



OCD
METROLOGY

3D
PACKAGING

THIN FILM
METROLOGY

MATERIALS
CHARACTERIZATION

DEFECT
INSPECTION

OVERLAY
METROLOGY

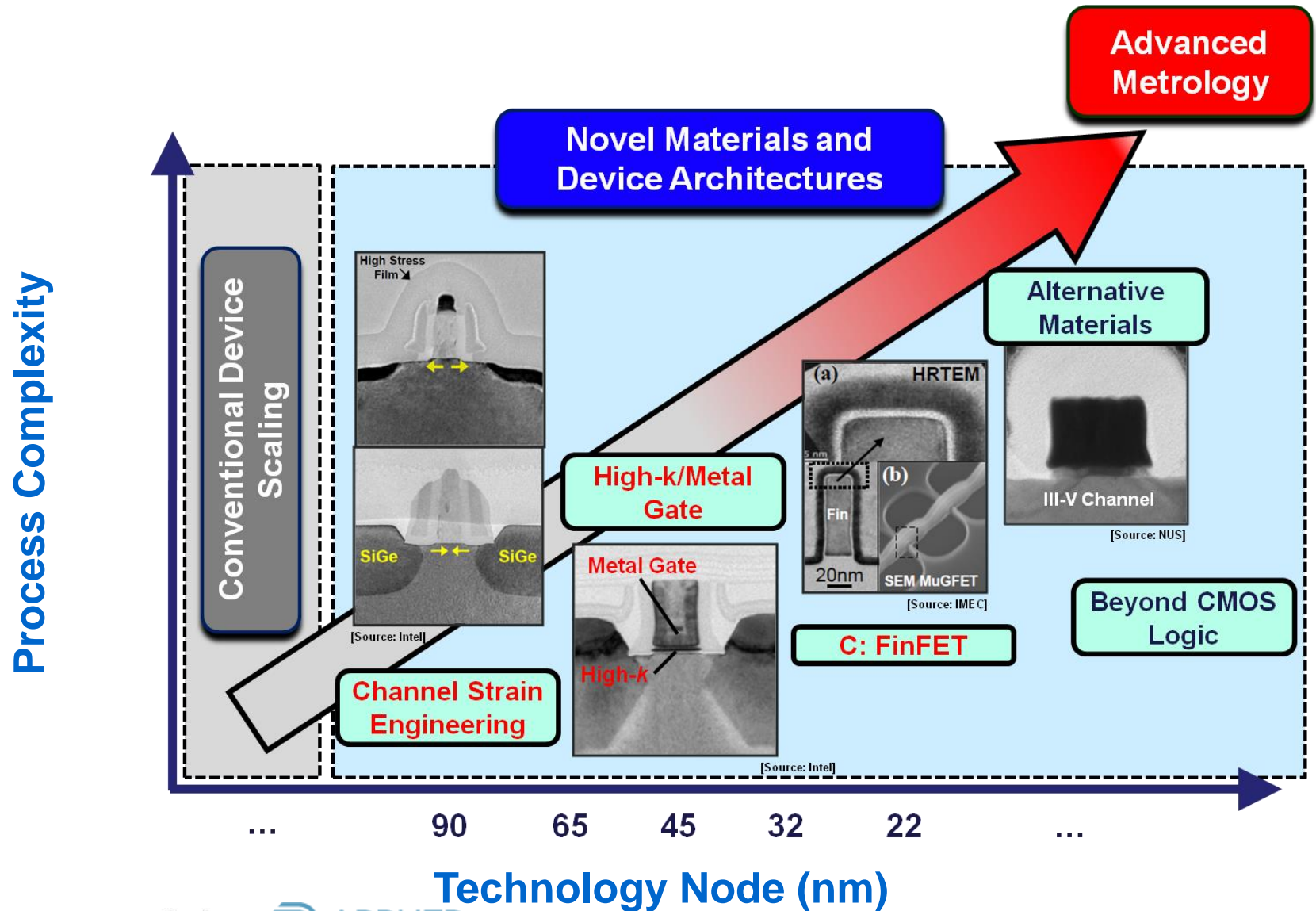
Integrated Metrology OCD for CMP Applications

*Yongdong Liu^a, Zhefu Wang^b, Stephen Jew^b, Yongbin Qi^a,
Bingqing Li^a, Moh Lung Ling^a, ChungHwa Wang^a*

