Polishing Pad Characterization with an In-situ Metrology Instrument

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Outline

- It's the pad!
  - Pad properties associate with process metrics
  - *pad*IMAGER system anatomy and features
  - Groove depth/width measurement
  - Potential under-performances
  - Porosity measurement
  - Roughness/micro asperity
- Or…is it? (When it's not the pad)
  - The conditioner
  - The slurry
  - Perhaps the others
- *pad*IMAGER Applications
  - Sustaining
  - Development
  - Consumables evaluation

It's the pad!

- When the CMP process goes out of bound, the first question raised is often: "Do the pads cause the process problems?"

- If a pad change would solve the issue, then when it happens again, the logical solution is:

Yank the pads and put on a new set!

✓ Tessellation's *pad*IMAGER in-situ metrology instrument†† gives you a microscopic examination of the fundamental parameters of the pad to determine when the pad is the cause.

†† PATENT PENDING

Pad Properties Associate with Process Metrics

- **Removal rates/WTW uniformity:** pad roughness, porosity, and groove dimensions
- **WIWNU:** pad profile uniformity, groove dimensions, roughness, compressibility
- **Feature dishing/erosion:** pad roughness, porosity, total pad thickness (top pad stiffness), compressibility (top/sub-pad), hardness
- **Pad Life (wafers processed per pad):** initial groove depths, pad wear, groove clogging.

*pad*IMAGER Characterizes

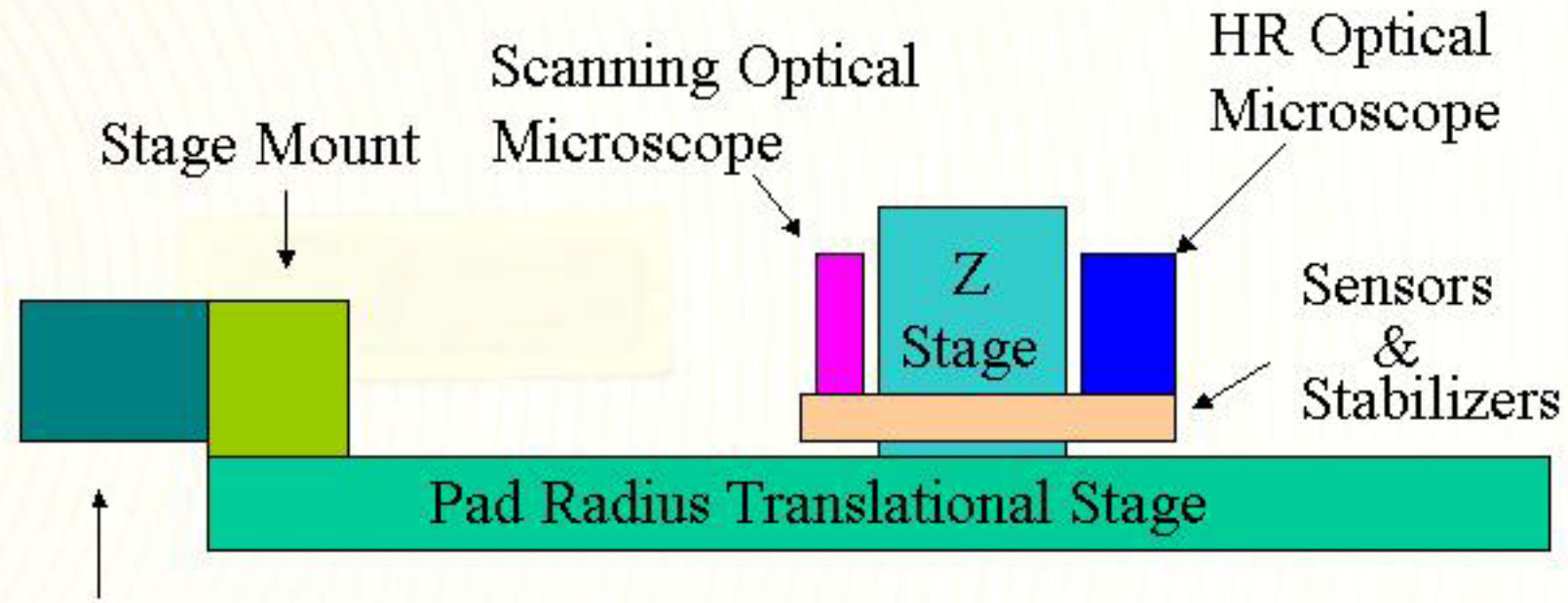
- Effect on RR/WTWNU: **pad roughness, surface porosity, groove dimensions**
- Effect on WIWNU: **pad profile uniformity, groove dimensions, roughness**
- Effect on feature dishing/erosion: **pad roughness, surface porosity, total pad thickness**
- Pad life: **groove's depths, pad wear, groove clogging**

Innovative Design ††

- **Inspect by imaging:** measures pad features accurately & unambiguously.
- **In-situ analysis:** eliminates bias information due to pad demounting.
- **Full pad coverage:** identifies topographic averages and anomalies.
- **Versatility:** powerful but compact design allows the *pad*IMAGER to fit in all polishers currently on the market.

