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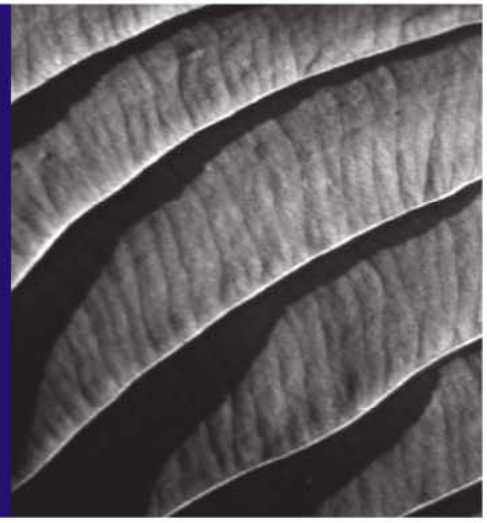
Accelerating Yield

Non-contact Sheet Resistance for Determining Polish Rates



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Walter Johnson, HaiJing Peng

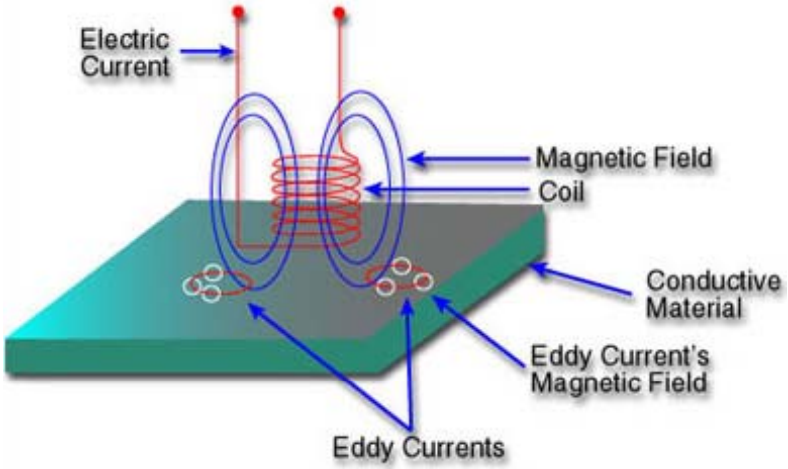
Outline

- Abstract
- Technology
- Typical Performance
  - Repeatability
  - Effects of frequency change
- Use Case
  - ECP Copper monitors
  - Polish Rate on monitors
  - ECP Copper on pattern wafers

Abstract

With the move to larger wafers, monitor wafers are getting more expensive. The introduction of non-contact Rs measurements to replace traditional contact Four-point Probe measurements saves money through measuring directly on pattern wafers. There are also advantages when determining, polishing rates with a non-contact method, in that 4PP generated particles or pits are avoided allowing the same wafer to be used for both particle inspection and thickness. Eliminating these particles or pits can also prevent their affect on subsequent polishing steps.

Non-contact Sheet Resistance (NCRs) capability for thick metal films



- Technology :
  - Conductive layer close to the coil modifies the coil impedance
- Benefits:
  - Better repeatability performance on thick-metal layers with low resistivity (Cu)
    - Unaffected by surface oxidation
    - Superior Repeatability: 0.3% NCRs vs. 4PP at 0.5%
  - Product wafer capability – Rs measurement on complete Copper process (Barrier/seed, pre/post Cu CMP)
    - No mechanical damage to the film or underlying structures
    - 'Real' Rs for process monitoring of thick-metal layers
    - Reduces monitor wafer usage, low COO

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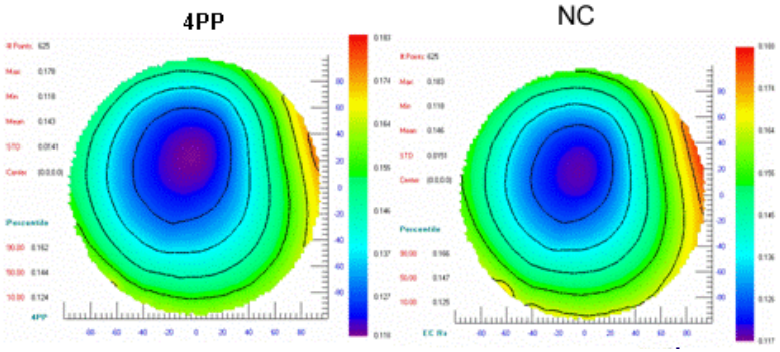
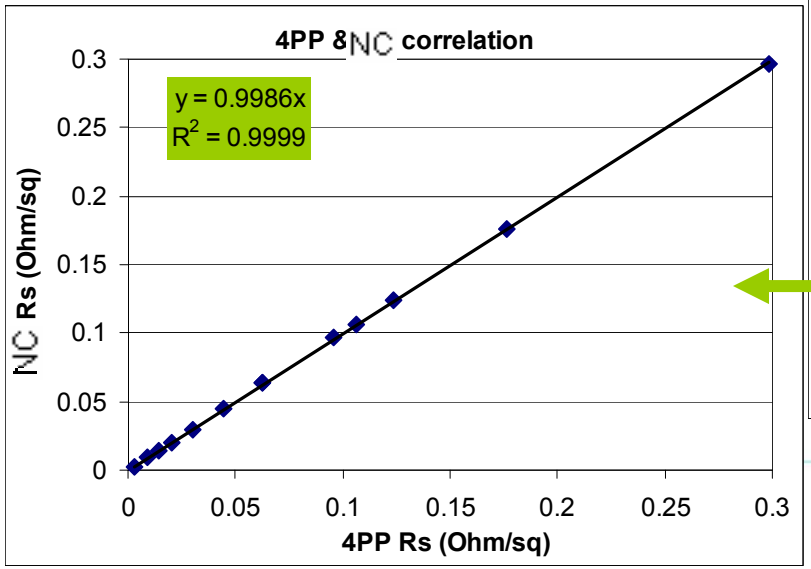
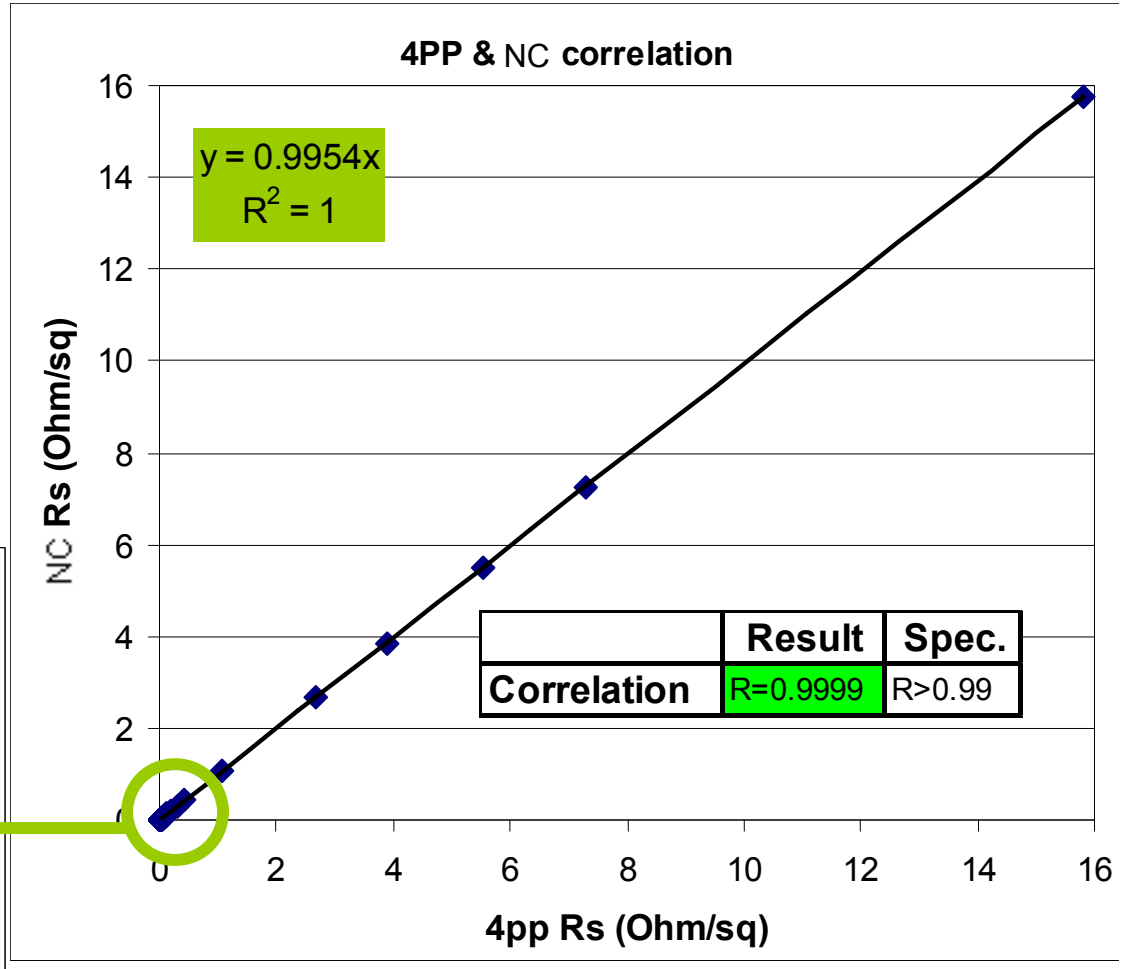
Correlation between 4PP and NCRs

Map comparison: 4PP and NC
8" wafer, 625 site, 4mm edge exclusion

- Slight difference in average value due to spot size difference
  - 4PP spot size ≈ 4mm
  - NC probe spot size ≈ 2mm







