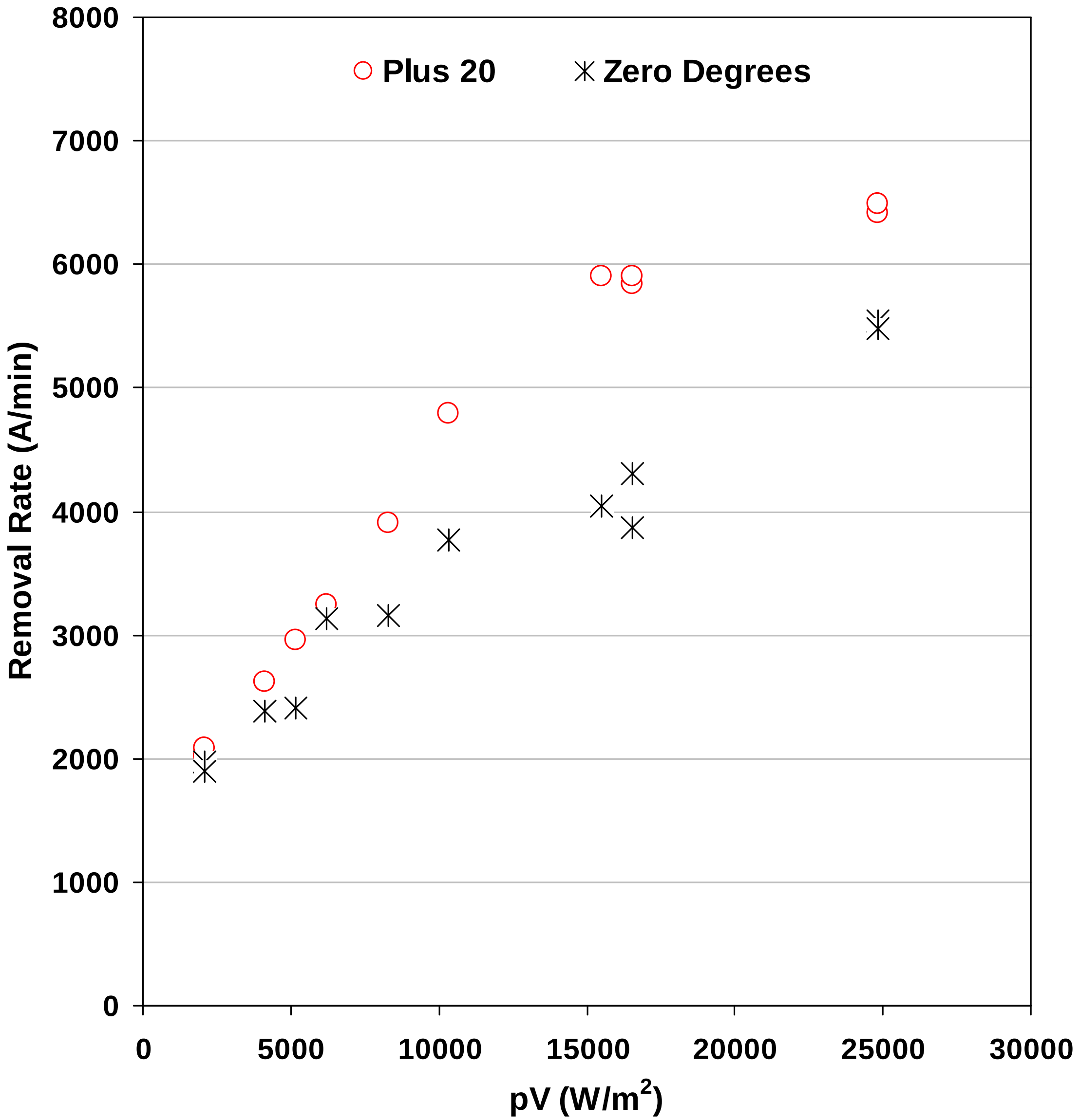
Negative Direction



Side View

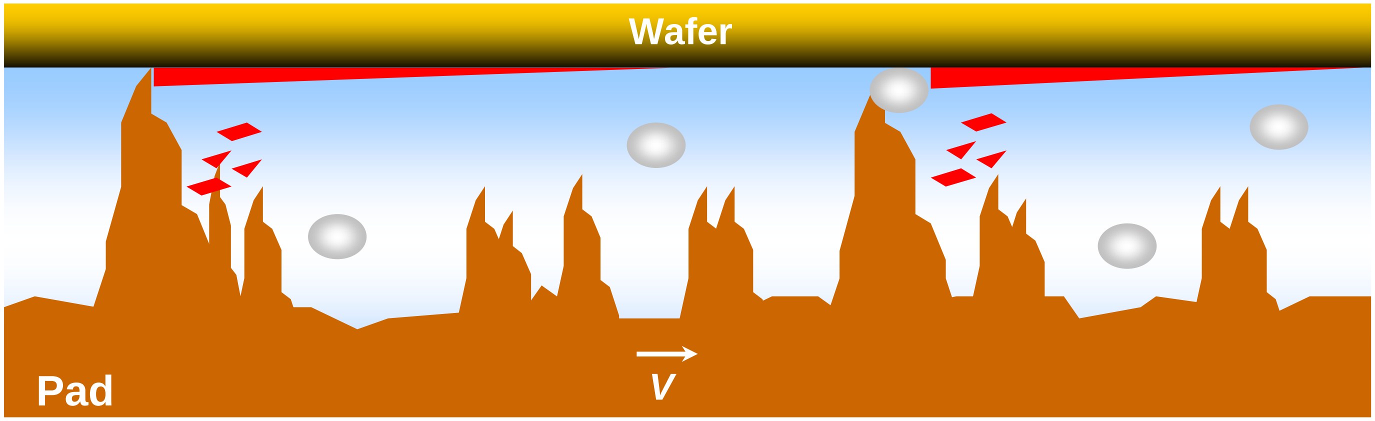
Top View

Motivation

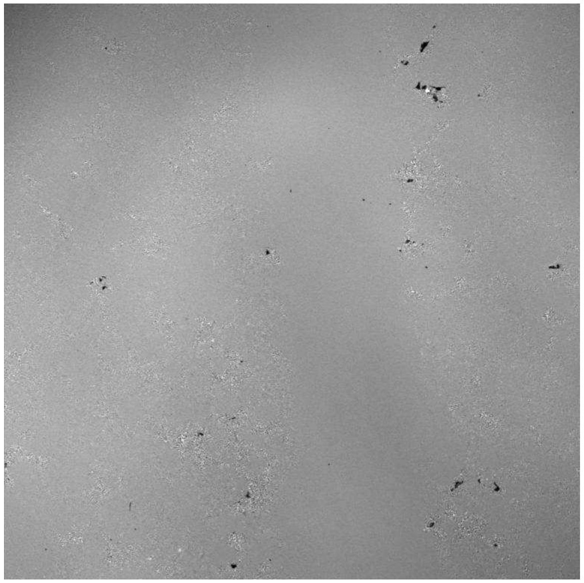


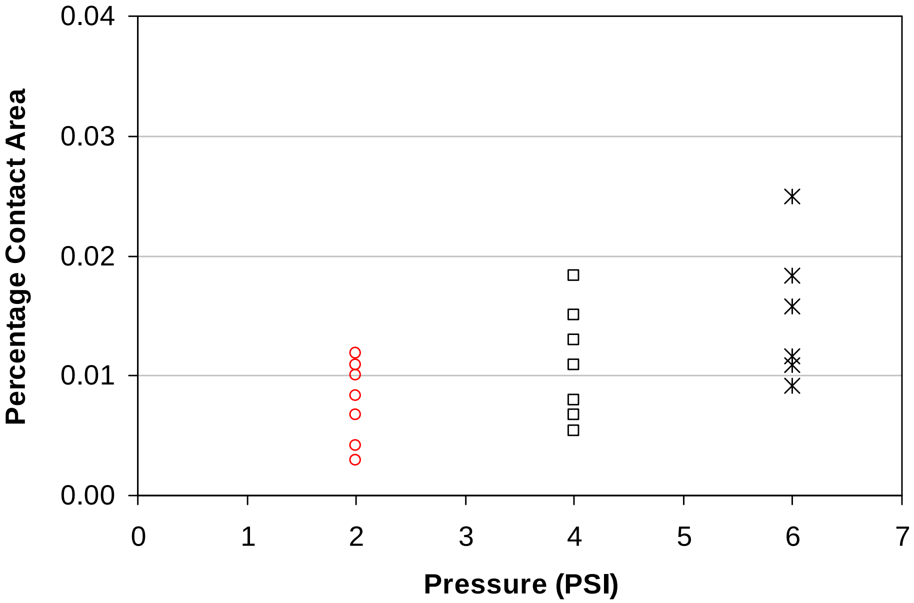
Understanding CMP process hydrodynamics will allow process optimization through "smart" groove design for decreasing COO and positively affecting ESH metrics (i.e. reduction of pad and slurry consumption)

Motivation (continued)