†† PATENT PENDING

*pad*IMAGER Anatomy ††

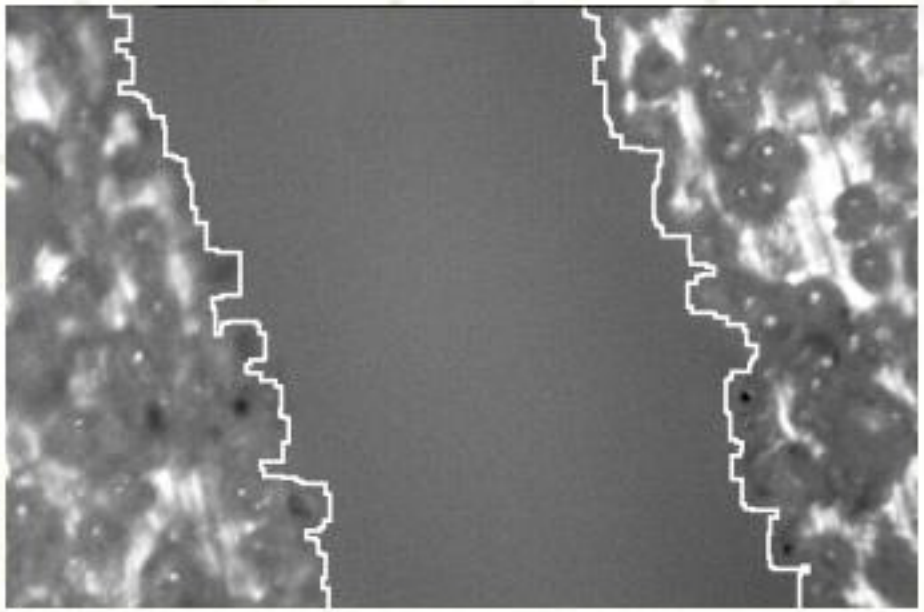


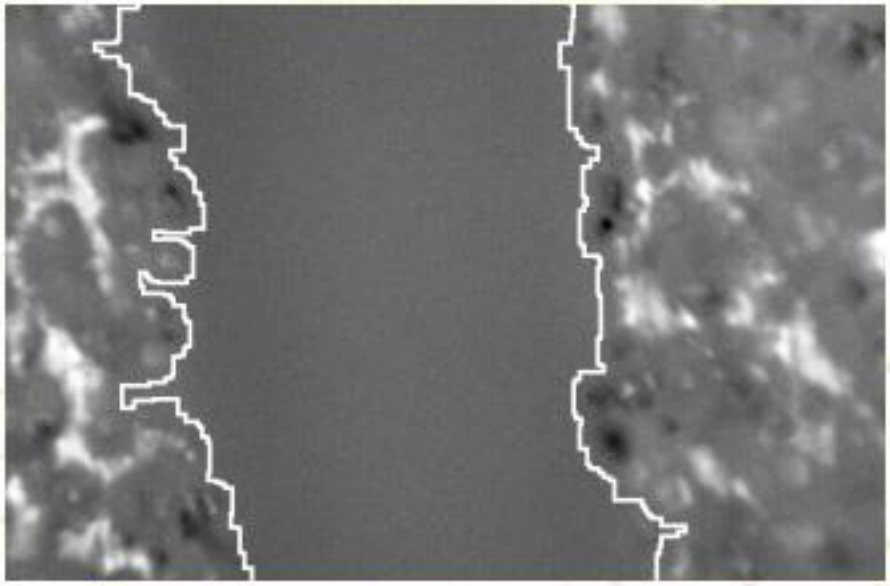
†† PATENT PENDING

Groove Width/Depth Measurement

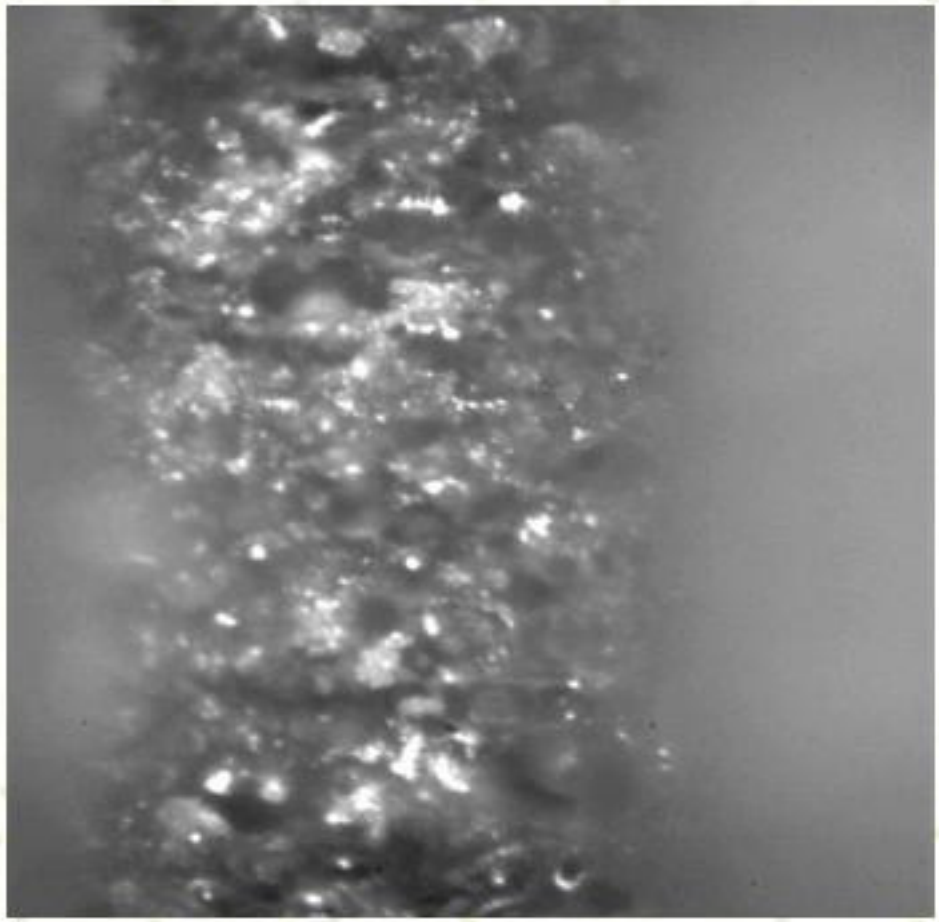
- Groove width/depth affect:
  - Removal rate
  - Uniformity
  - Pad life
- Groove dimensions measurement:
  - Advanced groove width and depth recognition algorithm
  - Averaging groove over large area