	Result	Spec.
Correlation	R=0.9999	R>0.99

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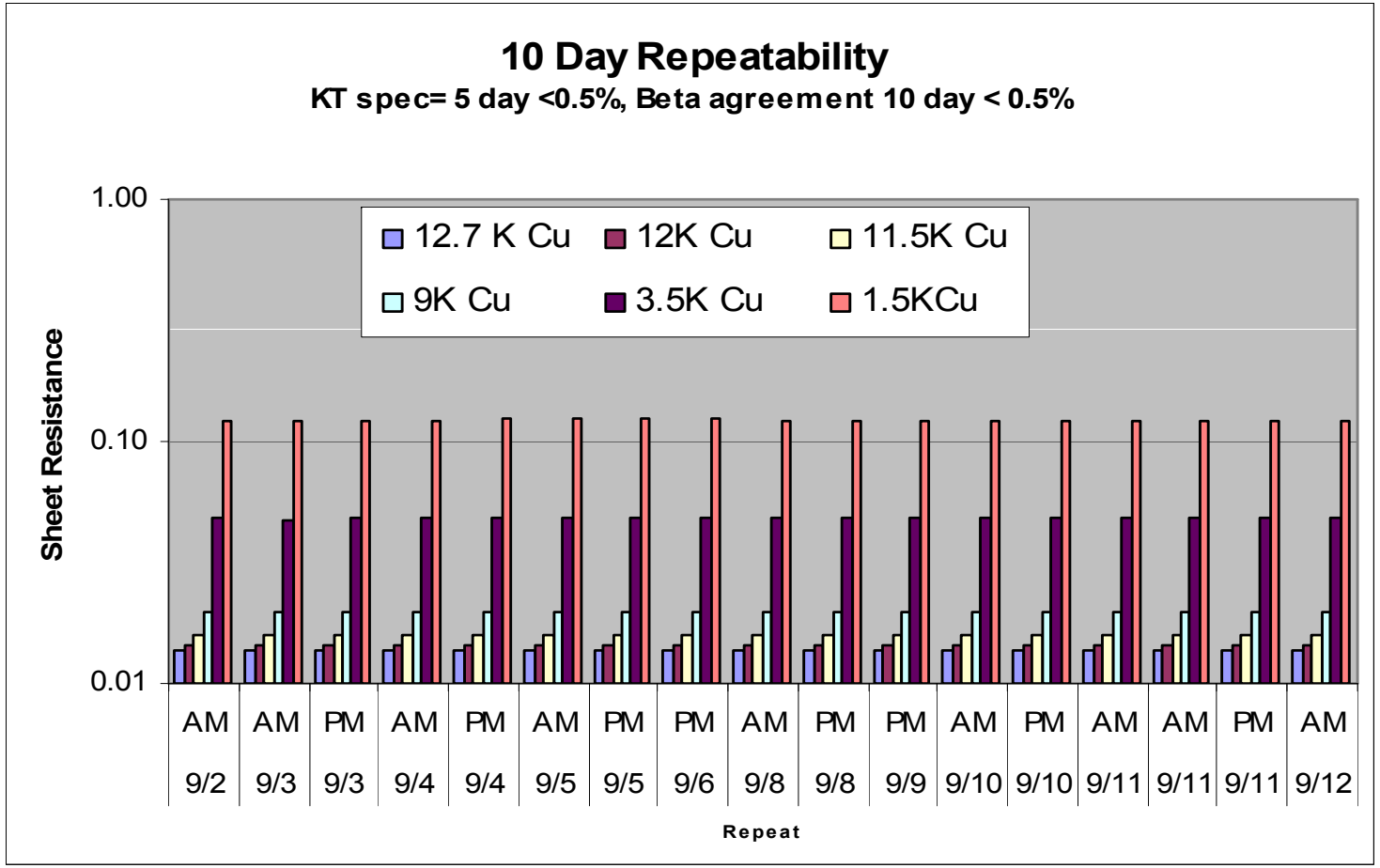
Long Term NCRs Repeatability



NCRs	12.7 K Cu	12K Cu	11.5K Cu	9K Cu	3.5K Cu	1.5KCu
Repeatability	0.23%	0.19%	0.18%	0.15%	0.21%	0.35%

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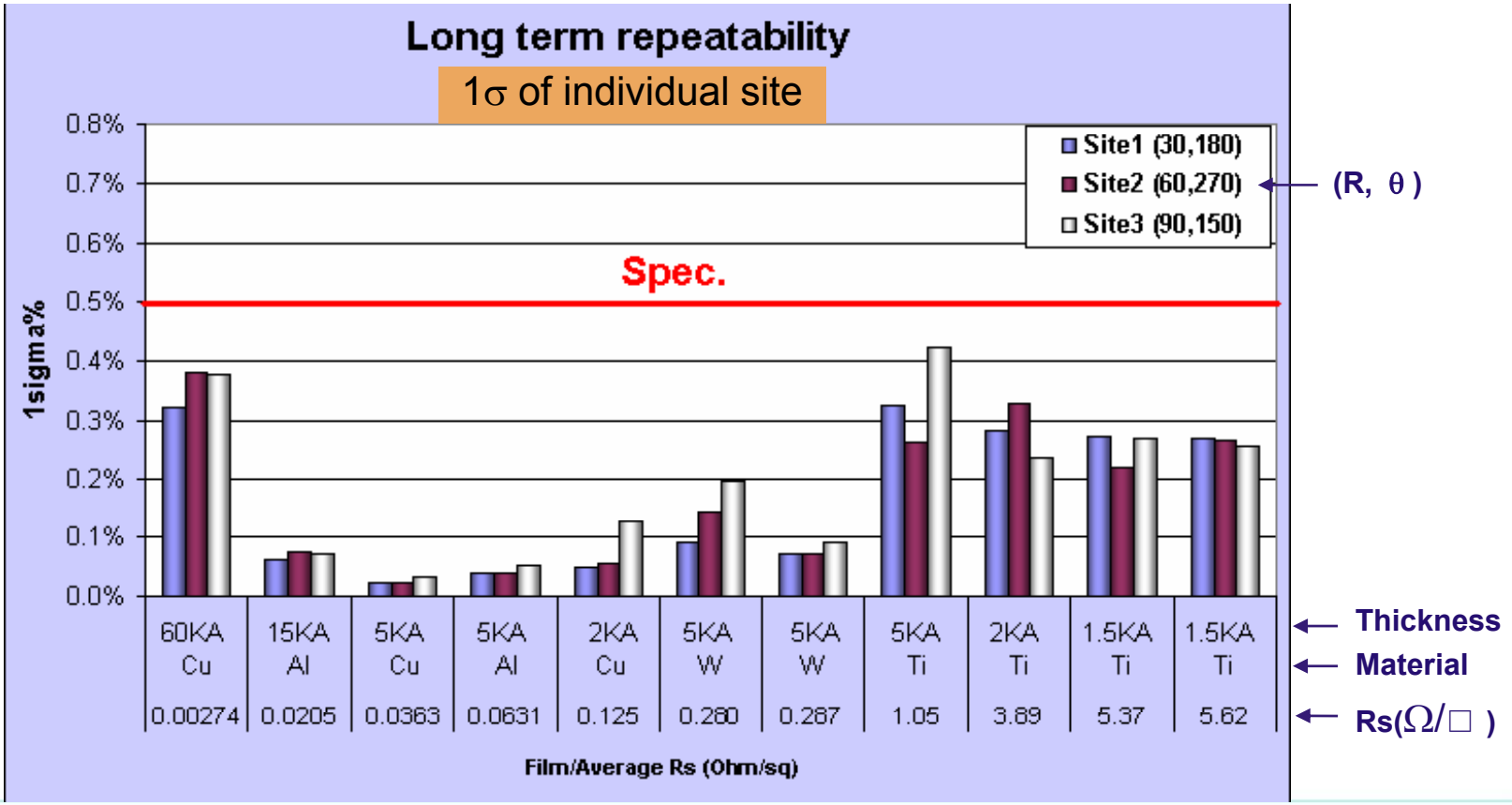
10MHz Long Term Repeatability (2)

- Total 11 wafers(200mm), Rs : 0.003~6Ω/□, different film thickness/ material
- Test conditions: 49 sites/test, 5 tests/day, 6days
- 1σ is calculated based on Rs of **each individual site**



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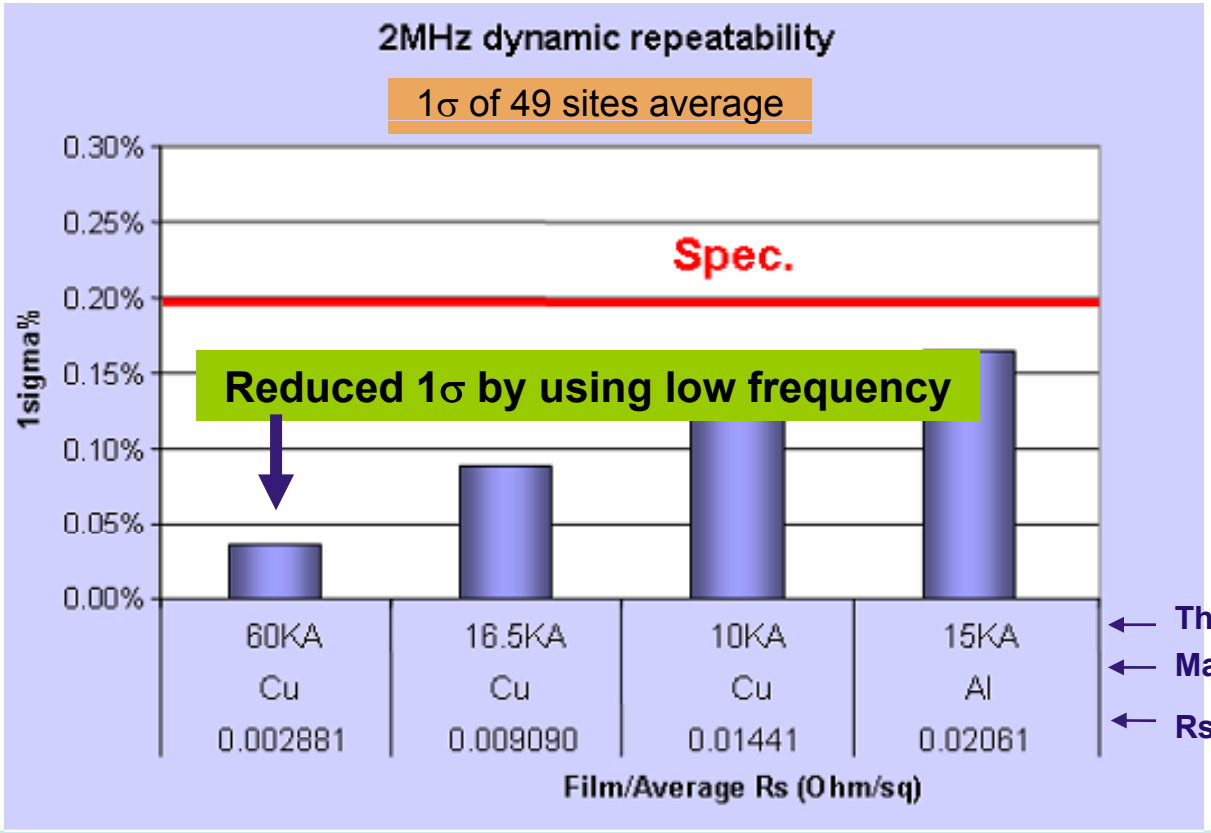
2MHz Dynamic Repeatability

