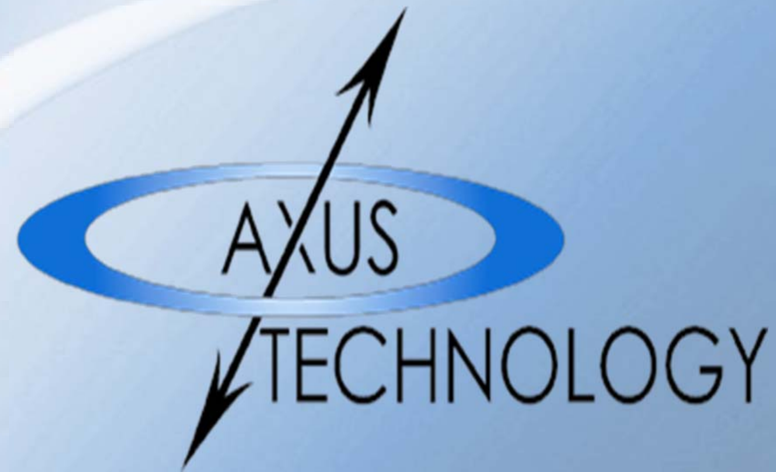

Back to the Future of CMP Non-Uniformity

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Agenda

- Original multi-wafer templates
- Rigid plate carriers
- Advances for 200-450mm
- BEOL need example
- Back integration for 150mm
- New multi-wafer templates
- Summary

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Multi-Wafer Templates

- Original CMP tools fashioned from prime wafer polishing machines
- Multi-wafer templates were used for Ox/W
  - 125mm W uniformity was so bad that wafers were stopped in middle to rotate 180^0
- Single wafer rigid carriers introduced
  - Referred to as back-referencing carriers
  - Included features like back-pressure for NU

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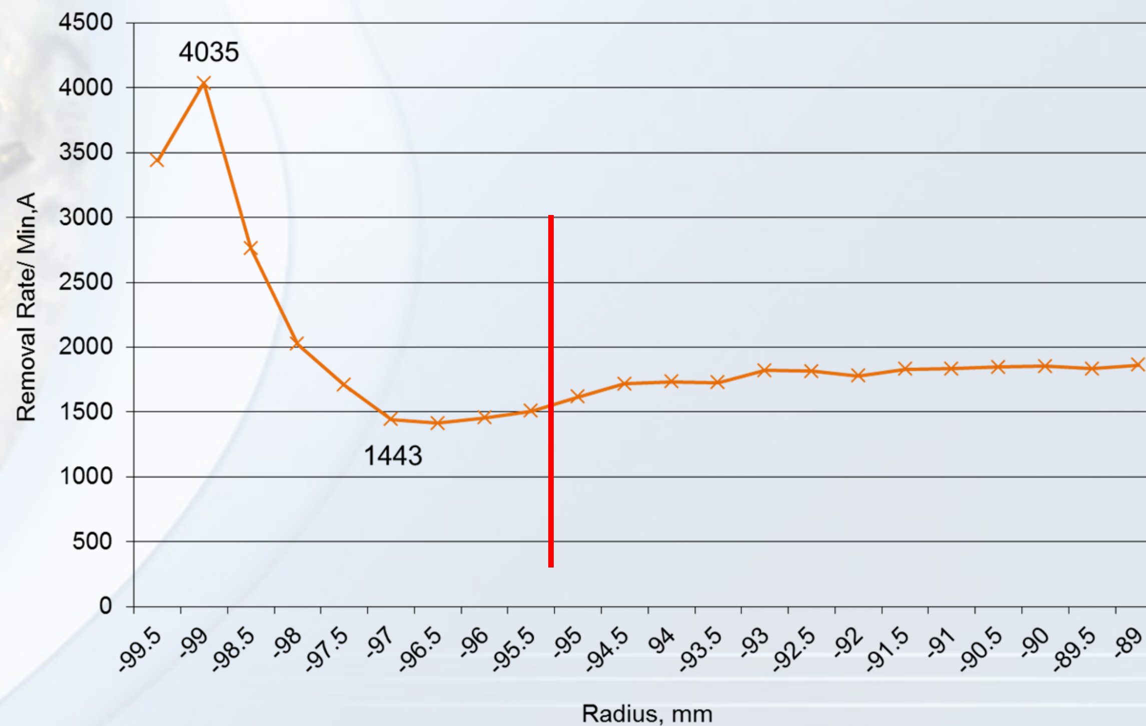
Rigid Plate Carrier Edge Exclusion