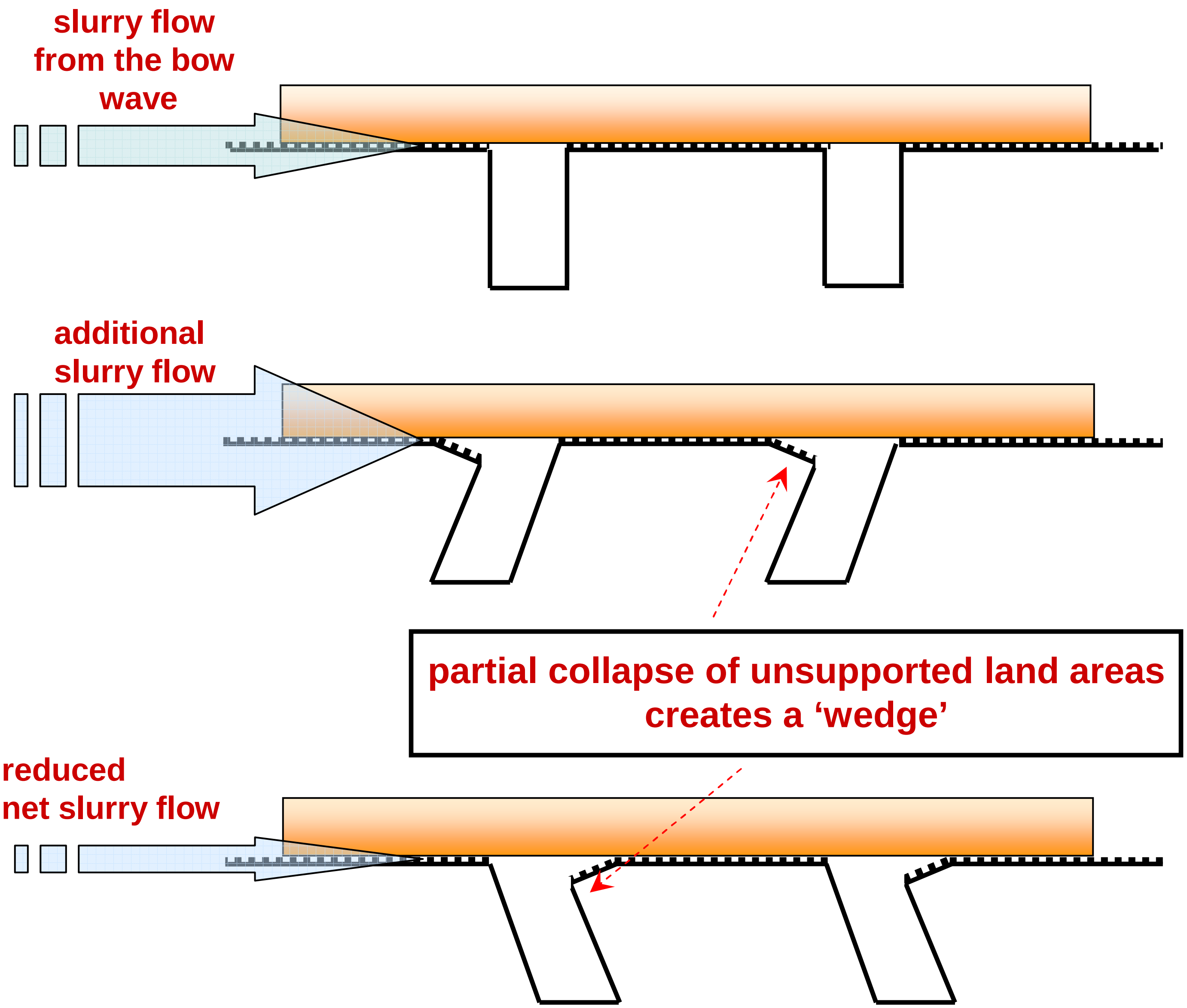


Confocal Microscopy of a Polyurethane CMP Pad





The Hypothesis



slurry flow
from the bow
wave

additional
slurry flow

partial collapse of unsupported land areas
creates a 'wedge'

reduced
net slurry flow

Wafer load is supported by pad land areas.

Wafer load is partially supported by pad land areas and by the slurry.

Slurry must flow continuously INTO the wedge of the 'land area' to balance hydrodynamic forces.