Reduced 1σ at extremely low Rs

- Total 4 wafers(200mm), Rs : **0.003~0.02**Ω/□, different film thickness/ material
- Test conditions: 49 sites/test, 18 repeats, with load/unload
- 1σ is calculated based on average Rs of each test



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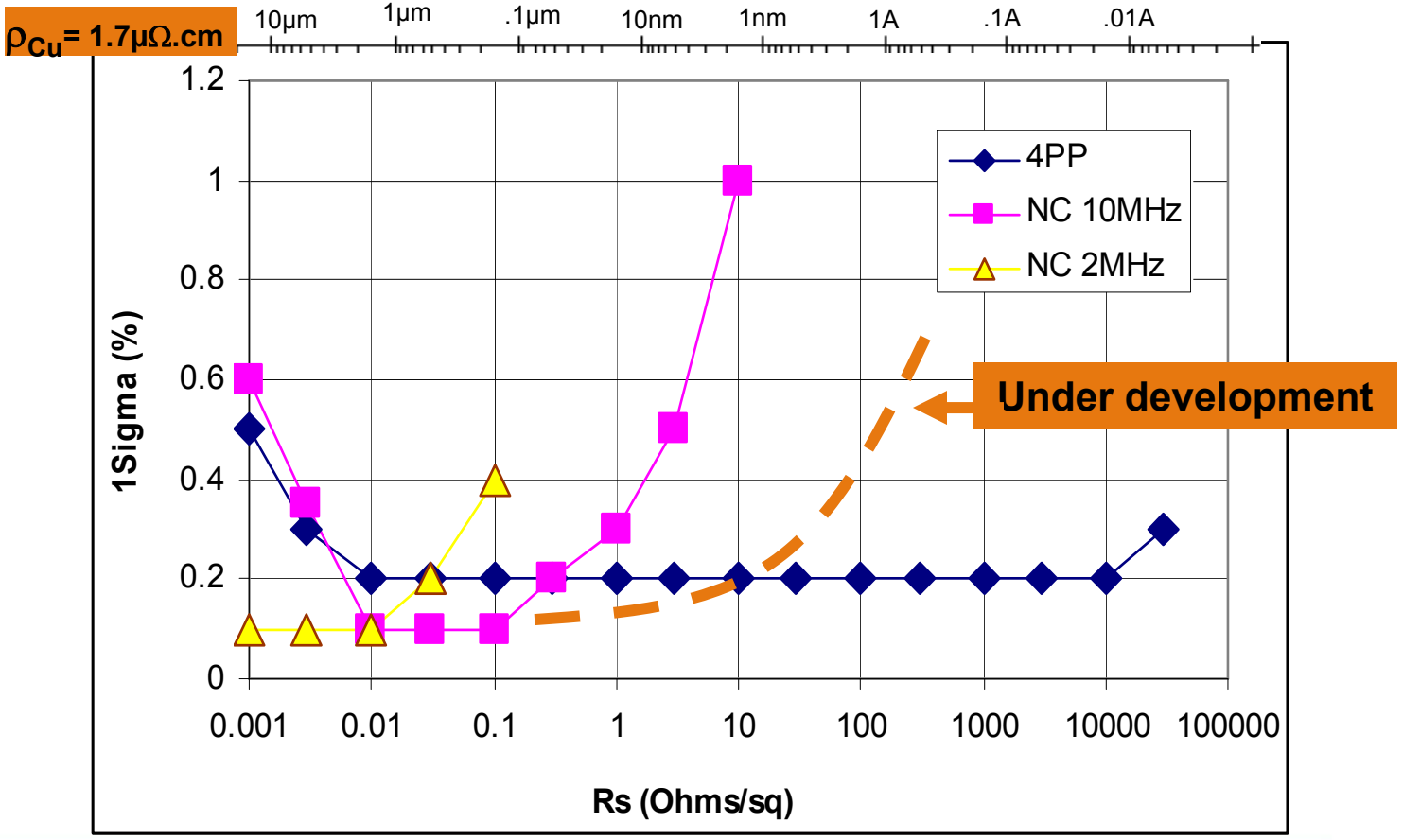
Measurement Range

- NCRs is complementary to 4PP measurement, towards extremely low sheet resistance

Material	ρ Ratio
Cu	1.00
Al	1.64
Mo	3.02
W	3.22
Pt	6.09
Ta	7.60
Ti	24.8
$TiSi_2$	9.30
TiN	12.8
TaN	130
Ag	0.94
Ni	4.20
Co	3.85



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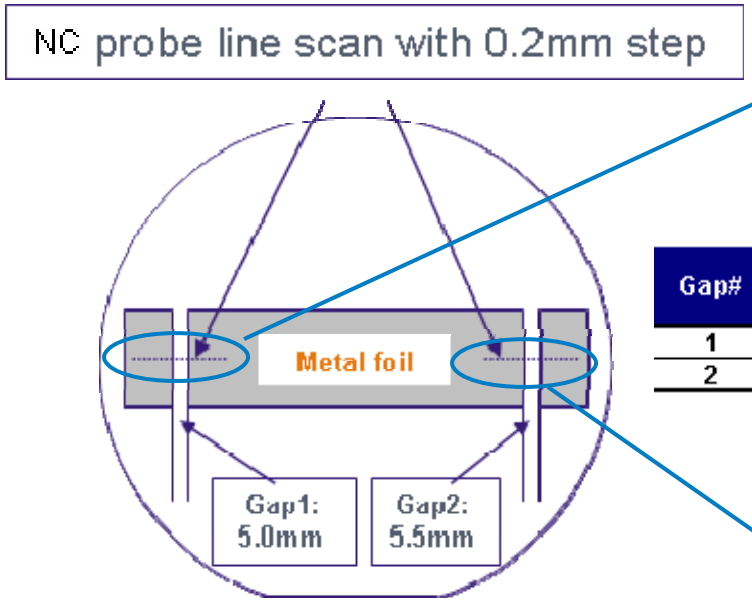
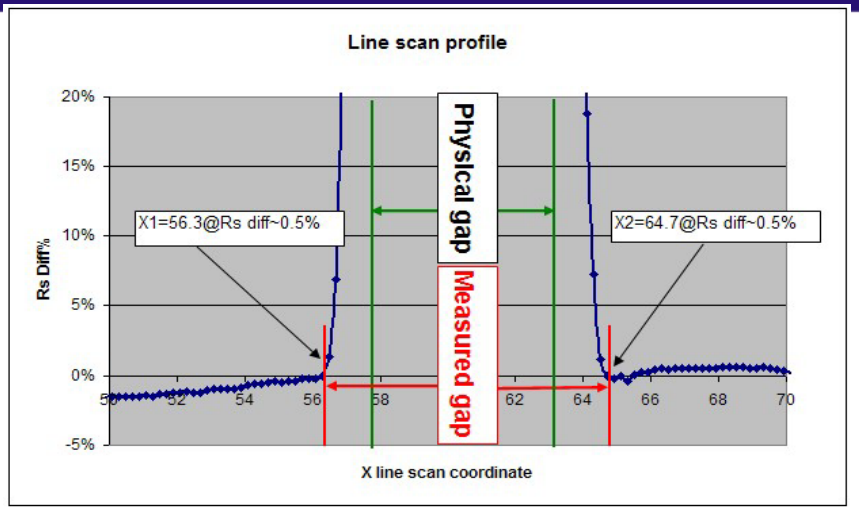
NCRs Edge Exclusion

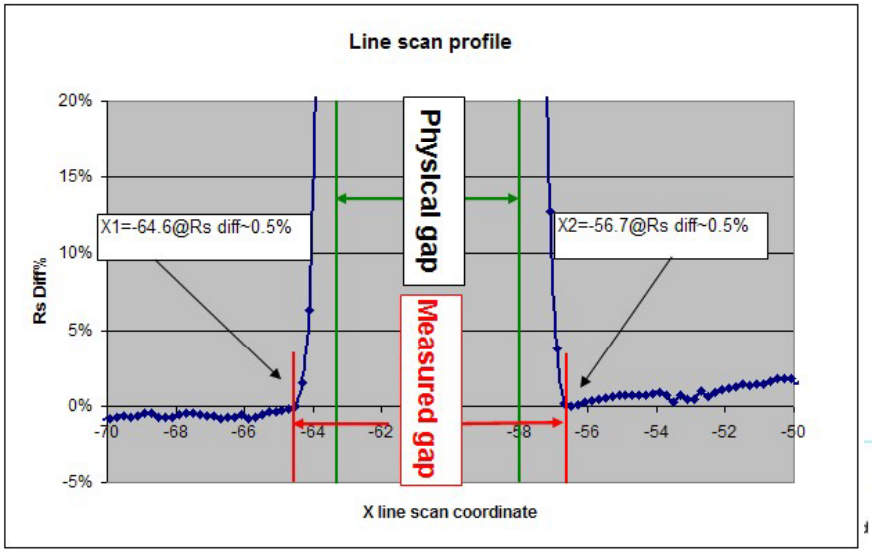
Edge Exclusion (EE) Calculation:

EE = (Measured Gap - Physical Gap) / 2



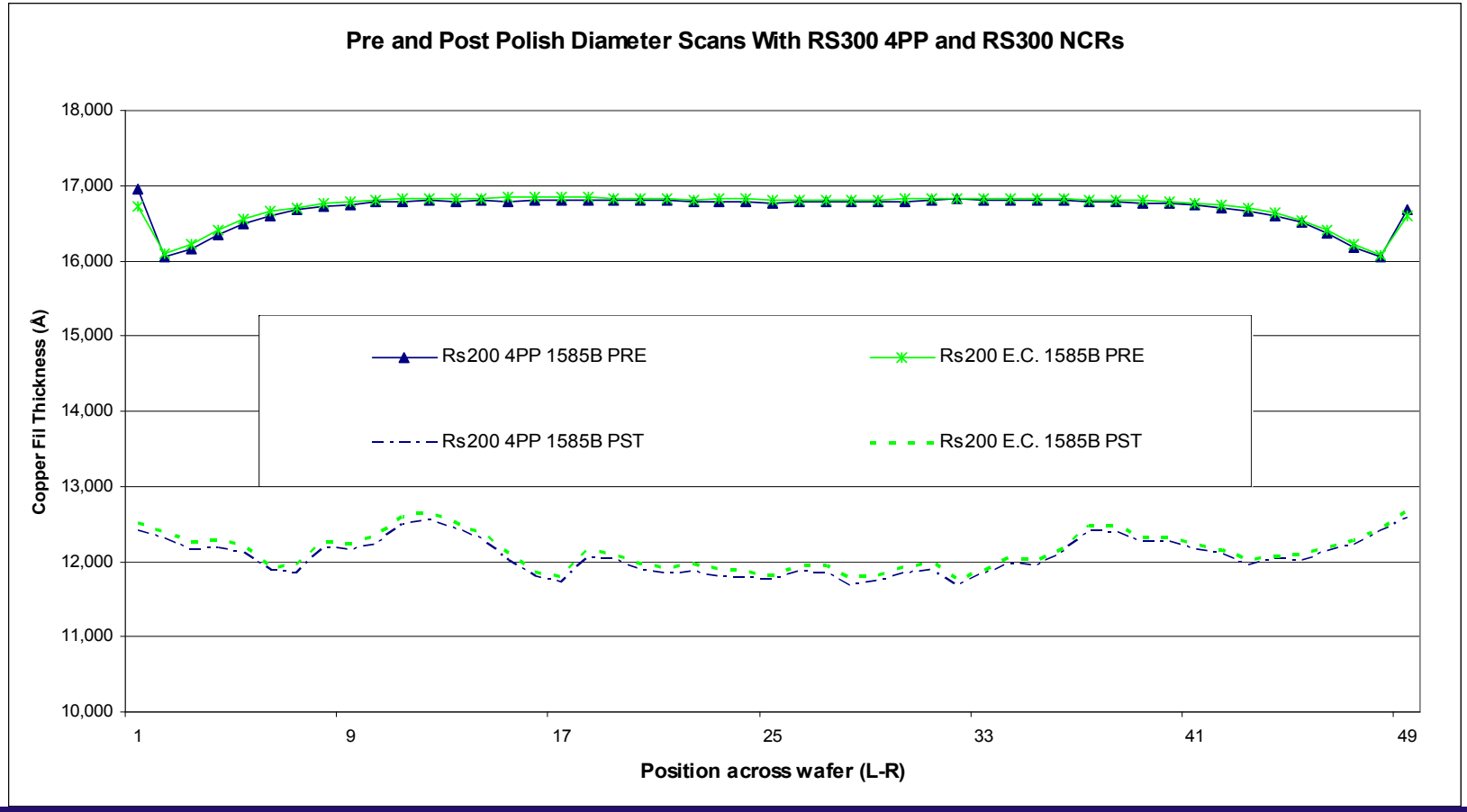


Gap#	X1 (mm)	X2 (mm)	Measured gap (mm)	Physical gap (mm)	Edge exclusion (mm)	NC spec (mm)	Pass/failure
1	-64.5	-56.7	7.8	5.0	1.4	4.0	Pass
2	56.3	64.7	8.4	5.5	1.5	4.0	Pass



NC Probe used in EE test: SN37817, w/ shield

Cross Wafer Uniformity Pre & Post Polish



Good correlation between 4PP and NCRs from the same tool

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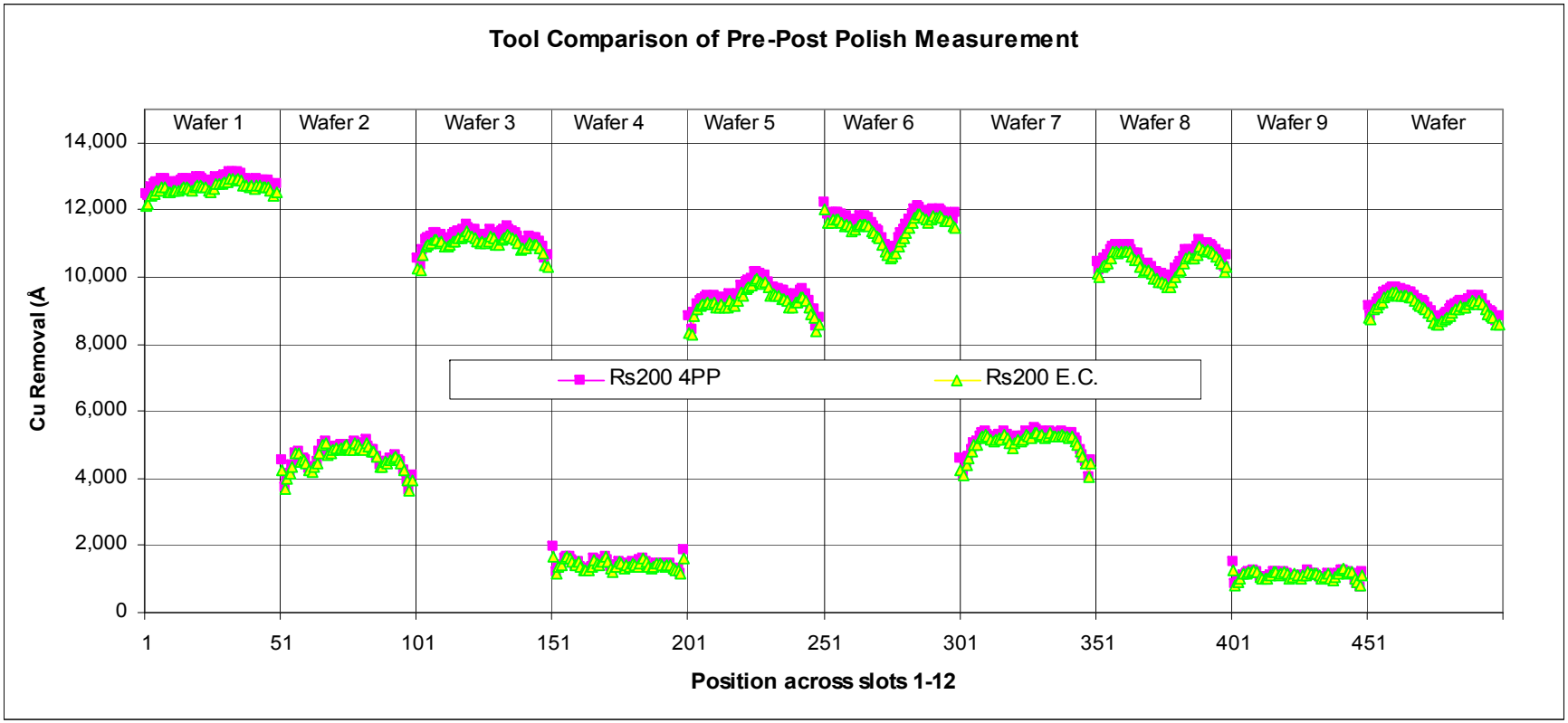
Copper Removal on 10 Wafers (EC vs 4PP)

Sequential Diameter Scans Across 10 Wafers (plotted on one chart)



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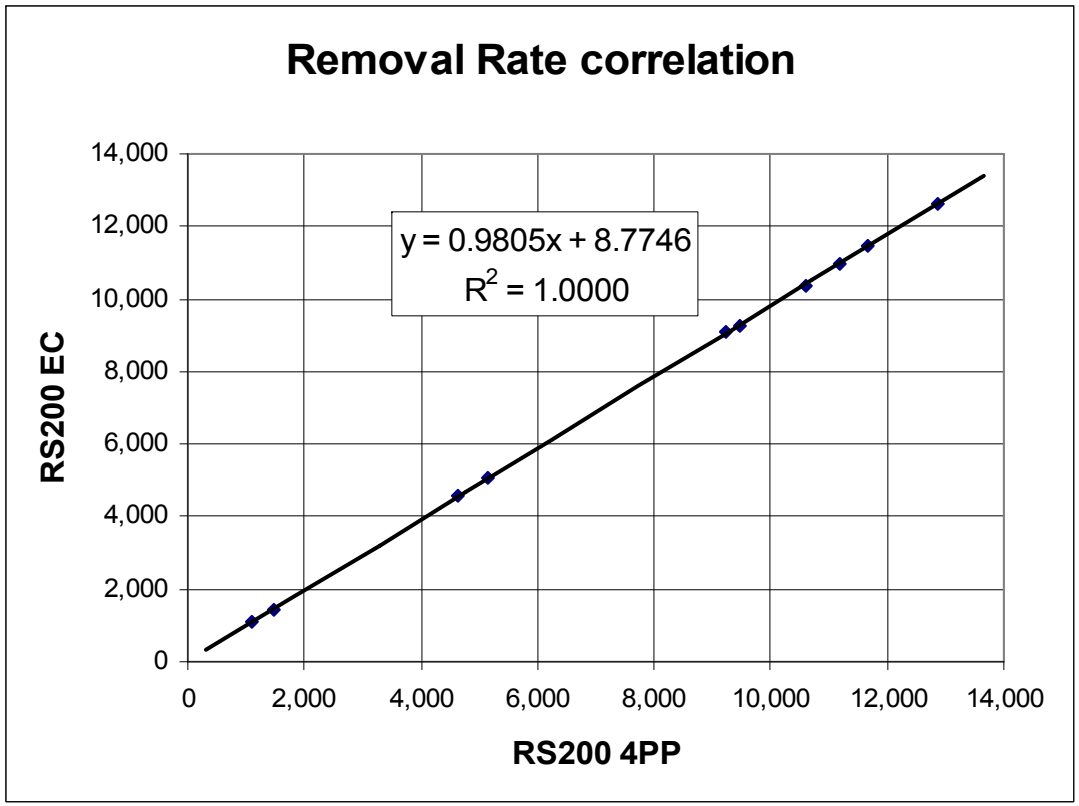
Removal Rate Correlation



Removal is in total thickness

With units in Angstroms (Å)