- Best NU only achieves 5mm edge exclusion
- Requires high downforce and slow speeds
  - Incompatible with most modern processes



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200mm Mirra Taken Through Upgrades

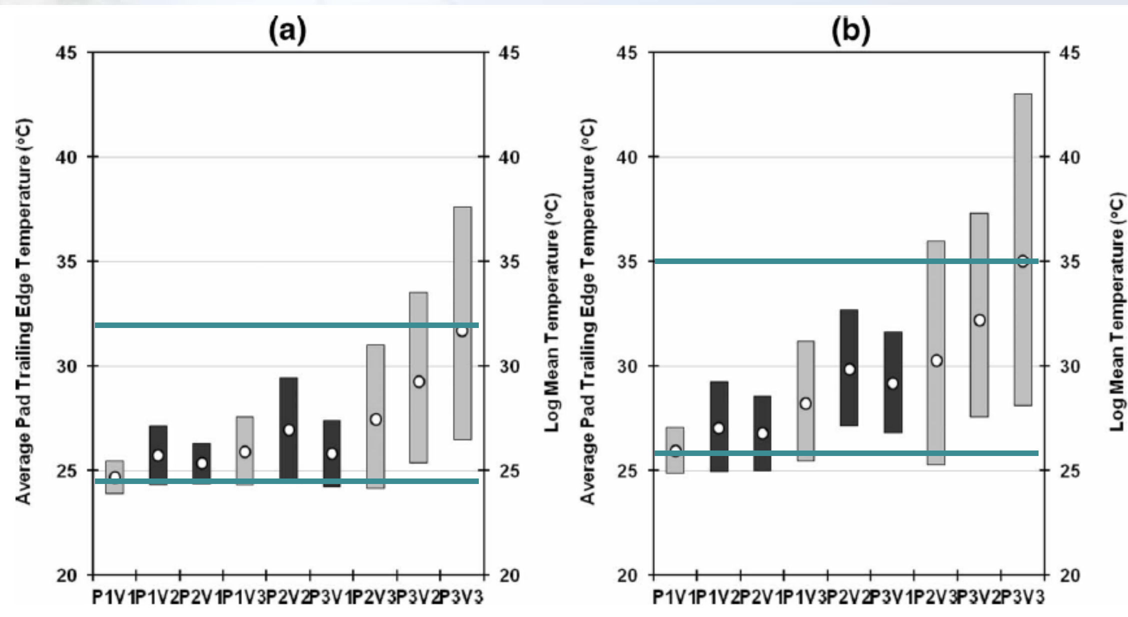
- Started with Titan (3 zone) membrane carrier
  - Membrane enables front referencing technology
  - Flat edge to 3mm, some edge tuning
  - Has advantages for volume production applications
    - ISRM, multi-platen, etc.
- Upgrades have been available
  - Profiler (4 zone) head
    - Increased edge tuning
  - Contour (6 zone) head
    - Full radial control

300mm and Now 450mm

- 300mm Reflexion Options
  - 3 zone Titan or 6 zone Contour
  - New option of 8 zone Titan Edge with ≤2mm edge exclusion
- 450mm Options
  - Initial offering is Titan Edge
- Differences from 300 to 450
  - Industry has seen real but incremental changes to CMP processes with size changes
  - Will there be something different this time?