Groove Width

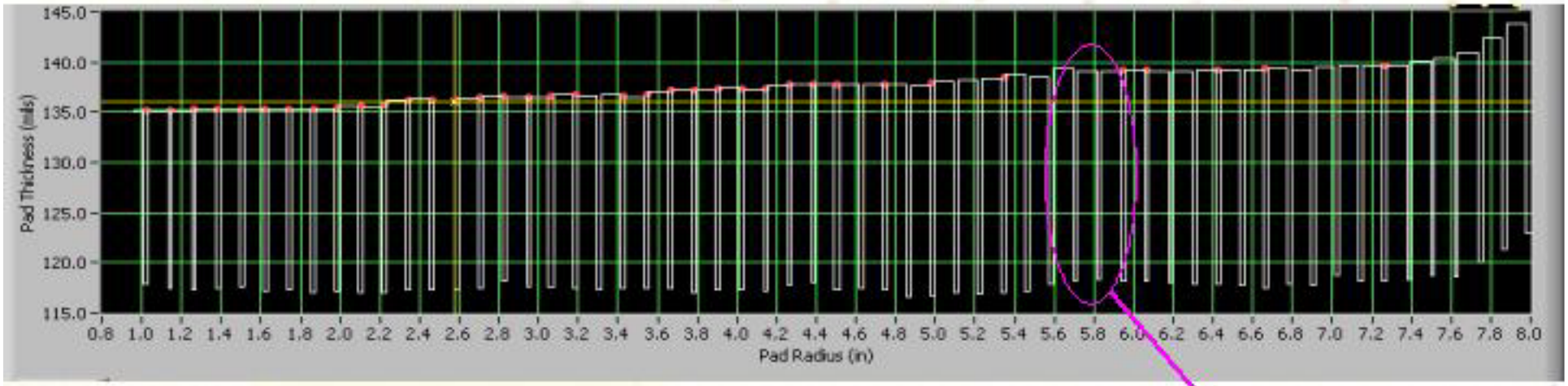




Groove Depth

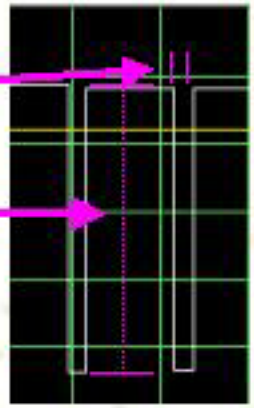


Pad Profile

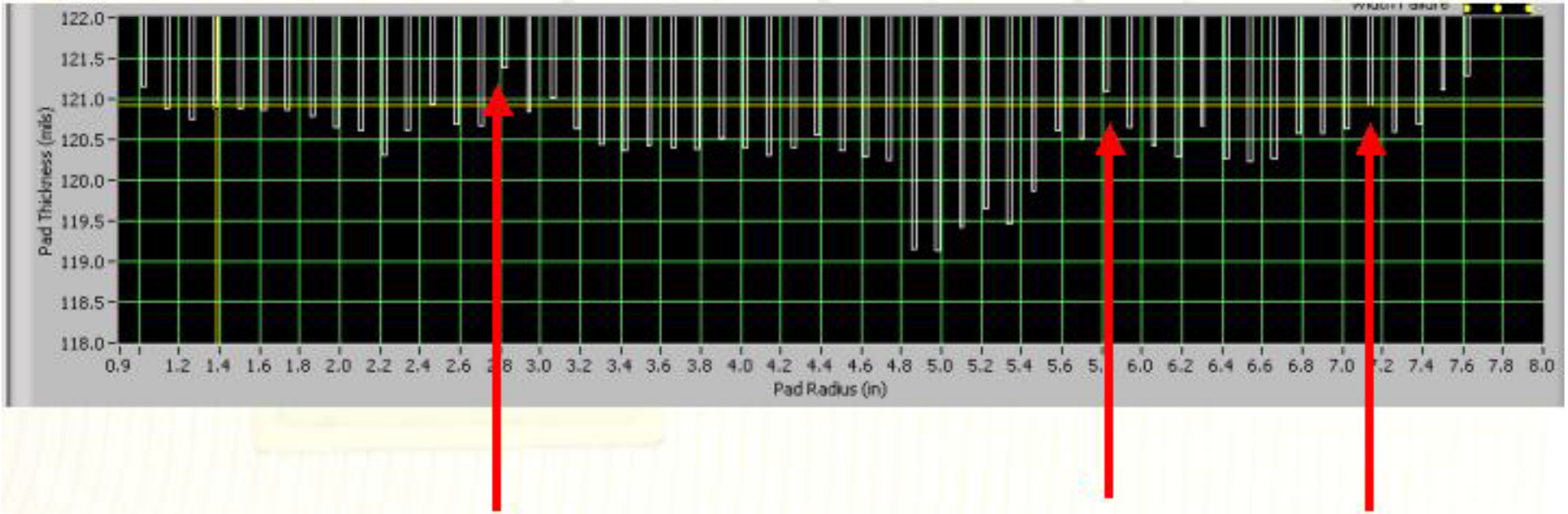


– **Radius scan:**

- Groove width
- Groove depth.



Magnified Grooves' Bottoms

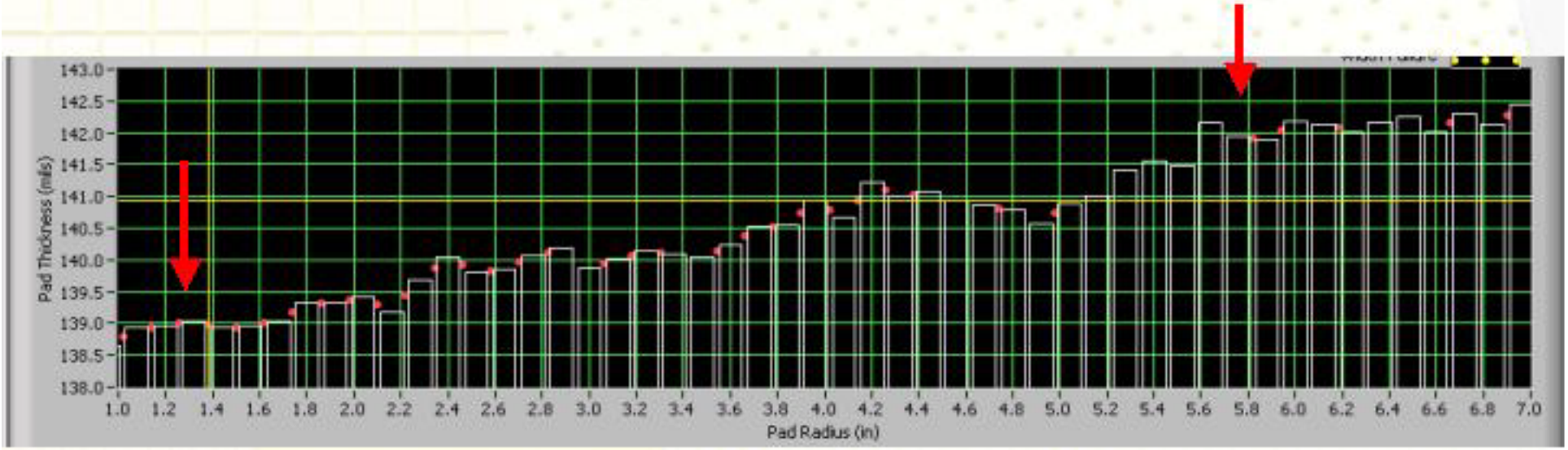


- Areas to be seen as "bald-spots" at the end of pad life.
  Assuming pad wear rate is uniformed, pad life is determined by shallowest grooves (red arrows), not the average groove depth.