Perfect Cu removal rate correlation between 4PP and NCRs

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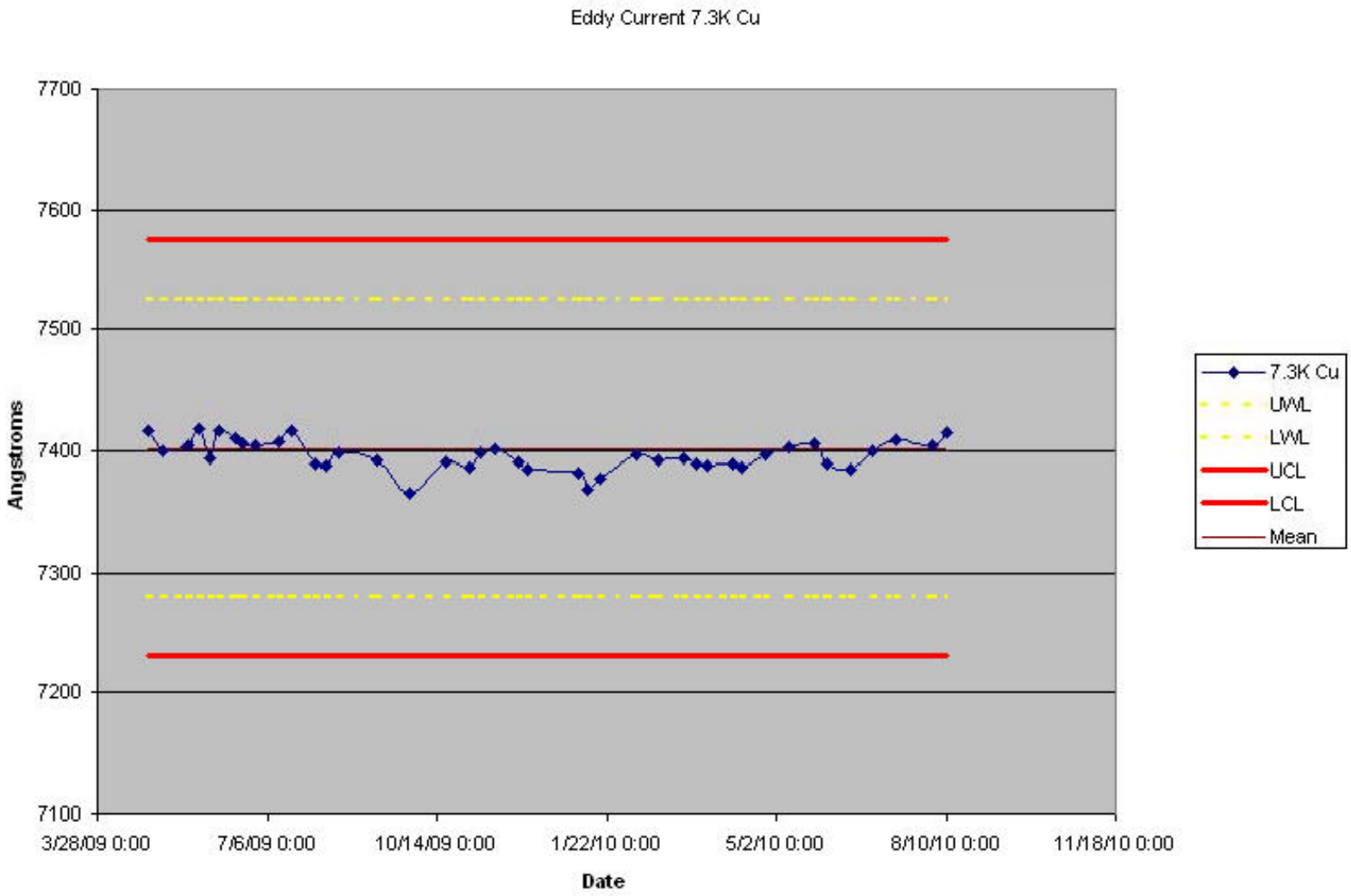
18 Month Operation (without re-cal)



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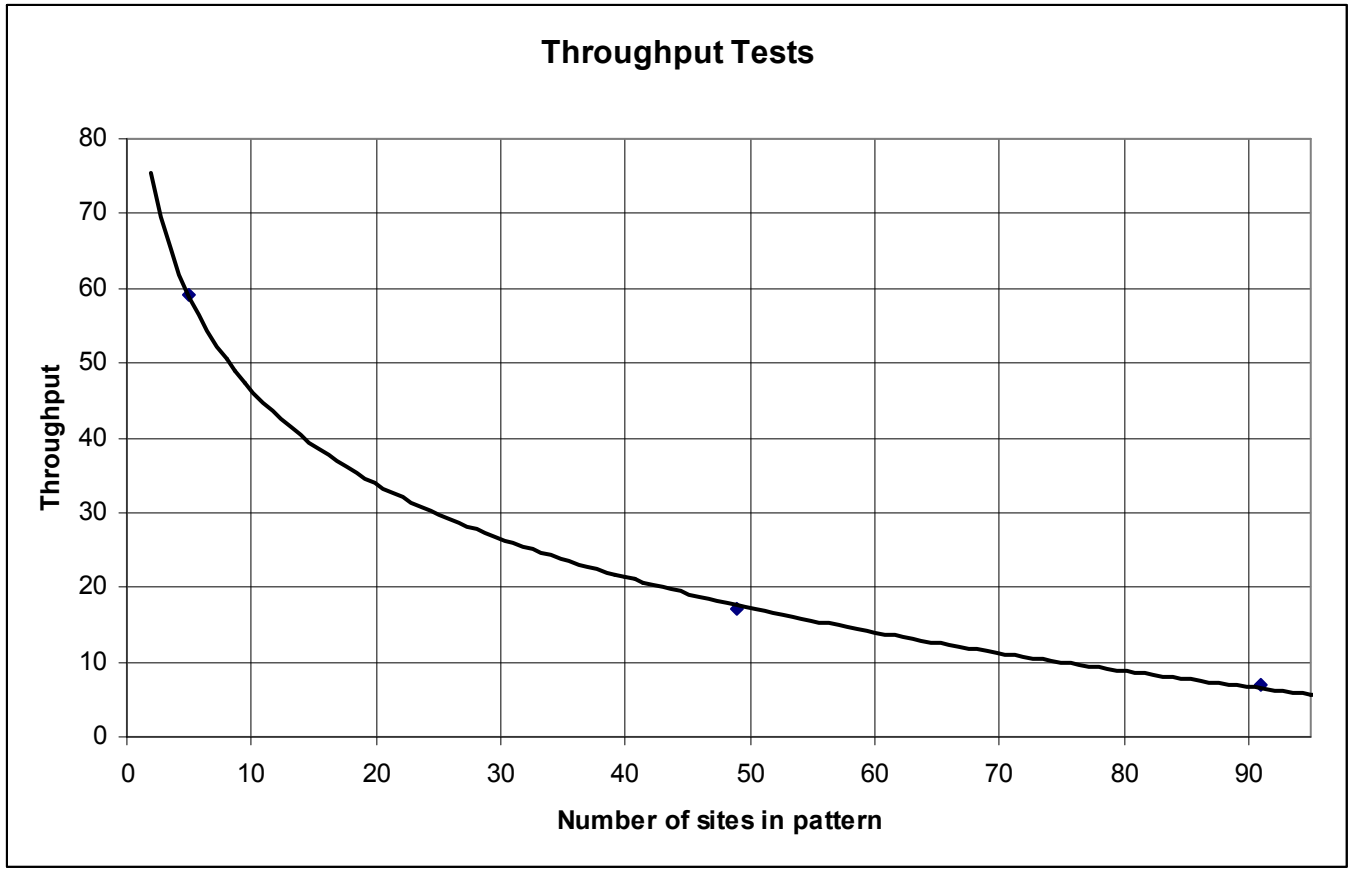
NCRs Throughput



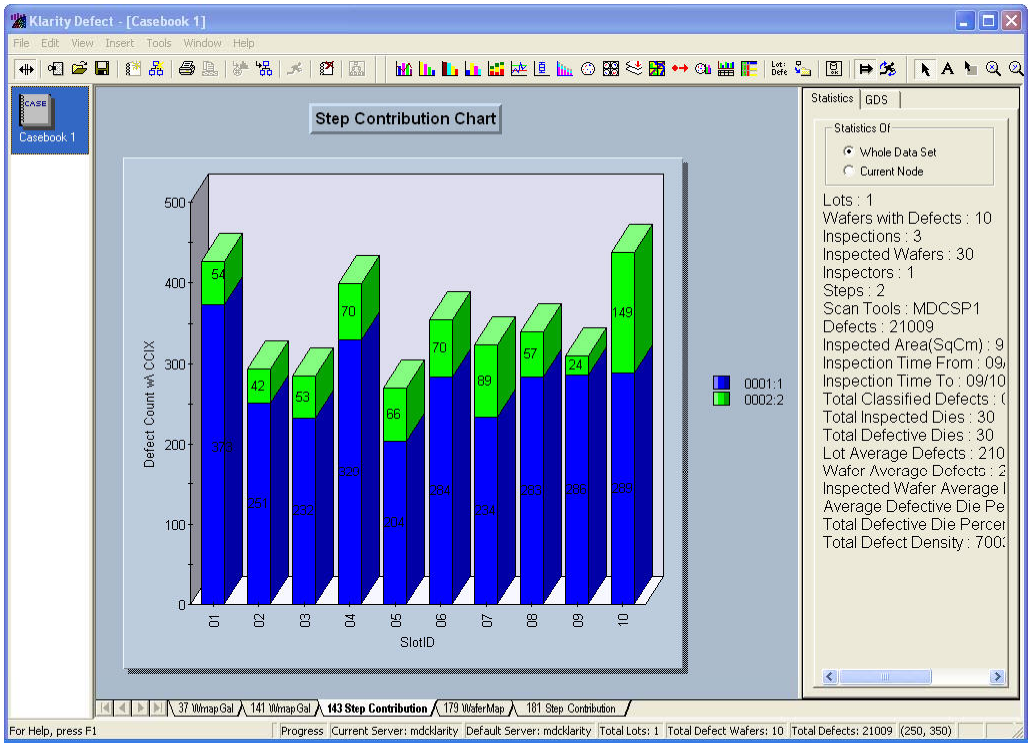
Sites	Spec	Measured
5	40	59
49	15	17
81	6	7

Particle Tests

Baseline

Slot #	1	2	3	4	5	6	7	8	9	10	
Original Defects	373	251	232	329	204	284	234	283	286	289	
Defects Added	54	42	53	70	66	70	89	57	24	149	Avg
Tested Wafers	54		53		66		89		24		57.2
Control Wafers		42		70		70		57		~~149~~	59.75