Objectives

- Determine and explain the effect of:

  Degree and direction of groove slanting

  Wafer load

  Slurry flow rate

  Sliding velocity

  on the overall hydrodynamics in a 200-mm CMP process.

- Verify the hypothesized ‘pumping’ mechanism believed to be present when slanted grooves are used during CMP by investigating slurry film thickness in pad – wafer region using Dual Emission UV Enhanced Fluorescence (DEUVEF).

DEUVEF

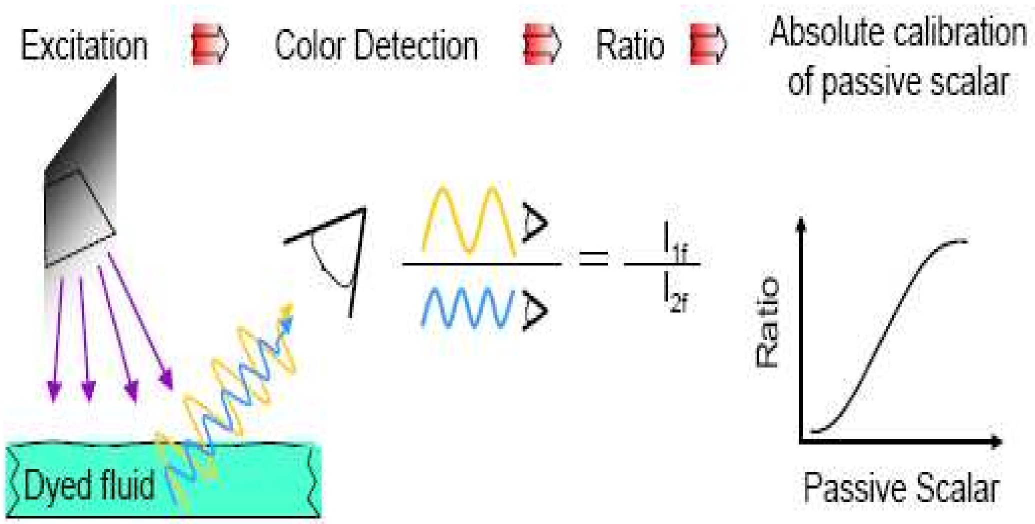
Slurry is tagged with 2 different fluorescent dyes:

Coumarin at 0.25 g/l

Calcein at 1.00 g/l

When excited by UV, each dye emits fluorescent light at a different wavelength

Two CCD cameras capture emitted light



During the excitation process:

1) **UV excites Coumarin**
2) **Coumarin emits fluorescent light**
3) **The light emitted by Coumarin, is absorbed by Calcein**
4) **Calcein then emits fluorescent light**
5) **The intensity ratio of Calcein-to-Coumarin is related to fluid film thickness**

Amount of light (intensity) emitted is proportional to:

Extent of UV radiation

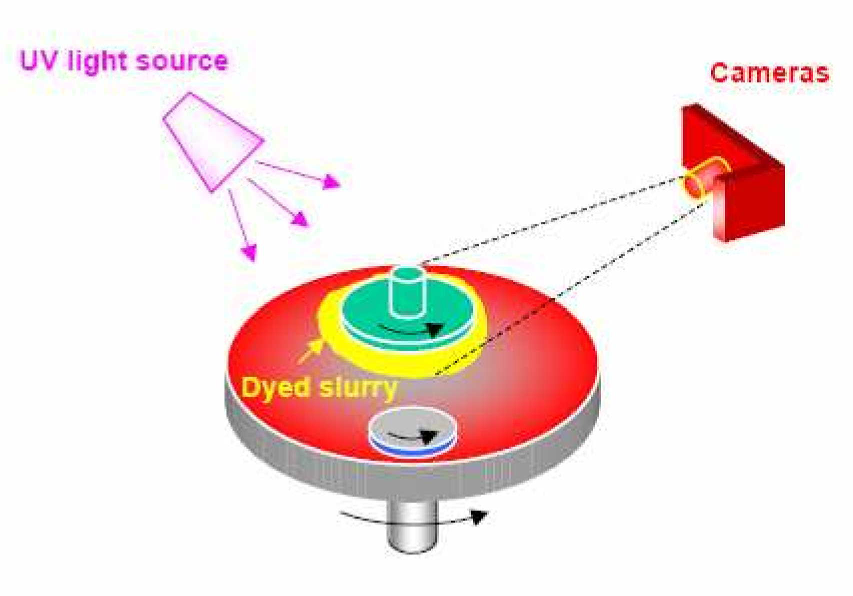
Ability of a dye to convert UV light into fluoresced light

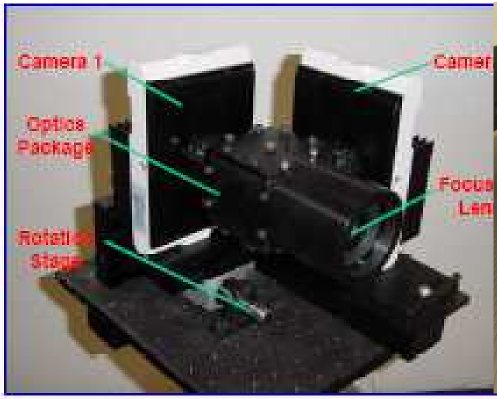
Amount of UV light absorbed

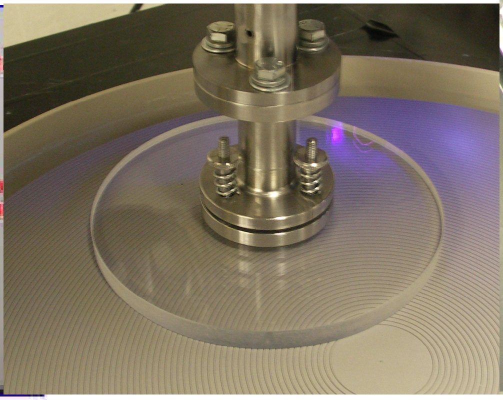
Dye concentration

Amount of dye exposed

UA 200-mm Polisher fitted with DEUVEF Capability



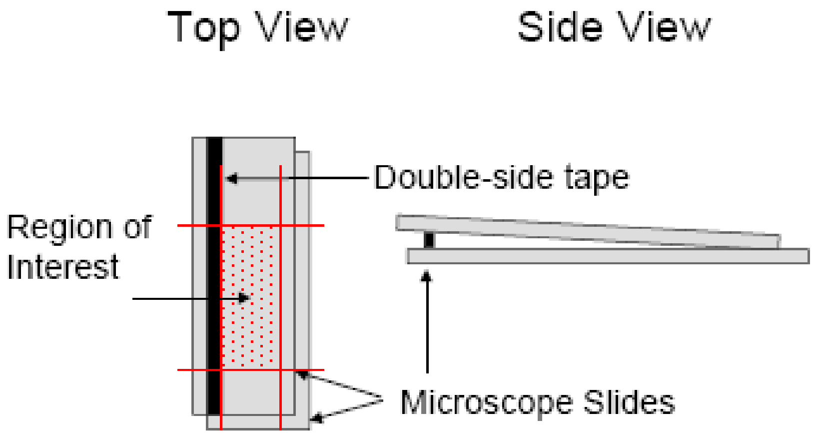




Two CCD cameras are aligned orthogonally and rotationally

The optics configuration allows each camera to record the exact same spatial image, but in a different color (i.e. different ranges of wave lengths)