450mm differences

- Things that could influence NU
  - Depletion of reactants
    - Some low dose additives need to be tuned to size
    - Often are inhibitors → center fast?
  - Temperature rise
    - Trailing edge temperature higher for same PV



Source: Jaio et al
Journal of ECS 159

BEOL ITRS Example

- ITRS max thinning (dish/eros) = 10% of height
  - Assumes Cu remaining ~90% of ideal

Level	Top Width nm	Bottom Width X	Aspect Ratio	Barrier nm	Cu loss nm	Cu % Ideal
Global	2000	1X	2	30	400	89.9
Metal 1	54	1X	2	2.4	10.8	89.8
Metal 1	54	1X	2	5	10.8	82.9
Metal 1	54	0.7X	2	5	10.8	66.4
Metal 1	54	0.7X	2	5	0	76.0

Even perfect NU/recess/erosion leaves too little Cu
Need to overpolish to clear all hardmask material

Extending Legacy Equipment

- Older 150/200mm equipment being pressed into service making advanced devices
  - ASIC's/Analog/RF/Magnetic Heads
  - More than Moore (MEMS, LED, 3DIC, etc.)
  - Research/Academia
- Performance falls short of modern needs
  - Incapable of 3mm edge exclusion or radial control
  - Poor results for removal rate and planarity
  - Compounds small wafer productivity disadvantage
- Non-Uniformity was a main theme of ICPT2011

Path for 150/200mm Legacy Tools

- Older equipment with rigid plate carriers being extended
  - IPEC 372M/472
  - Strasbaugh 6DS-SP/6EC
    - ViPRR controls retaining ring
  - Ebara EPO
  - Still good for lower volume / flexible purpose
- Carrier upgrade path developed
  - 200mm: ViPRR, Titan, and Profiler
  - 150mm: Titan

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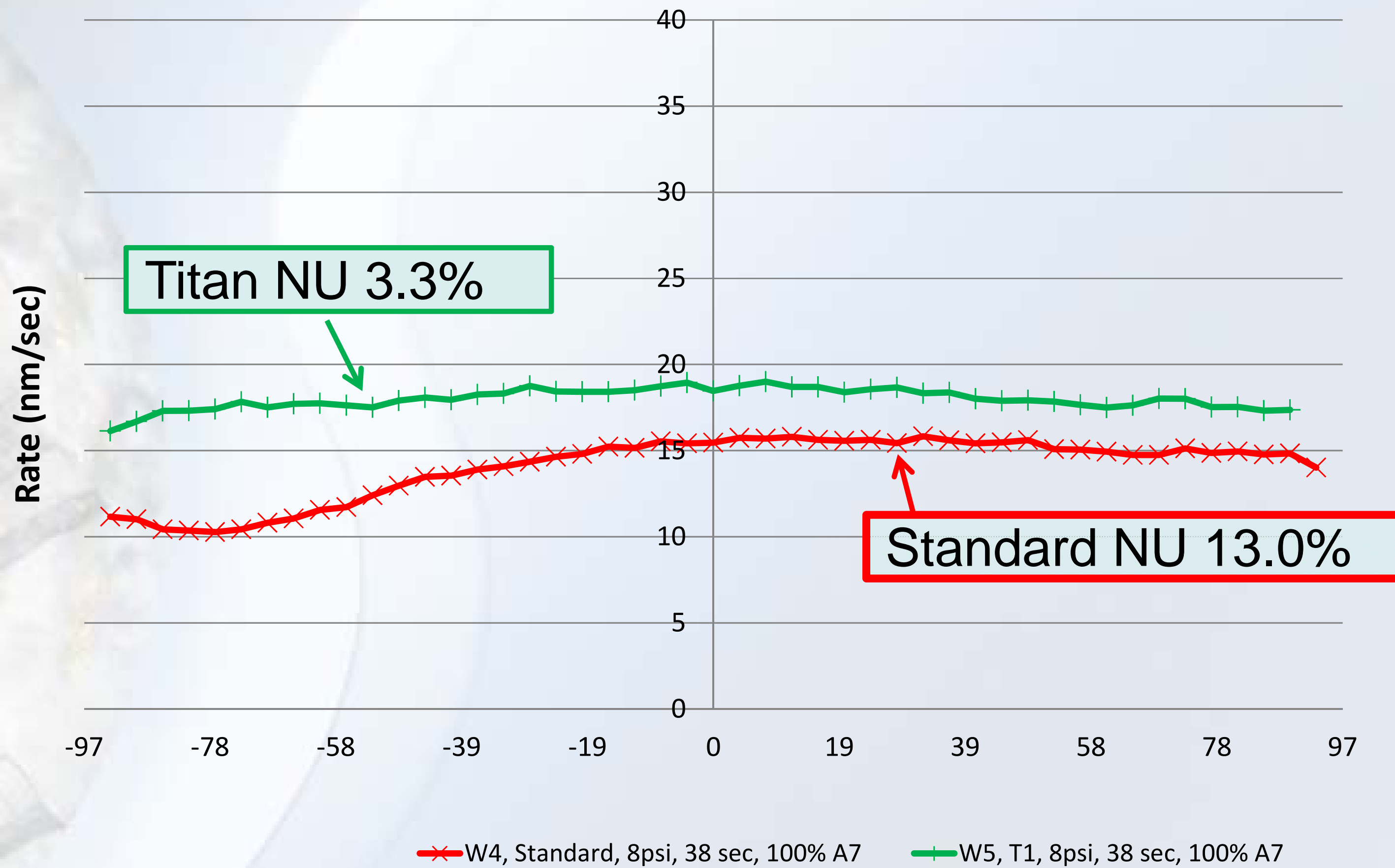
Customer Process on 6DS-SP/Titan