Slot 10 (a control) was the top wafer and was removed from the calculations



Average of -2 PWP indicate there is no particles added

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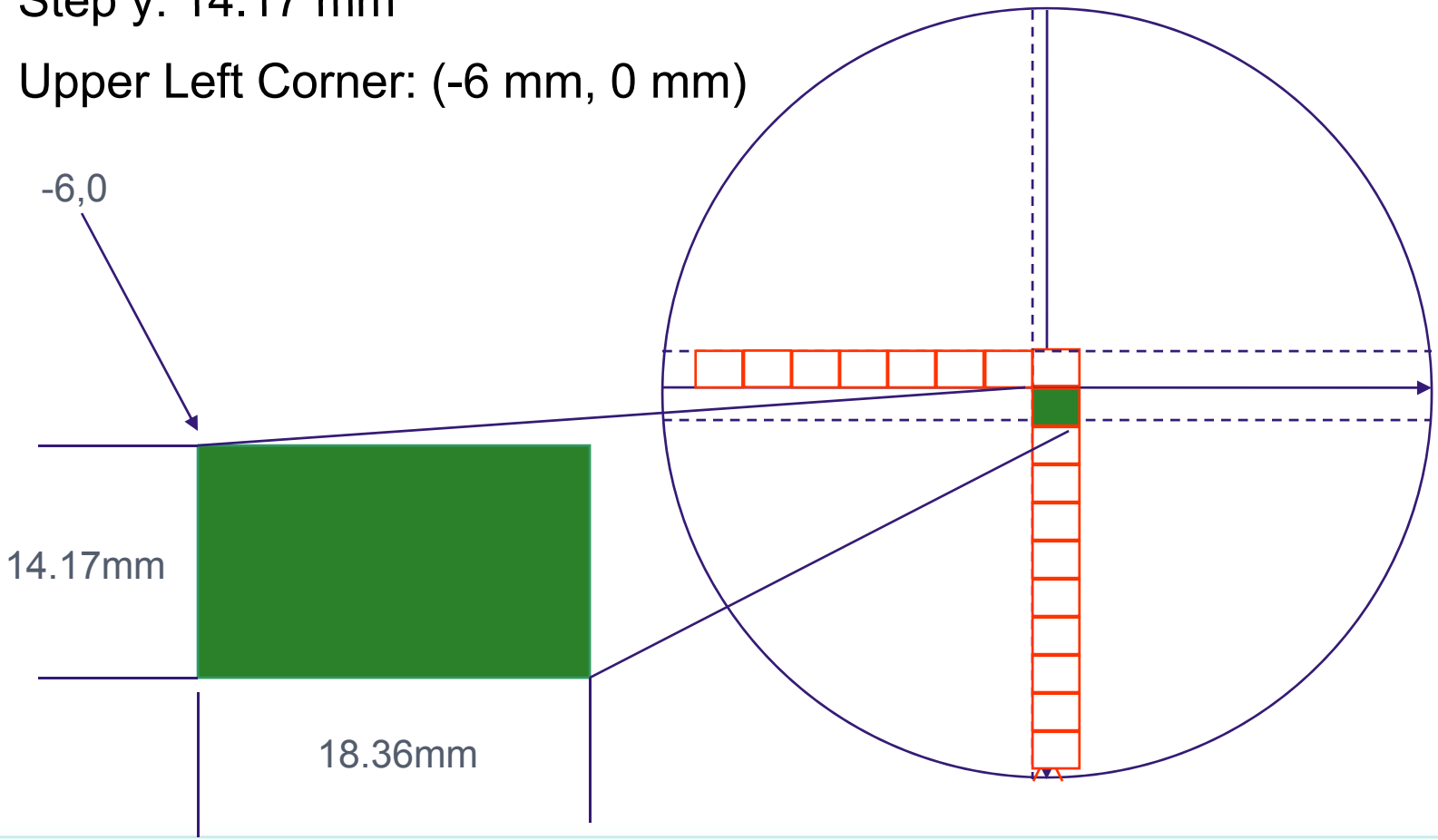
Pattern ECP Cu Demo Information

- Demo purpose:
  - Demonstrate the ability to measure sheet resistance of ECP pattern wafer with non-contact Eddy Current method on RS 300 platform, including:
    - EC Rs correlation with Cu thickness
    - Dynamic repeatability without pattern recognition to show positioning accuracy and impact to measurement result
- Wafers:
  - ECP pattern wafer with ~ 1 µm electroplated Cu
  - Diameter: 300 mm
  - Edge: ~2 mm edge clearance

Pattern Structure

- Step x: 18.36 mm
- Step y: 14.17 mm
- Upper Left Corner: (-6 mm, 0 mm)



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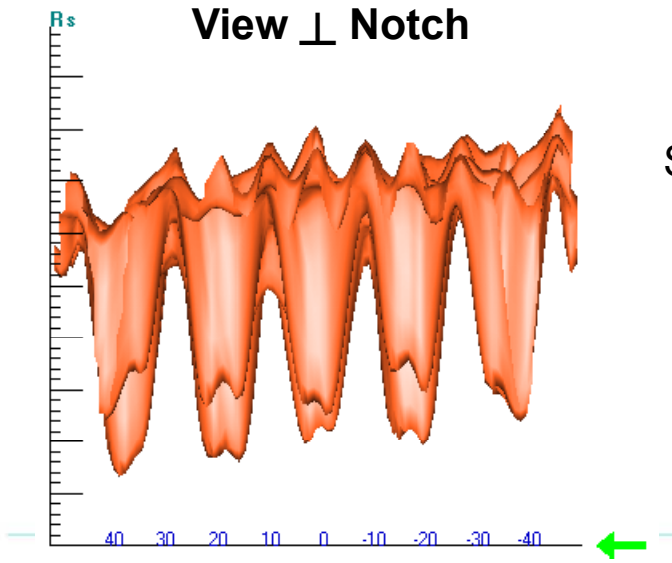
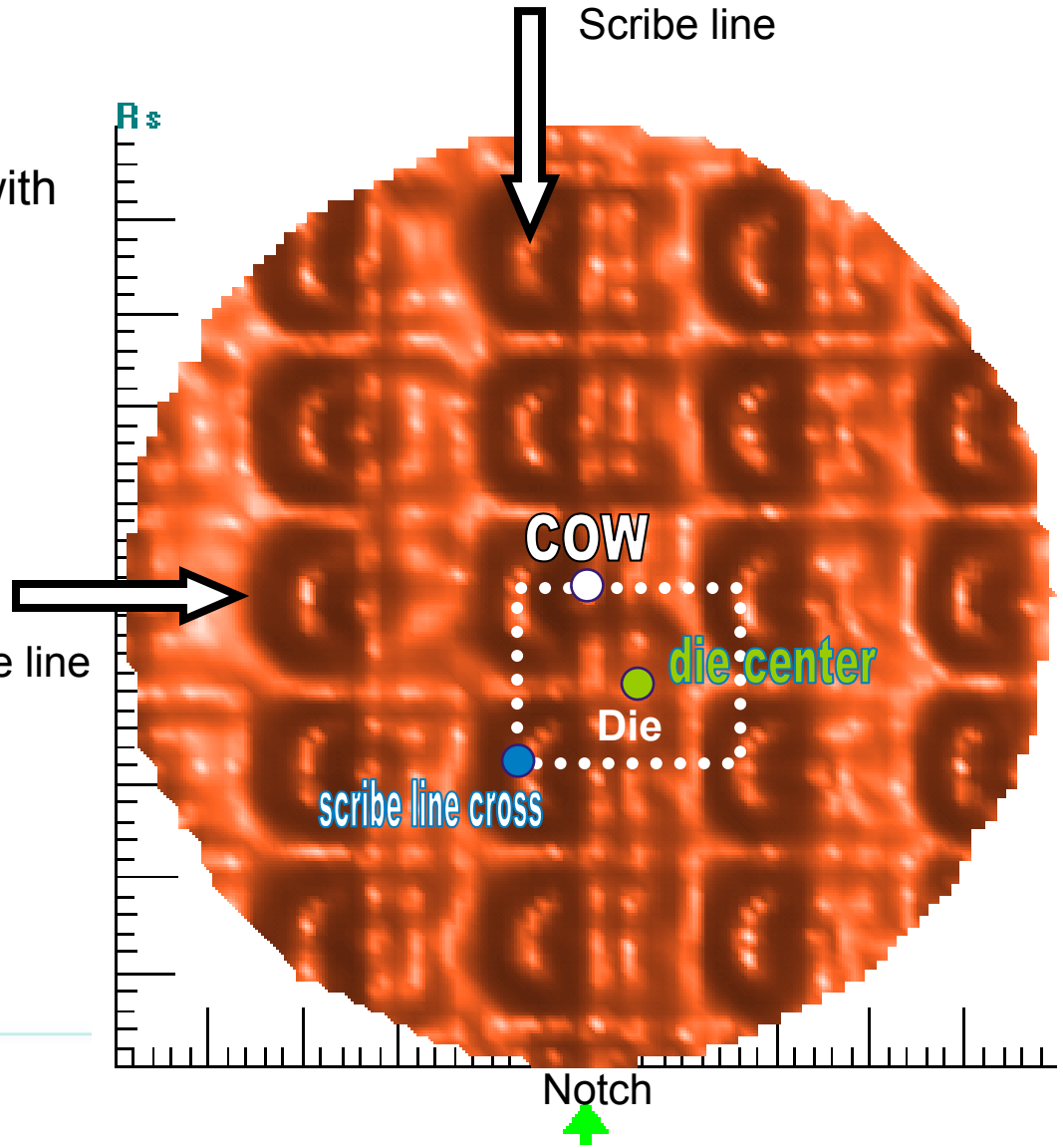
Small-Area Map

- Map scan (2mm square) in a circular area of 80 mm diameter near the center
  - Periodical RS pattern aligned with dies and scribe line features
    - Step X: 18.36 mm
    - Step Y: 14.16 mm