Intensity – Fluid Thickness Calibration Curve



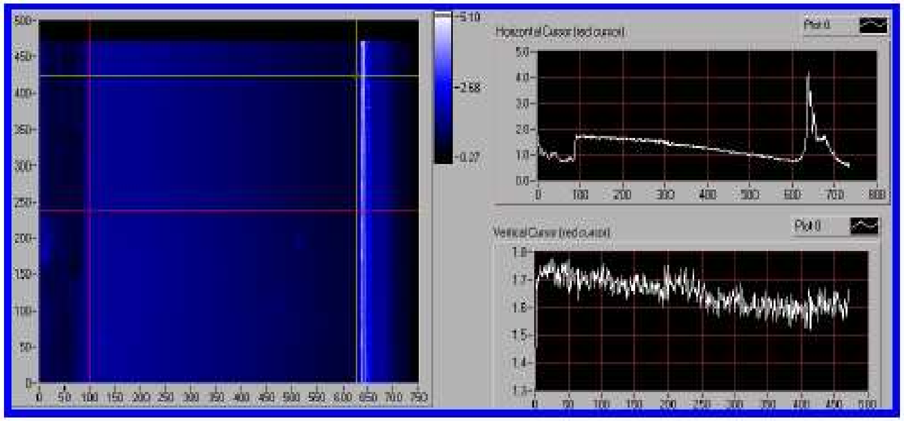
Top View

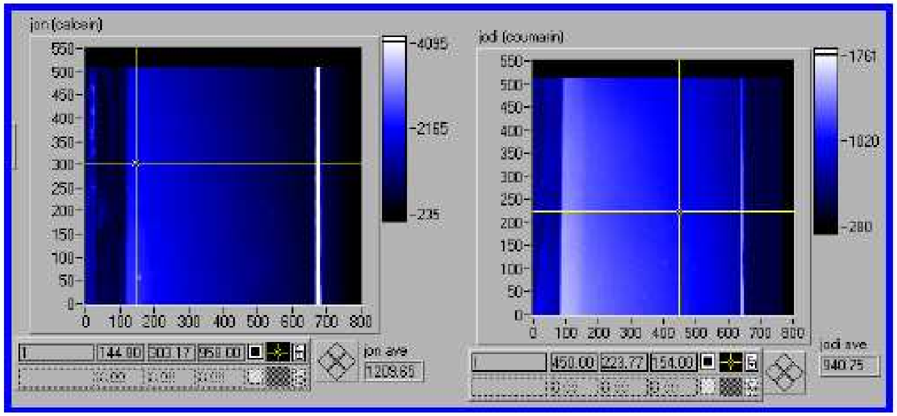
Side View

Double-side tape

Region of Interest

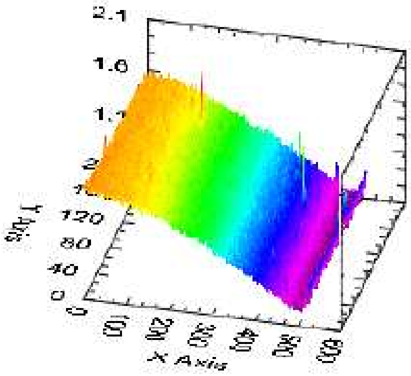
Microscope Slides



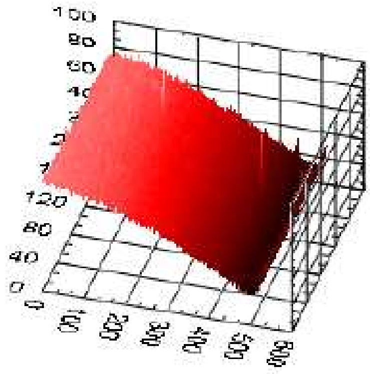


jon ave 1209.85

jodi ave 940.75



Intensity contour



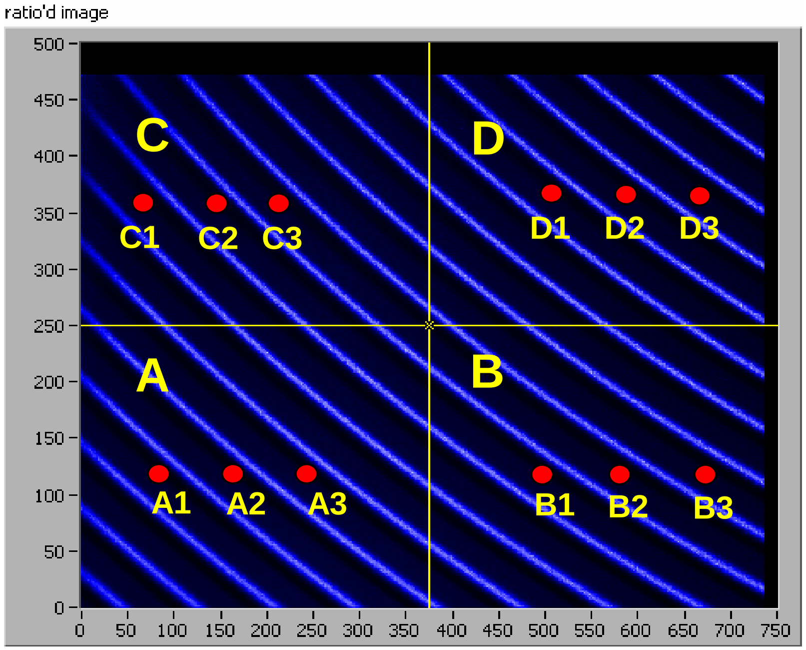
Film thickness contour

Experimental Conditions

- **Constants:**
  - **Pad break-in**
    - **100 grit diamond disc conditioner (TBW)**
    - **30 min with UPW at 30 rpm disc speed and 20 per min sweep frequency**
  - **Slurry**
    - **Fujimi PL-7102 (copper)**
  - **Wafer type**
    - **200-mm glass wafer**
  - **Pad type**
    - **Concentrically grooved dyed polyurethane pads with different degrees and directions of slanting (in-situ conditioning)**