Uniformity improved with 8 psi 55 RPM process

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www.axustech.com

Customer/New Processes on 472/Titan

Titan: NU 2.6% Rate 3391 A/min

Standard: NU 12.3% Rate 1476 A/min

10172A, 2.65%, Range 1604A

7381A, 12.33% Range 4239A

10838
9838
8893
7776
10913
10497
9694
7947

Amount Removed, A

14000
12000
10000
8000
6000
4000
2000
0

98 89 77 65 53 40 28 16 4 -8 -20 -32 -44 -57 -69 -81 -93

Radius, mm

Titan 2_ 3min polish time
"472 Std Carrier 5min polish time"

Uniformity improved 5X, Rate 2x with new process

Edge Tuning on 472/Profiler

Removal Rate/ Min,A

10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0

-99.5 -99 -98.5 -98 -97.5 -97 -96.5 -96 -95.5 -95 -94.5 -94 -93.5 -93 -92.5 -92 -91.5 -91 -90.5 -90 -89.5 -89

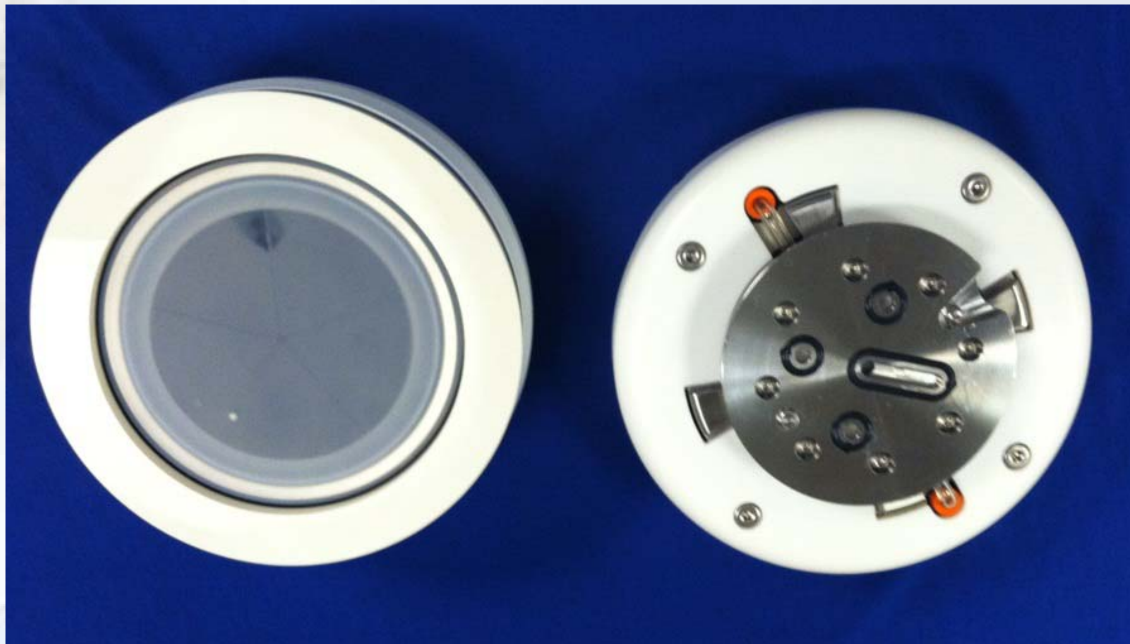
Radius, mm

Wfr6_472,Titan 2, UC 6.5psi
Wfr7_472,Titan 2, UC 0psi
wafer10_472,Titan2, UC 5psi

Dramatic changes in edge rate possible with Profiler
Similar results now available with modified Titan

Mirra Path 150mm

- Profiler (4 Zone) head developed by Axus and AMAT for 150mm
  - Now able to leverage Mirra platform for higher volume applications
  - Available only from AMAT



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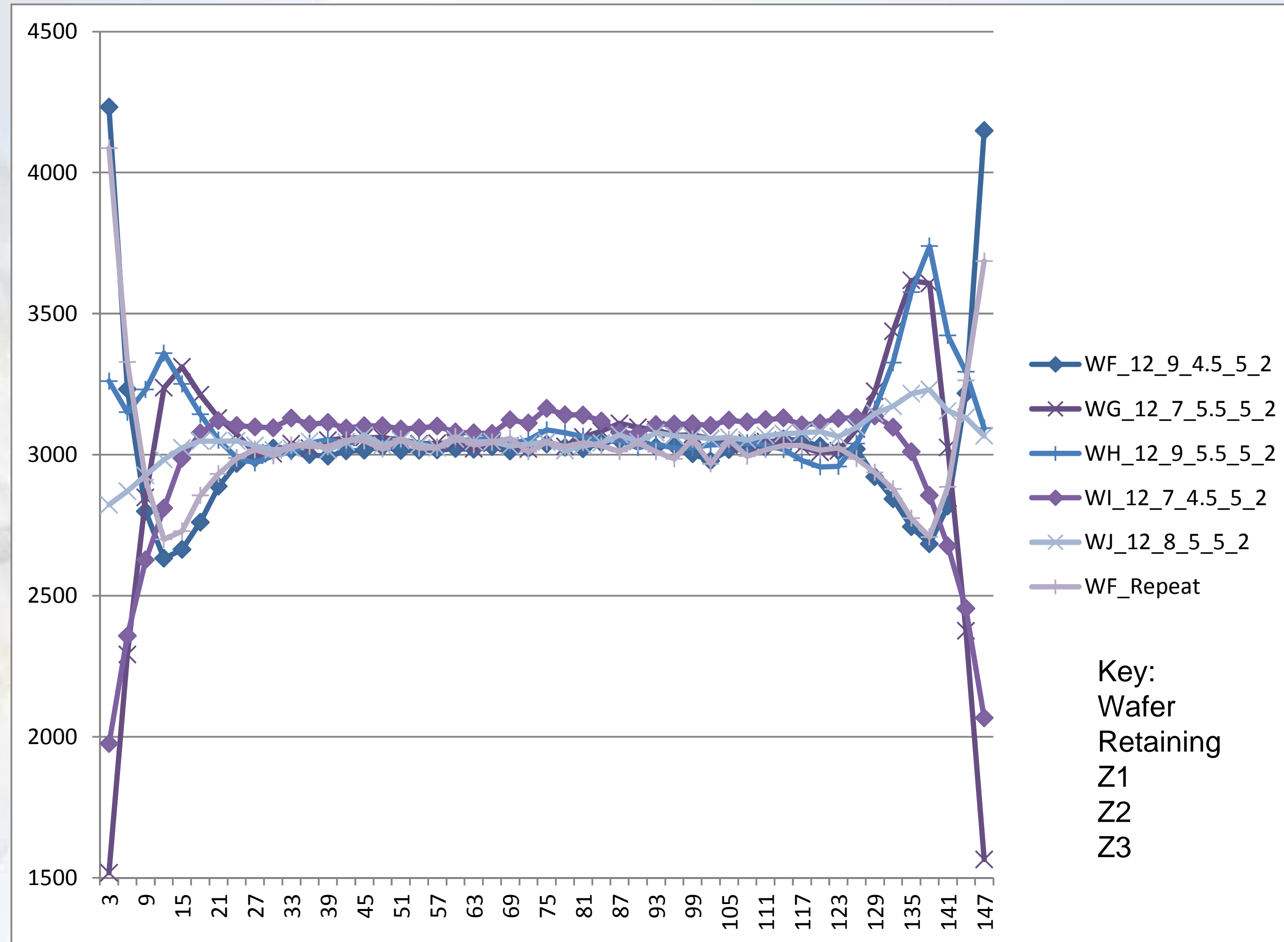
DOE with Zones 1 & 2 +/- 10%