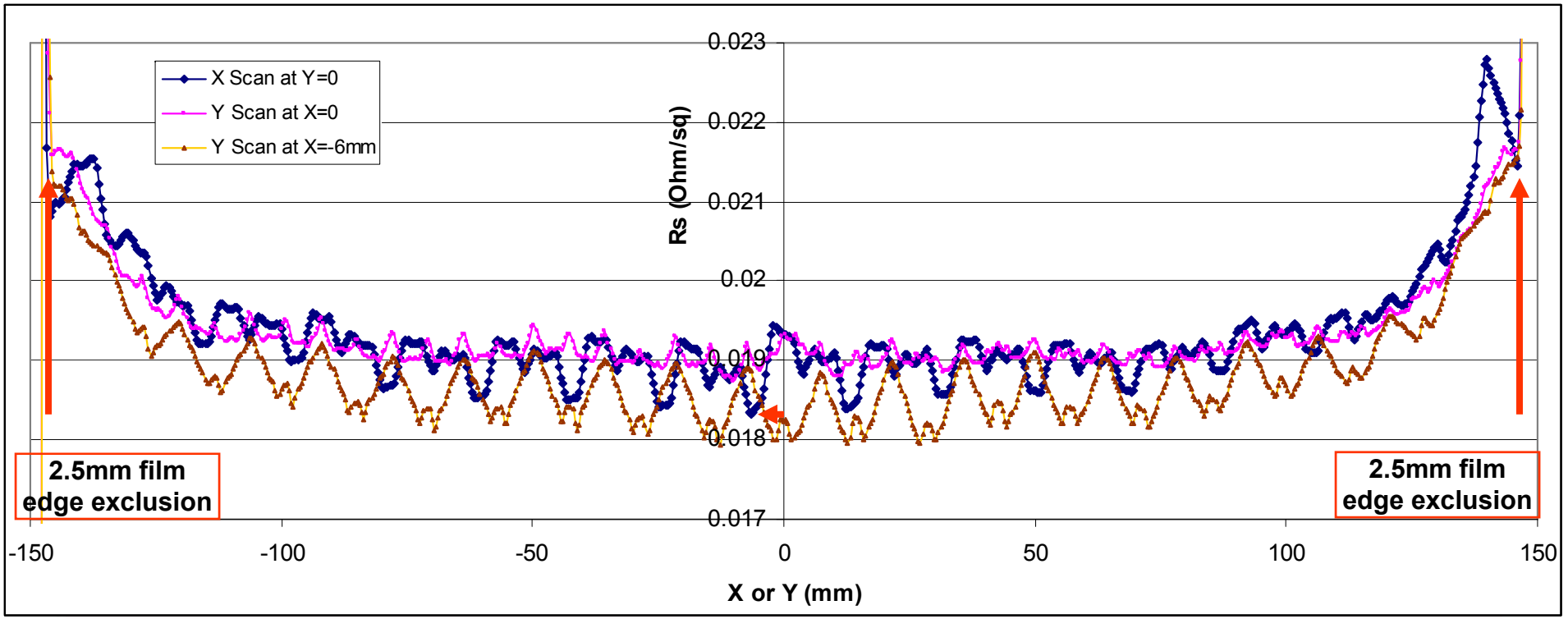


View ⊥ Notch



Diameter Scan Across Whole Wafer

- 3 Line scans with step size 400 µm, 1 for x direction and 2 for y direction
  - X scan at Y = 0 (diameter scan across COW)
  - Y scan at X = 0 (diameter scan across COW)
  - Y scan at X = -6 mm (scribe line)



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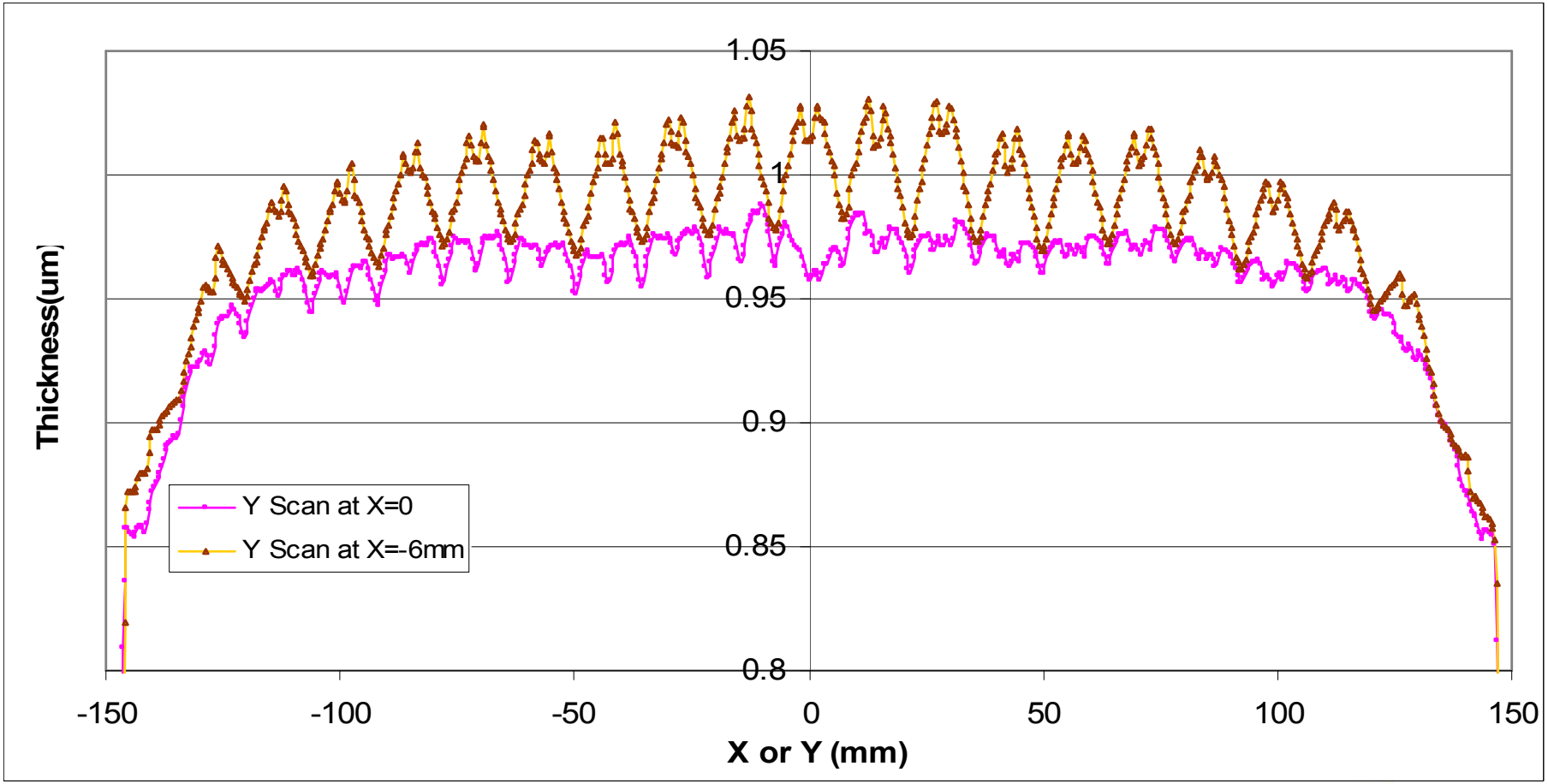
Diameter Scan Converted to Thickness

A typical copper resistivity of 1.85 μΩ-cm was used for this conversion. Lines scans at two X values are used for comparison.



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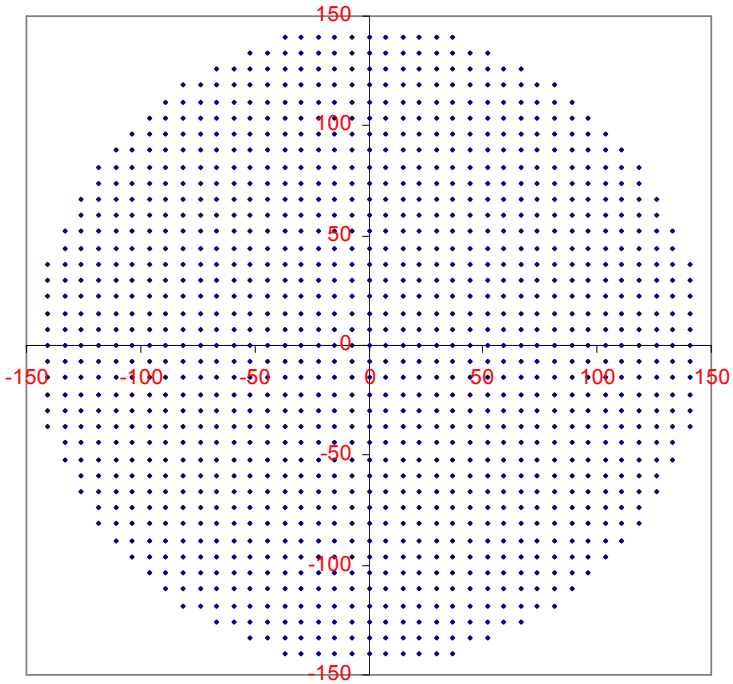
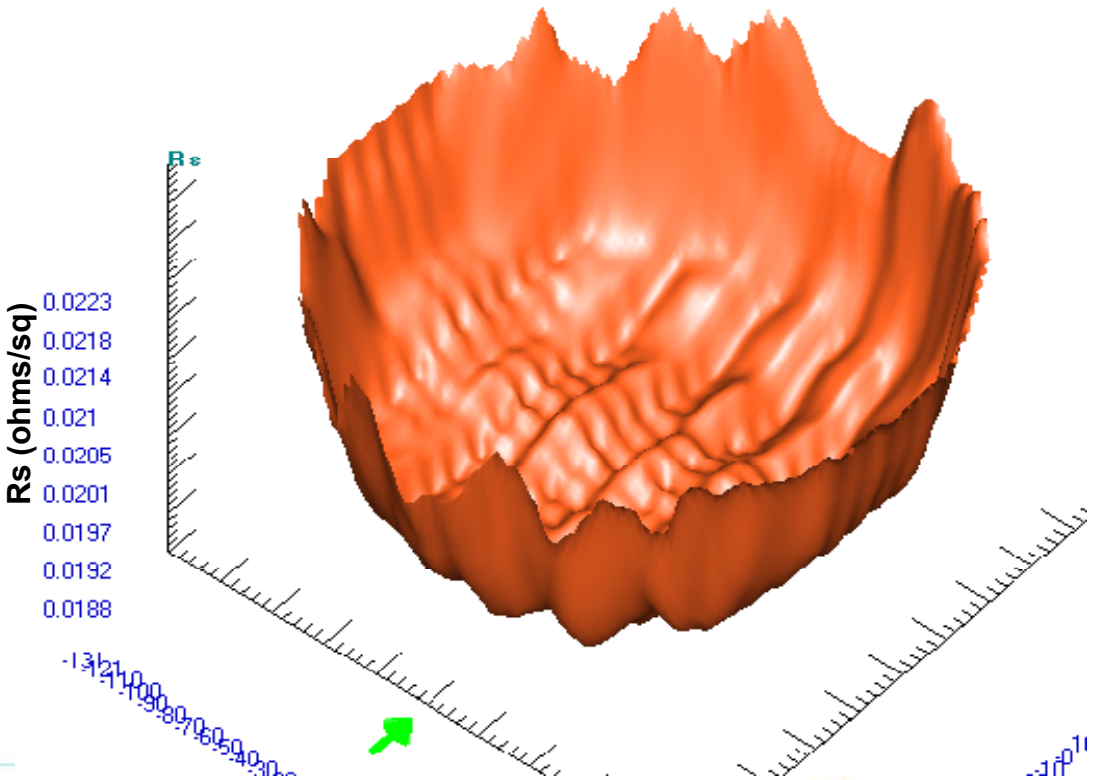
Overall Map