- **Variables:**
  - **Sliding velocity (m/s)**
    - **0.30**
    - **1.20**
  - **Wafer pressure**
    - **1.0 (6,894 Pa)**
    - **2.0 (13,780 Pa)**
    - **3.0 (20,684 Pa)**
  - **Slurry flow rate**
    - **220 cc/min**
    - **165 cc/min**
    - **110 cc/min**
  - **Pad groove design**
    - **Concentric Slanted (Minus 30°, Minus 20°, Plus 20° and Plus 30°)**
    - **Concentric (0°)**

Area Analyzed Under the Wafer



The area analyzed under the wafer was divided into four smaller sites:

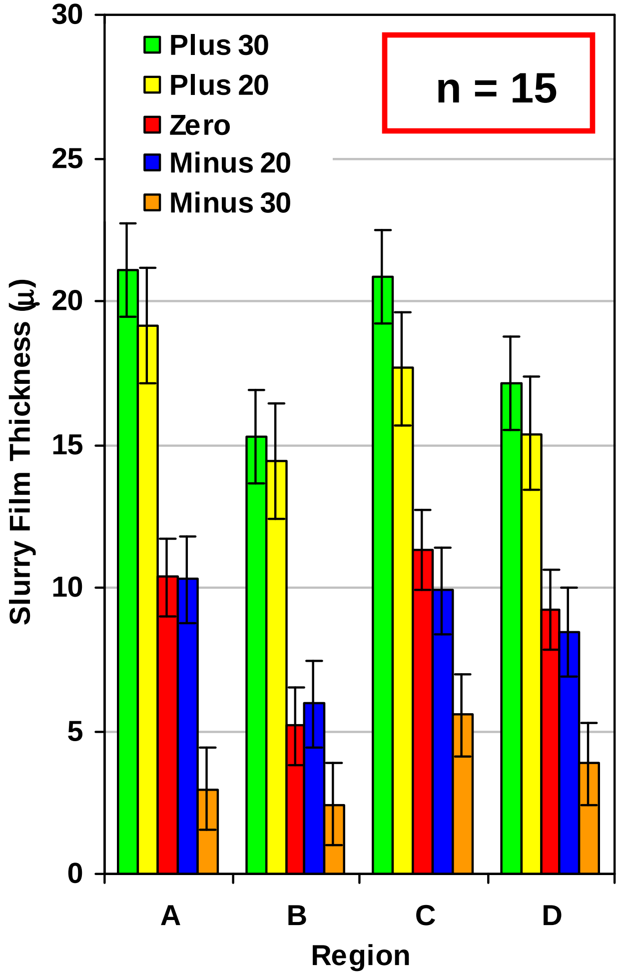
A, B, C and D.

Sites A & C are closer to the edge. B & D closer to the center of the quartz wafer

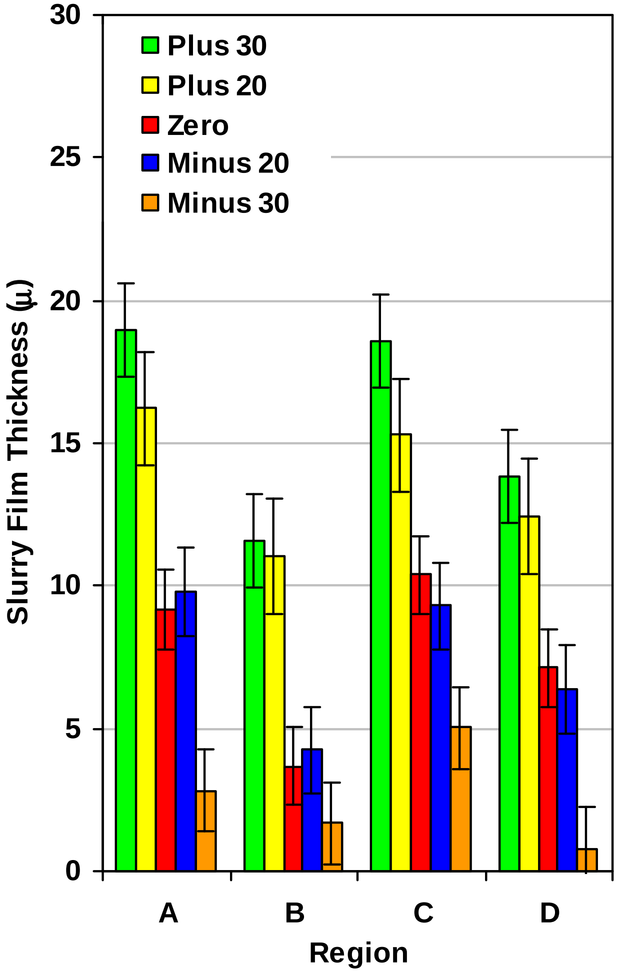
In each site, land areas where analyzed at 3 specific positions (sub-sites)

Values reported for each site (A, B, C and D) are an average of the 3 sub-sites

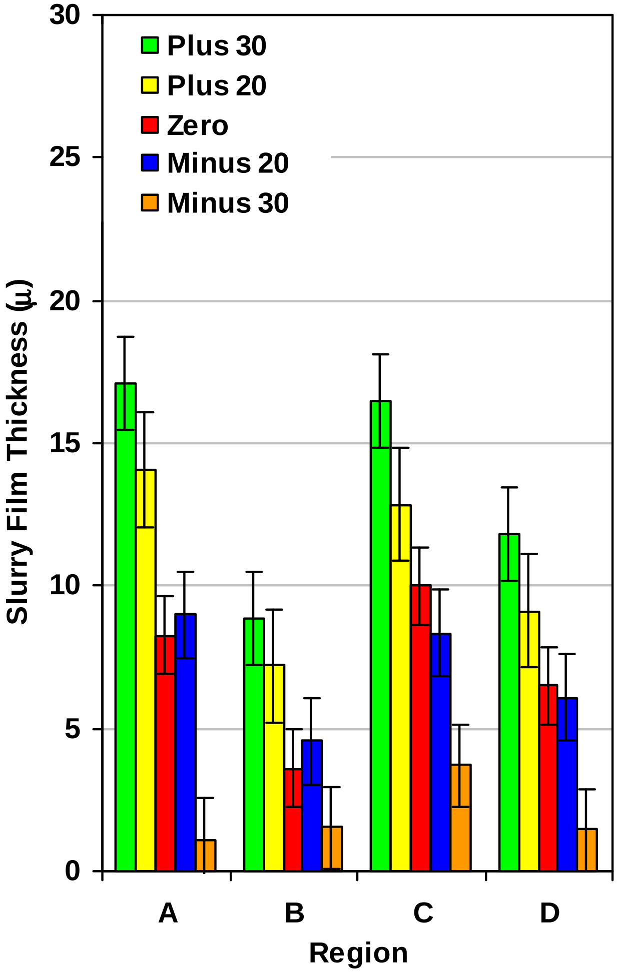
Effect of Groove Slanting on Slurry Film Thickness