Able to toggle both 3mm and 12mm regions
above and below wafer center

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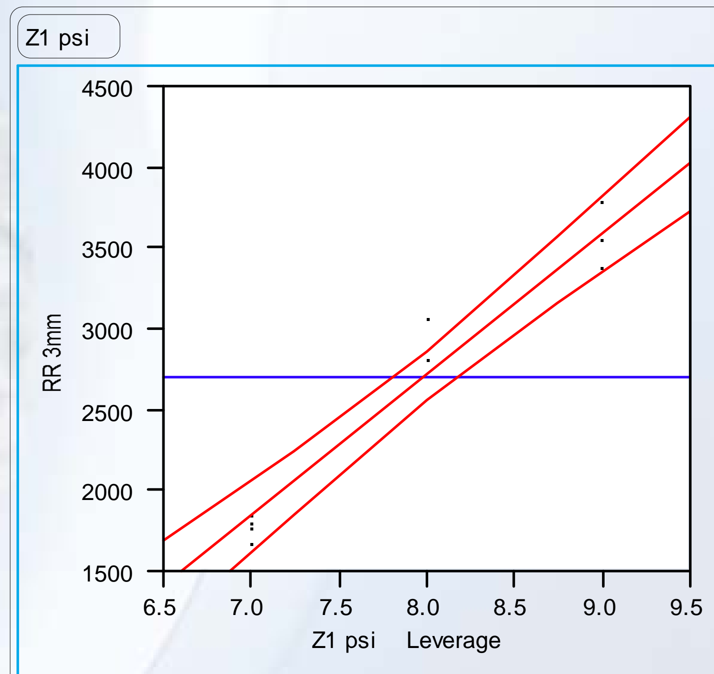
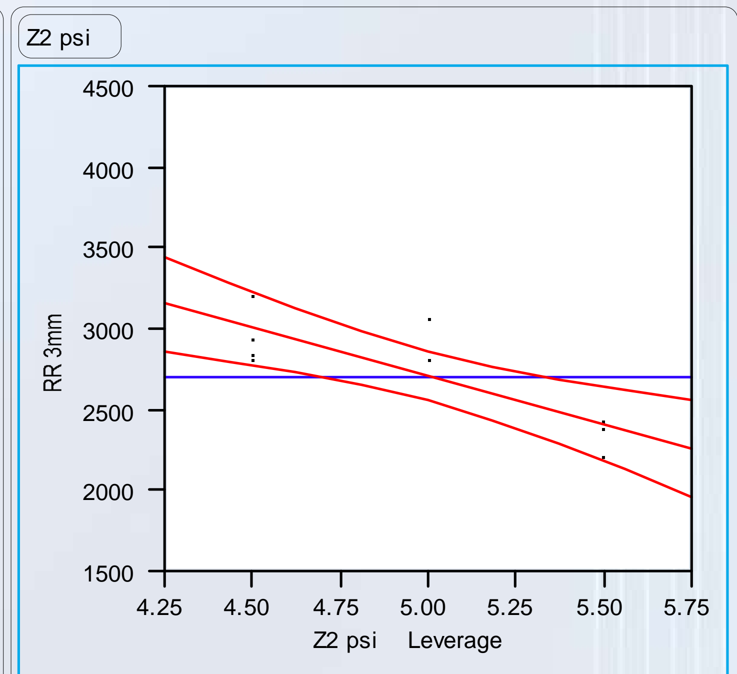
Excellent Model of 3mm Region