Top Pad Profile

- Top pad topography affects:
  - Uniformity
  - Pad life

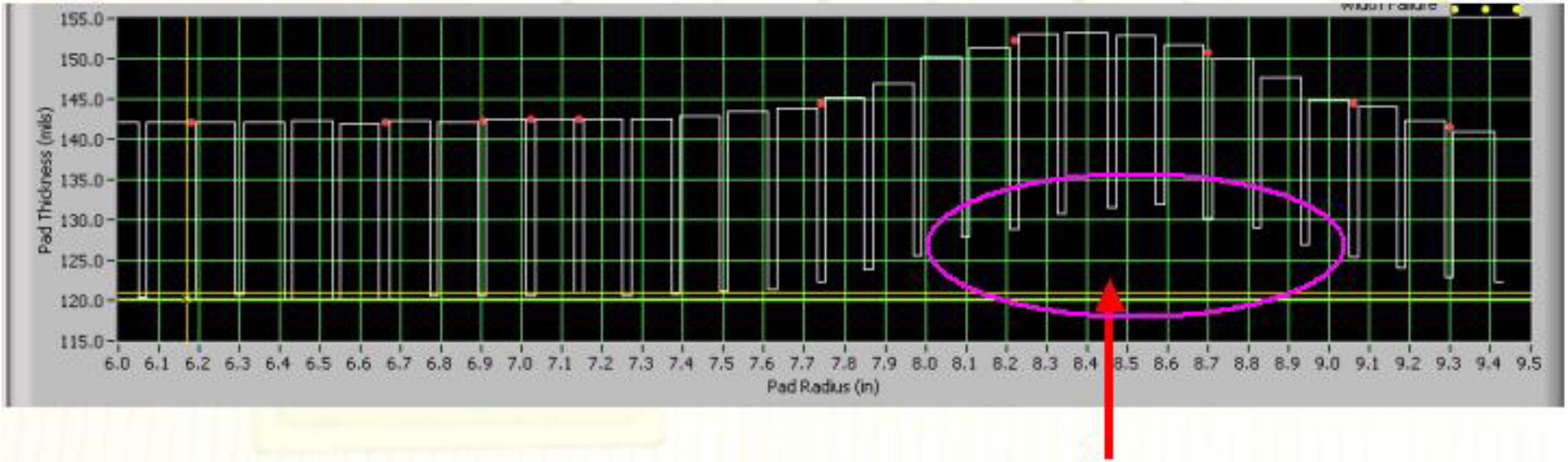
Uneven Pad Profile



- Uneven pad profile affects WIWNU and pad life:

  Assuming wafers are perfectly flat, uneven pad can create a wafer uniformity issue. In the above Figure, there is a 3 mils different across 5" of pad (between 2 red arrows), affecting WIWNU and pad life.