- Dense map with 1209 sites (square array, up to R = 145.5 mm)
  - Some internal feature of the dies visible
  - Overall non-uniformity of Rs





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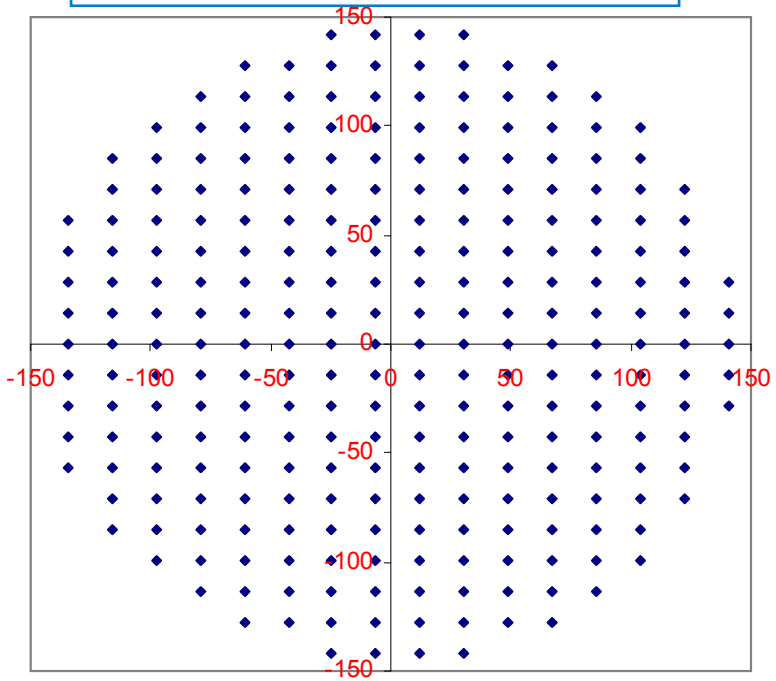
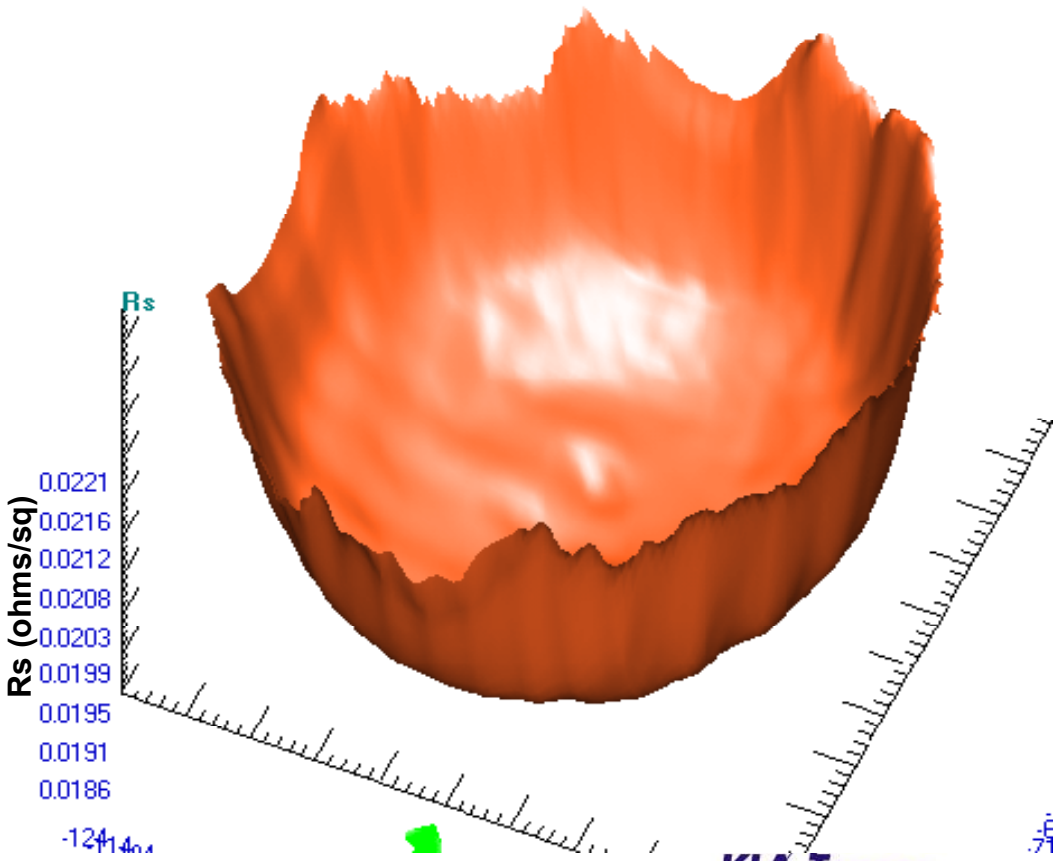
Map at Scribe Line Crossing

- Rs mapped at 262 scribe line crossing sites up to R = 145.9 mm
  - No feature of die visible
  - Overall non-uniformity of Rs

X(mm) = -6.0 + column × 18.36

Y(mm) = +0.0 + row x 14.16





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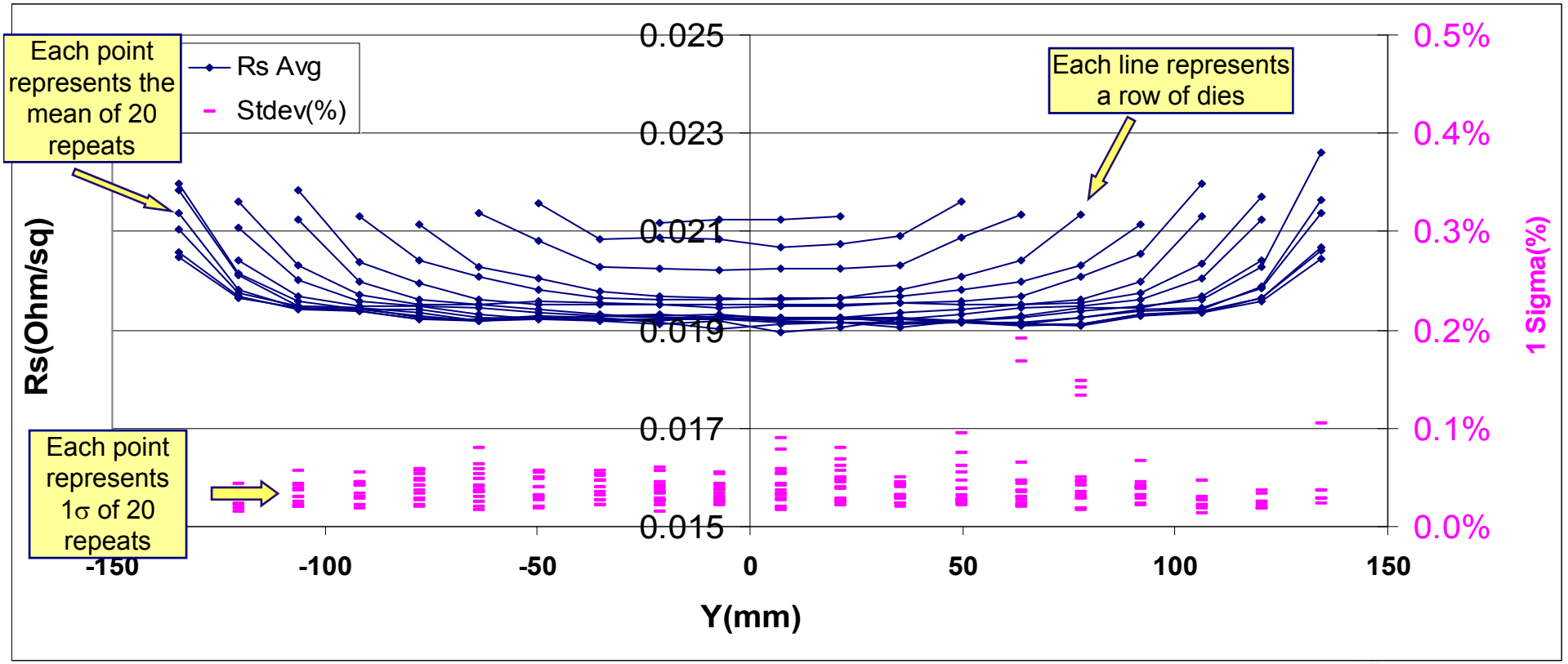
Short Term Repeatability Map on Die Center

- Dynamic repeatability shows current system is well below the standard Rs system spec of 0.5%
  - 254 dies, 20 load/unload repeats
  - Average Rs and 1 sigma based on each die



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RS 300 (RS200 w/NCRs) is Complementary to 4PP

BENEFIT	NCRs	4PP
Improved thick metal Rs measurement	No probing damage to films; inert to surface oxidation; better repeatability	Performance subject to native surface oxide and probe metal contamination
Blanket film on-product-wafer Rs measurement capability	Metal Rs capability on Cu ECP process. Measurement of barrier/seed/Cu films on product wafer	Probing damage to patterned structures underneath metal films
No metal cross contamination	Non-contact	Residue metal on probe causes cross contamination
Lower CoO	No consumables	Probes are a consumable item
Single platform advantage	Cover entire sheet resisitivity application space; on-tool calibration for Eddy current; customers do not need to justify a stand-alone tool	

Summary

- Non-contact Rs (NCRs) or thickness shown for thick metal films
- NCRs can eliminate issues resulting from 4PP marks on monitors which could effect polishing, particle tests or reclaim
- Huge cost savings
- Product or pattern wafers can be used instead of monitor wafers in many cases (using die intersection values)
- Potential valuable on-product information relating to over die or pattern values