- Rate at 3mm affected by both Z1 and Z2
  - Model R2adj = 0.95, both p values < 1%



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
6132002.0	148.9261	1	<.0001



Effect Test

Sum of Squares	F Ratio	DF	Prob>F
706860.50	17.1673	1	0.0043

Z1 Coef =

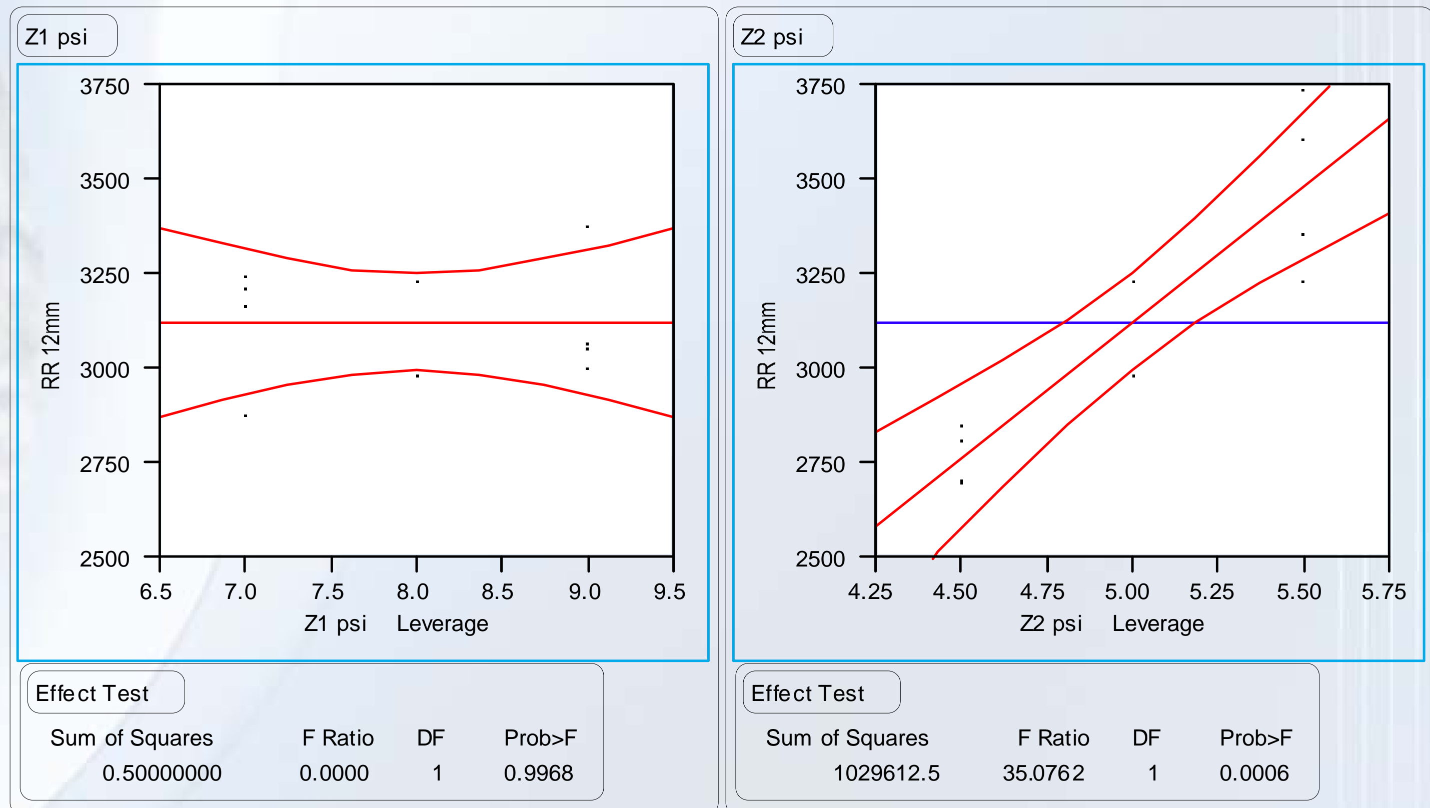
+875 A/min/psi

Z2 Coef =

−594 A/min/psi

Excellent Model of 12mm Region

- Rate at 12mm affected by Z2, not by Z1
  - Model R2adj = 0.94, p either >99% or <1%

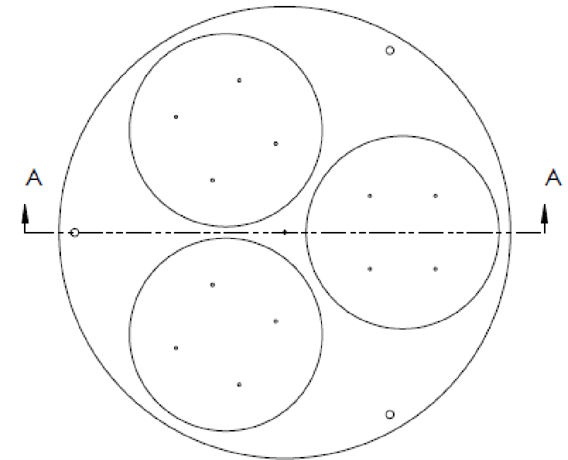


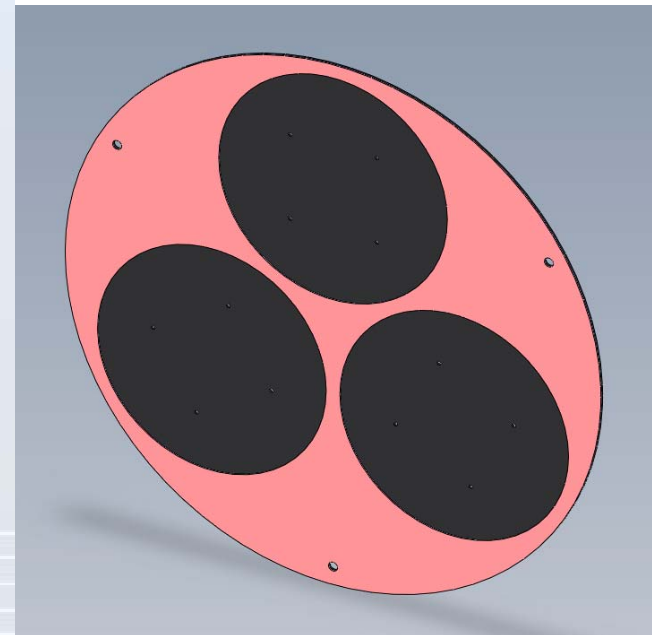
Z2 Coef = +717 A/min/psi

Easy to tune Z2 for 12mm, then Z1 for 3mm

Rigid Plate Potential Solution for 100nm

- 100mm is common size for alternate substrate materials/LEDs and MEMS/sensors
- Several minutes of CMP required following thinning
- COO improved with 3-pcket carrier
- New design capable of 3.4%NU at 7mm





Summary

- Improvement in non-uniformity has been a significant issue since multi-wafer CMP was implemented
- Path to single-wafer full radial control ability well-established for 200mm and 300mm
- 450mm designs likely to be extended from 300mm
- Tightest dimensions and possibly 450mm will continue to push the requirements for non-uniformity
- Better processes enabled on legacy equipment for 200mm
- Advanced 4 Zone carrier capability now available for the Mirra for 150mm
- Back to the future – Multi-wafer CMP for <150mm wafers?