Beyond Groove Depths and Conditioning Profile

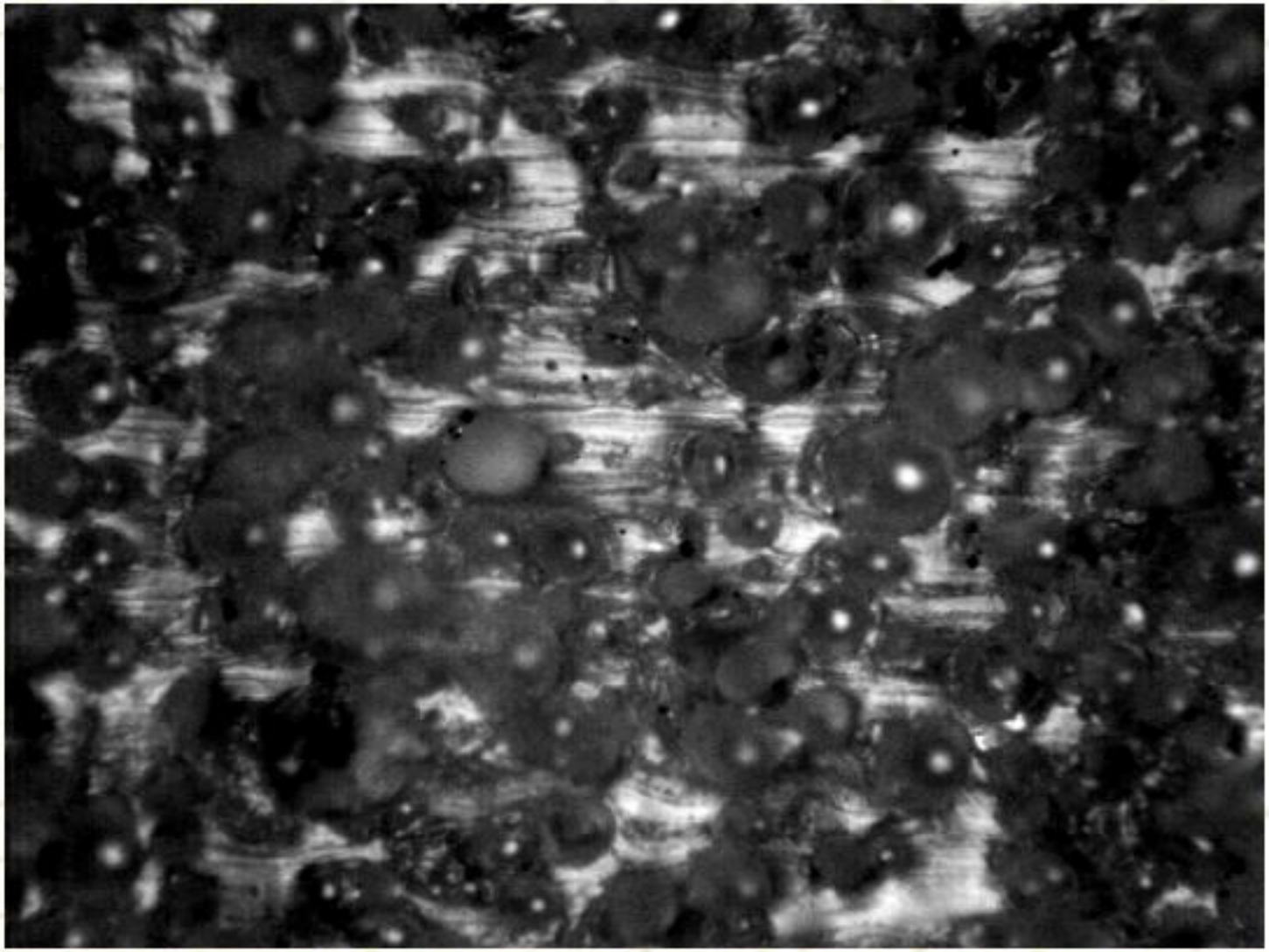


- An Unexpected Pad Issue: **the above Figure identifies an air inclusion underneath the pad, a result of improper pad mounting method, which can cause uneven pad profile, affecting wafer uniformity as well as shortening pad life.**

Porosity

- Porosity affects:
  - Removal rate
  - Uniformity
  - Dishing and erosion
- Porosity measurement:
  - Flat area recognition, outlining pores
  - pore-to-land area ratio

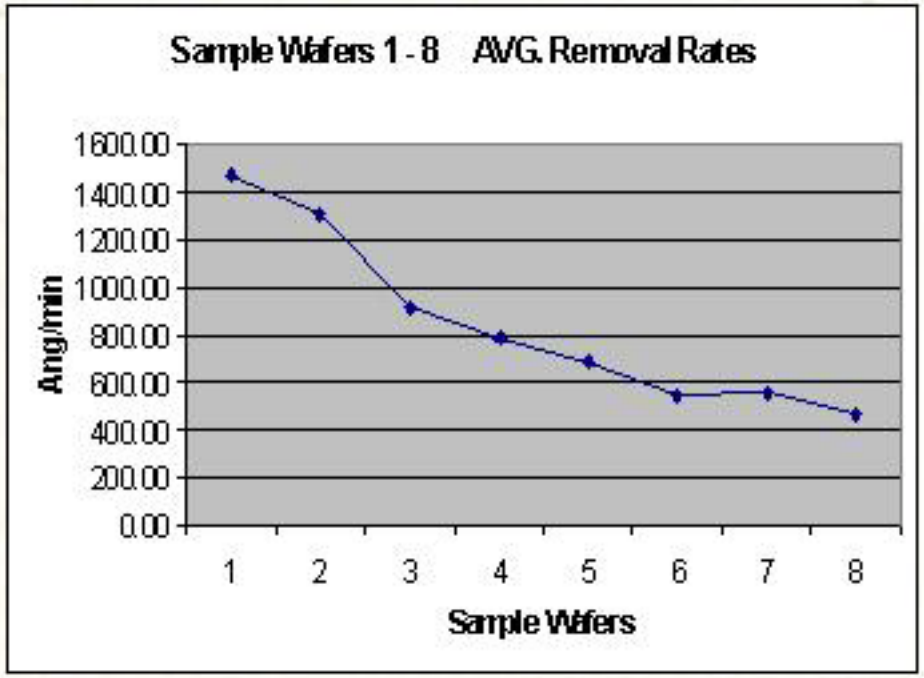
IC1010 Pores image

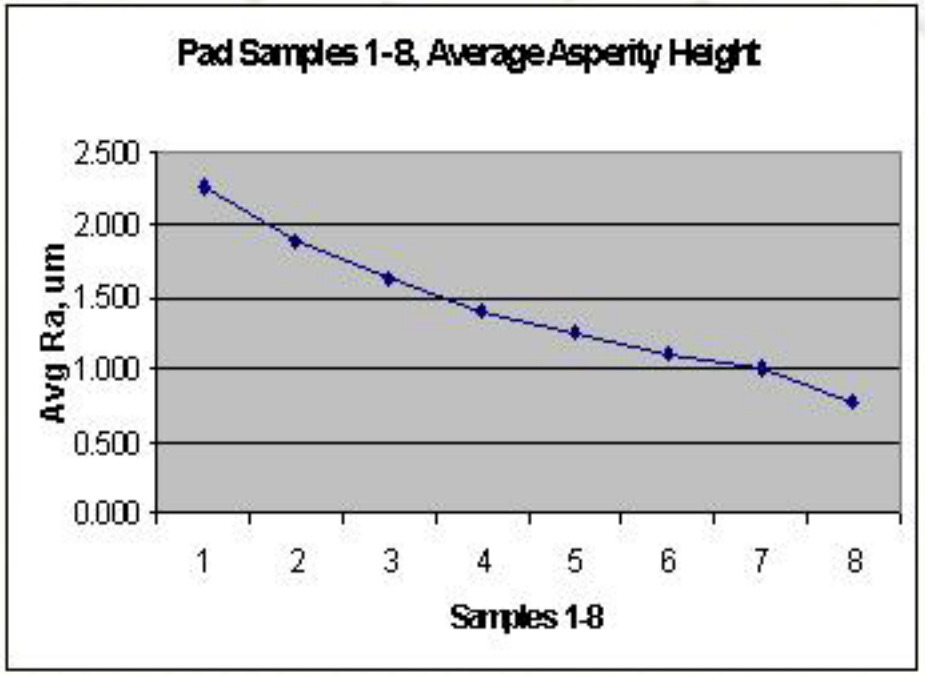


Pad Roughness/Micro Asperity

- Pad roughness affects:
  - Removal rate
  - Uniformity
  - Dishing and erosion
- Roughness measurement:
  - high lateral resolution, millimeter sampling size capability
  - high vertical resolution, large dynamic range