1.0 PSI, 1.2 m/s and 220 cc/min



2.0 PSI, 1.2 m/s and 220 cc/min

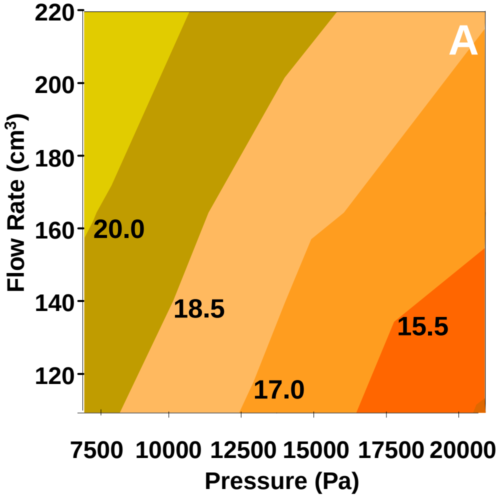


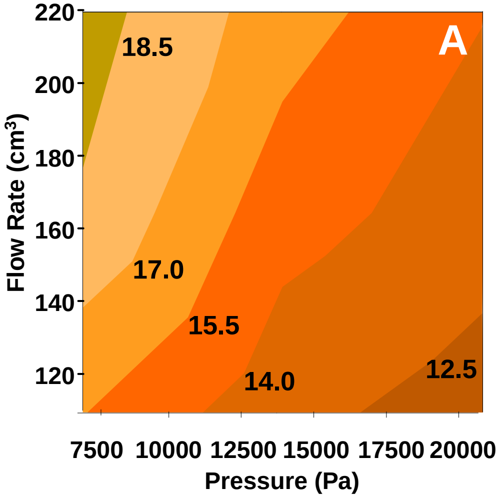
3.0 PSI, 1.2 m/s and 220 cc/min

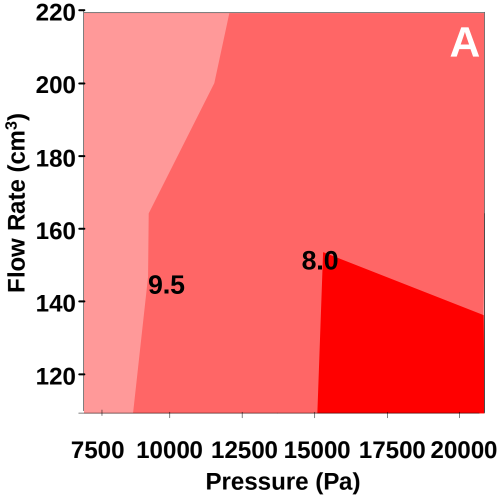
Slanting the grooves towards the edge of the pad (i.e.. positive direction) contributes to slurry flow onto the pad land areas

Not slanting, or slanting the grooves towards the center of the pad (i.e.. negative direction) reduces slurry flow onto the pad land areas

Effect of Pressure and Flow Rate on Slurry Film Thickness

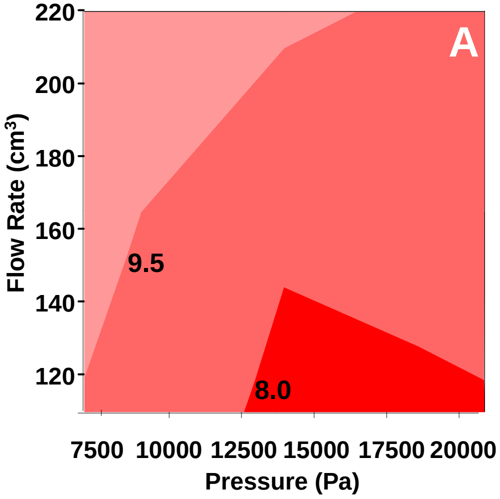

Plus 30°

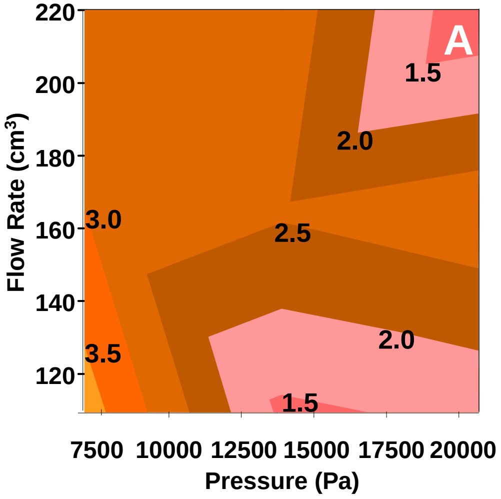

Plus 20°


0°

Slurry film thickness increases with flow rate, showing evidence of saturation at higher rates

Higher pressures further compress pad asperities thereby diminishing slurry flow in the land areas