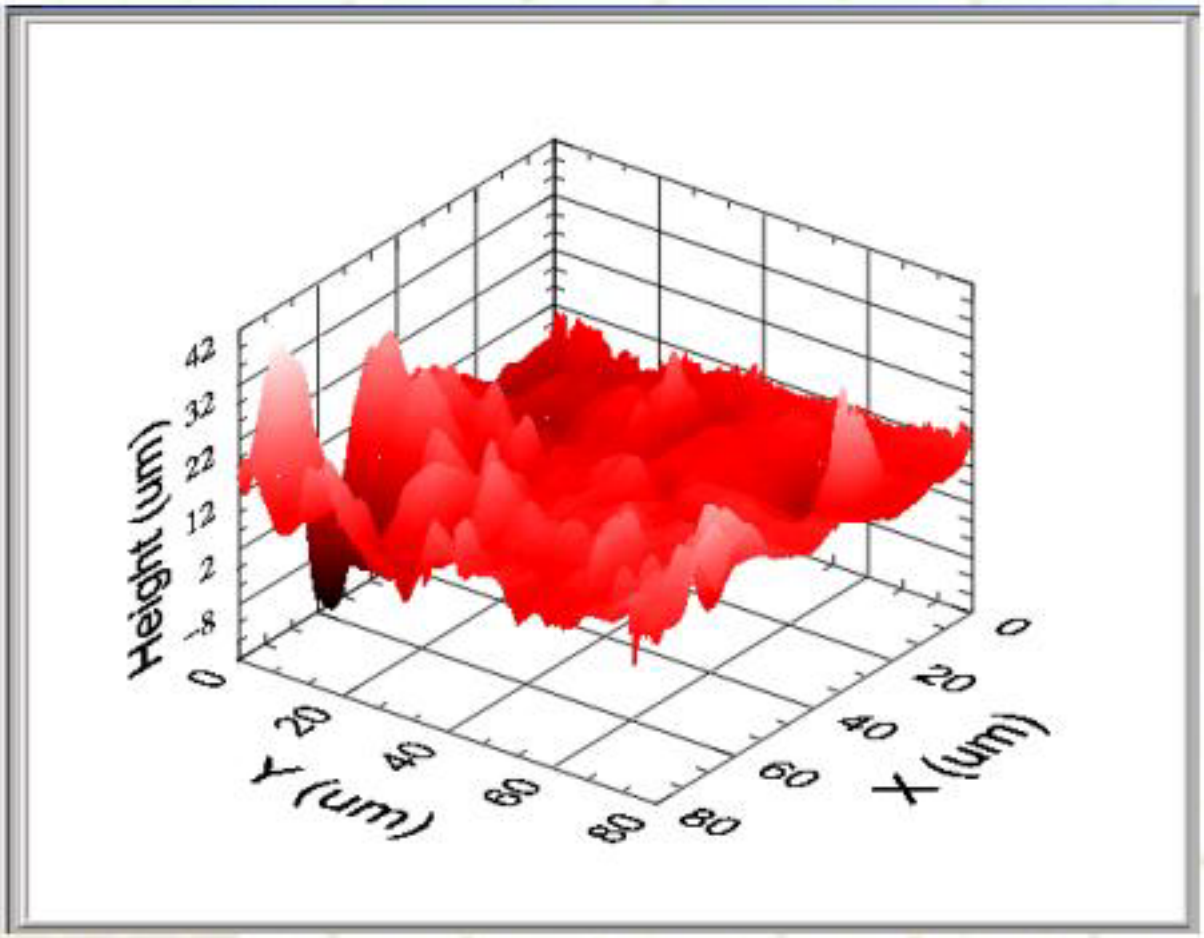
Removal Rate Vs Micro Asperity



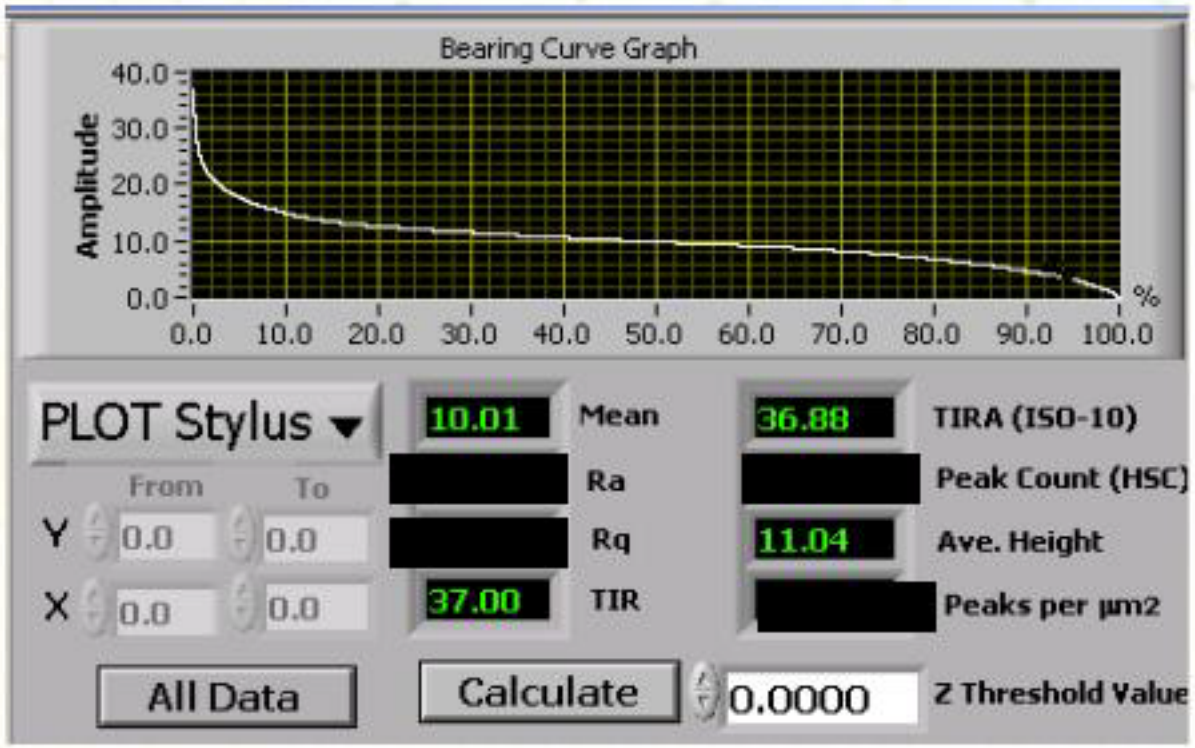


Data from M. Oliver et al, ECS October 2000

IC1010 Micro-spot Scan



IC1010 Micro-spot Analysis



When It's NOT the Pad

- To achieve good CMP metrics, the pads should meet certain quality.
- However, if their incoming thickness, groove dimensions, porosity, hardness, etc., are as expected, then more likely, it is beyond the pad's capability to cause any process instability. The guilty party is one of the other integral or independent parameters.
- In this case, when the CMP process goes out of bound, it is caused by conditioning disk, slurry, tool, or perhaps, wafers.

✓ The *pad*IMAGER can help pinpoint many of the root causes, and help taking the guess work out of the troubleshooting.

The conditioner

- A poor pad conditioning time profile erodes pads unevenly, in turns, creates a WTWNU (global uniformity) issue.

✓ One can map the top pad profile with the *pad*IMAGER and optimize the conditioning time profile to shape a flat polishing surface to improve wafer uniformity.

- An abnormally aggressive or under-performed conditioner changes pad roughness, in turns, alters polishing rate, uniformity, and dishing/erosion.

✓ One can check the roughness and actual pad wear rate (pad thickness change per unit time) with the *pad*IMAGER to determine if the conditioner is overly aggressive or too dull, and make the appropriate adjustments.

The Slurry

- If the interaction between the pad and the conditioner create a surface that is optimized for wafer polishing, they can not contribute to any process instability.

- Problems with removal rate, uniformity, dishing/erosion can be an issue of the percent solid, particle size distribution, or active chemical concentration in the slurry.

✓ One can characterize the pad surface with the *pad*IMAGER to assure the polishing surface is optimized, and redirect the focus on the slurry.