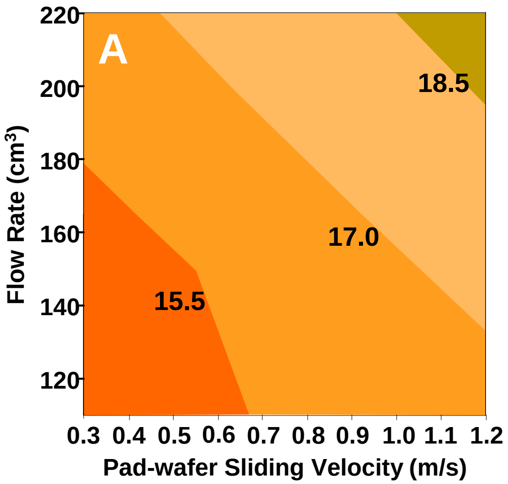

Minus 20°


Minus 30°

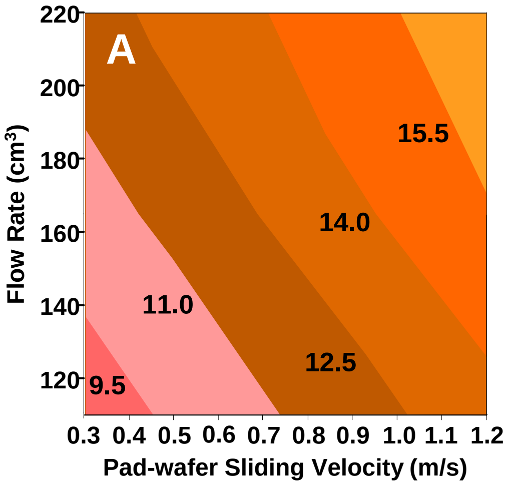
Sliding Velocity = 1.2 m/s

Effect of Sliding Velocity on Slurry Film Thickness

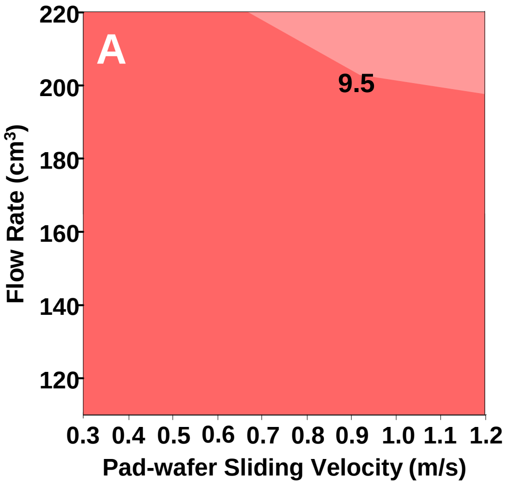
Plus 30°



Plus 20°

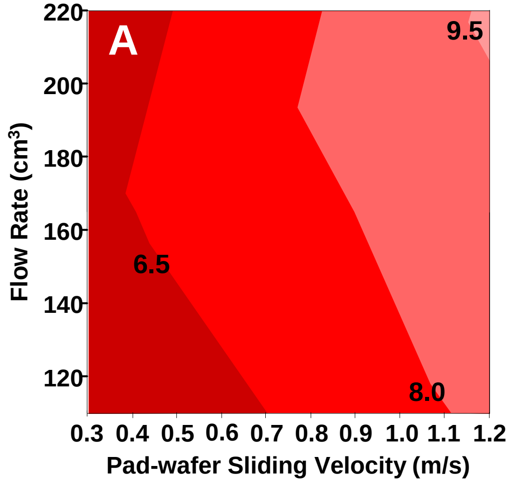


0°

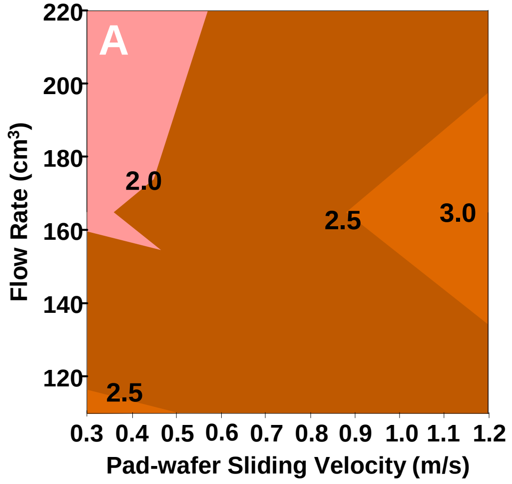


Increasing sliding velocity, increases the slurry film thickness

Minus 20°

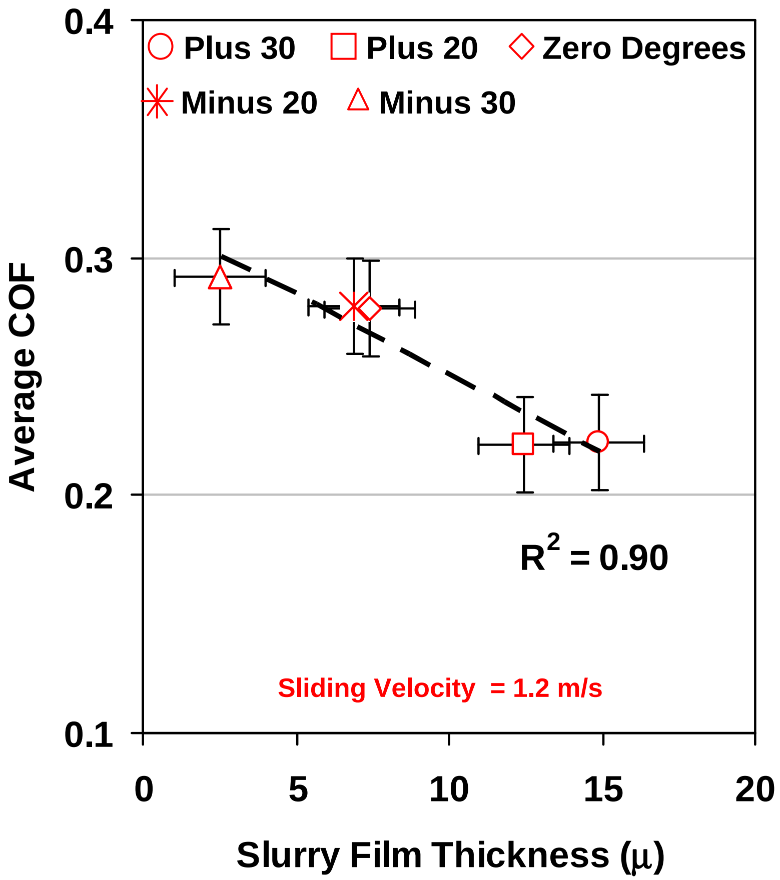


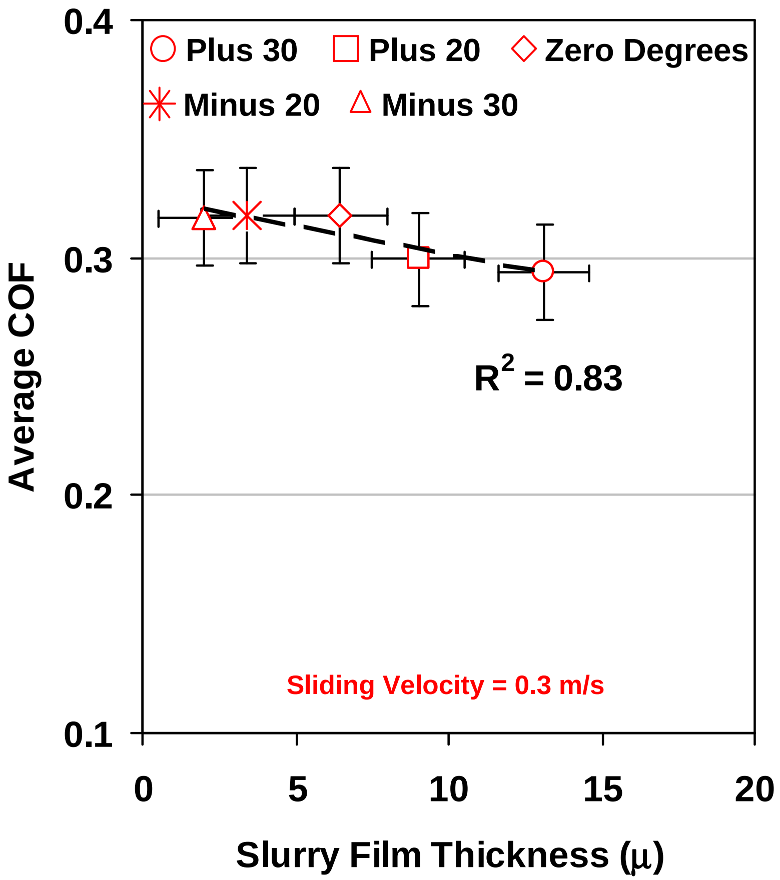
Minus 30°



Pressure = 3.0 PSI

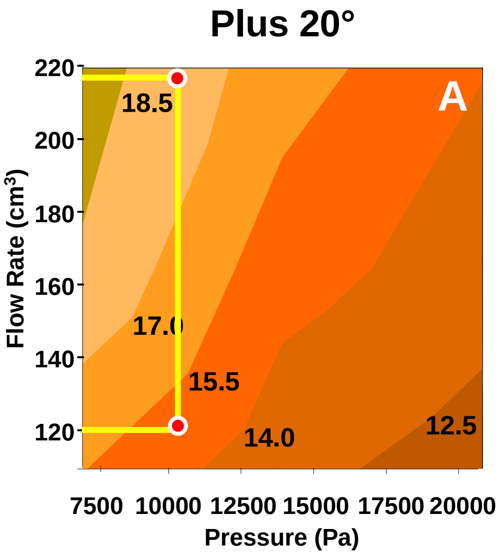
Effect of Slurry Film Thickness on the Lubricity of the System

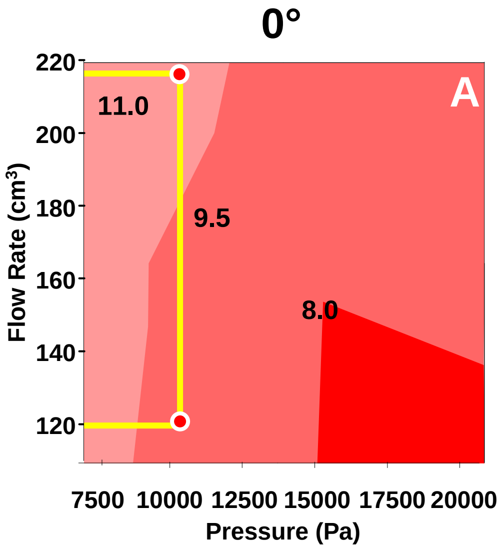




Downward linear correlation between COF and slurry film thickness
Groove slanting impacts lubricity
May be helpful in reducing defectivity

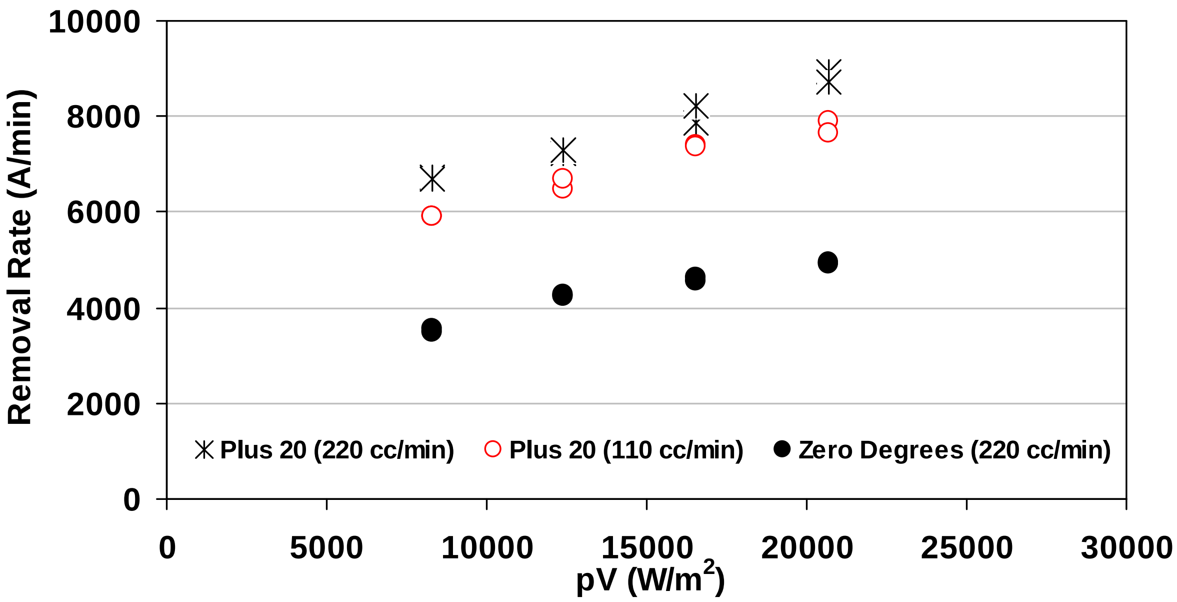
Effect of Groove Slanting on EHS and COO





At any given sliding velocity, pressure and flow rate, Plus 20° shows higher film thickness at the pad land area compared to 0°

This can have significant pad asperity – wafer contact area ramifications that affect RR and defectivity



RR slightly decreases as flow rate is cut by 2X for the Plus 20° pad

However, at this lower flow rate, the Plus 20° pad has significantly higher RR than the 0° pad at full flow

Summary

- DEUVEF measurement technique was successfully developed for a 200-mm CMP system.

- DEUVEF results showed that:

  - Film thickness changed as a function of degree and direction of groove slant. Hypothesized 'pumping' mechanism for the slanted groove pads was confirmed.

  - Slurry film thickness decreased with increasing pressure

  - Increasing sliding velocity or flow rate, increased slurry film thickness at the pad-wafer interface (consistent with our passive pump hypothesis).

  - Sites A and C (close to the bow wave) showed higher film thickness than sites B and D. Can DEUVEF tell us something about WIWNU?

Summary (continued)

- COF showed a downward linear correlation with slurry film thickness.

- We saw that certain groove patterns lubricate the system more effectively than others … possible approach towards understanding how to strike a balance between high lubrication and extreme contact such that number of defects may be reduced without significantly affecting removal rates.

Acknowledgements

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