Perhaps the Others

- ✓ If the *pad*IMAGER indicates a good polishing surface and the slurry is as expected, it is safe to assume that the CMP consumables are as stable as they can be.

- There is a good possibility that the tool or an odd batch of wafers may cause the process instability.

*pad*IMAGER Applications

- PROCESS SUSTAINING:
  - **In-coming Pad QC:** sorts out unqualified pads which may cause process problems.
  - **Troubleshooting:** quickly and efficiently identifies pad and/or conditioning disk anomalies, allowing quick decision to correct the issue.
  - **Improve pad and tool usage:** accurately predicts number of wafers processed based on actual groove's depths and wear rate, allowing scheduled maintenance done at the end of pad life and improving tool uptime.

*pad*IMAGER Applications

- PROCESS DEVELOPMENT
  - **Cycle time:** reduces the time to develop a process. The *pad*IMAGER helps correlate pad metrics to process metrics as well as establish a process baseline, and helps identify anomalies.
  - **Rate/uniformity:** improves conditioning to shape the optimal pad profile and roughness for a given type of pads.
  - **Dishing/erosion:** optimizes pad roughness to achieve better dishing/erosion while maintaining adequate removal rate.
  - **Pad life:** optimizes conditioning process to achieve long pad life while maintaining adequate pad roughness.

*pad*IMAGER Applications

- Consumables Evaluation:
  - **Pad:** characterizes key features that affect wafer performance.
  - **Slurry:** isolates pad effect from slurry effect on wafer performance, optimizes pad surface for accurate slurry evaluation.
  - **Conditioning:** compares conditioning effectiveness on a given pad, and optimizes profile, time, and down force for a given type of conditioner.
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