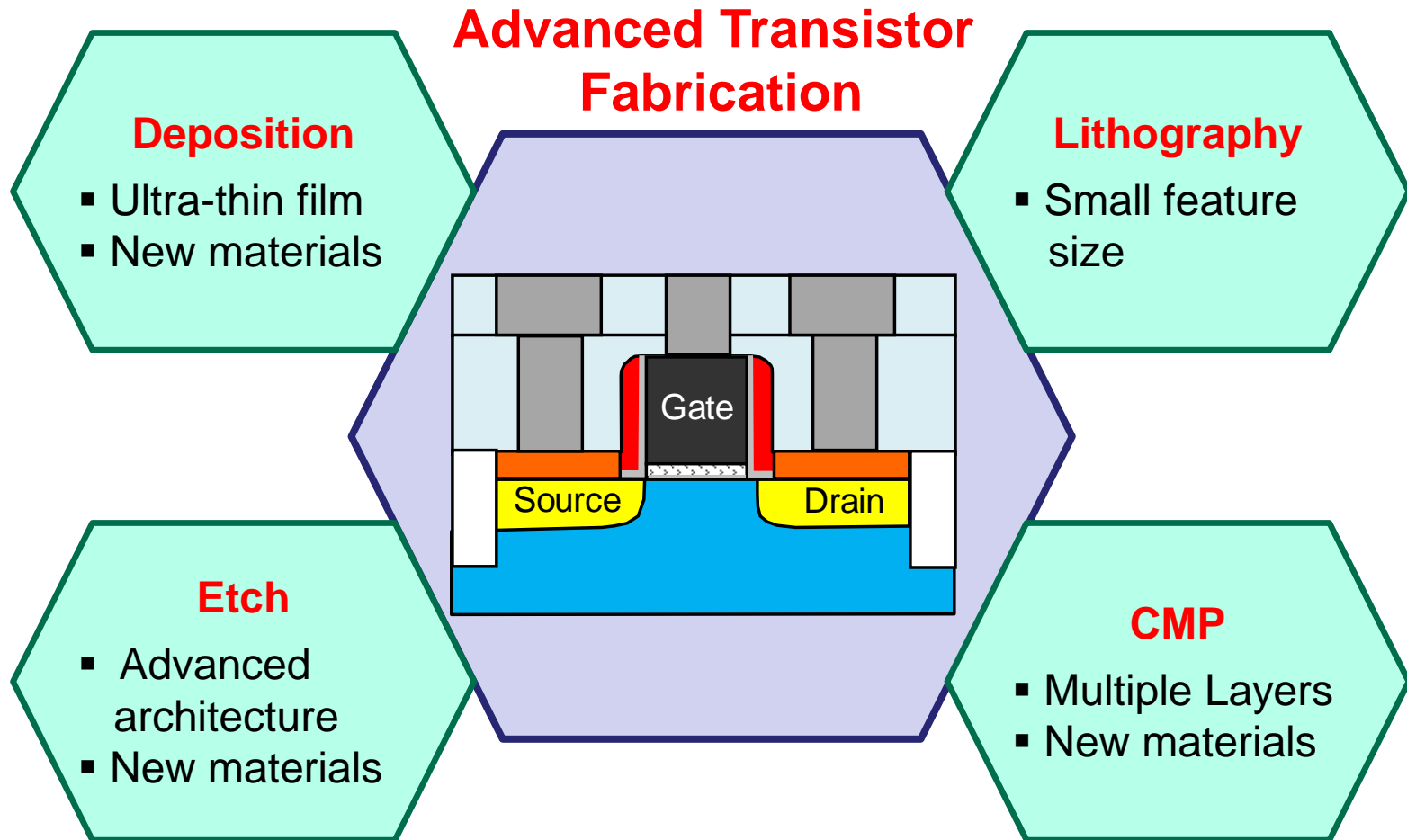
Topics

- OCD for Advanced Process Monitoring & Control
- Nanometrics OCD Technology
- Integrated Metrology OCD for Cu CMP Applications
- Summary



Process Complexity Increases with Device Evolution: Strong Demand of Advanced Metrology



Opportunity for Advanced Metrology

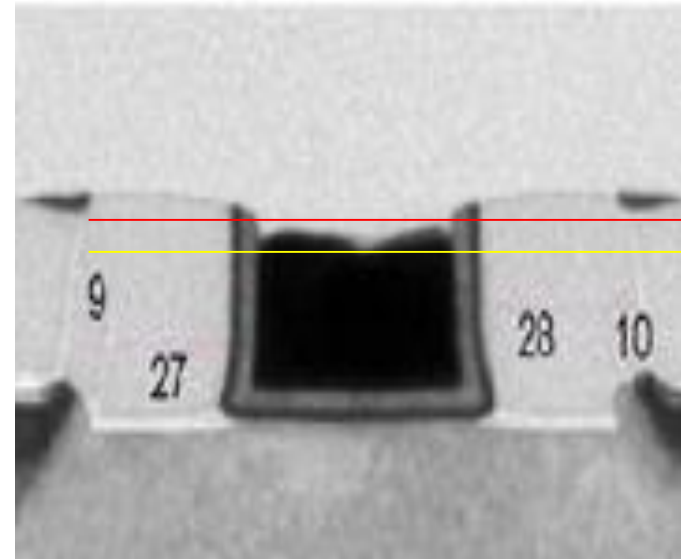
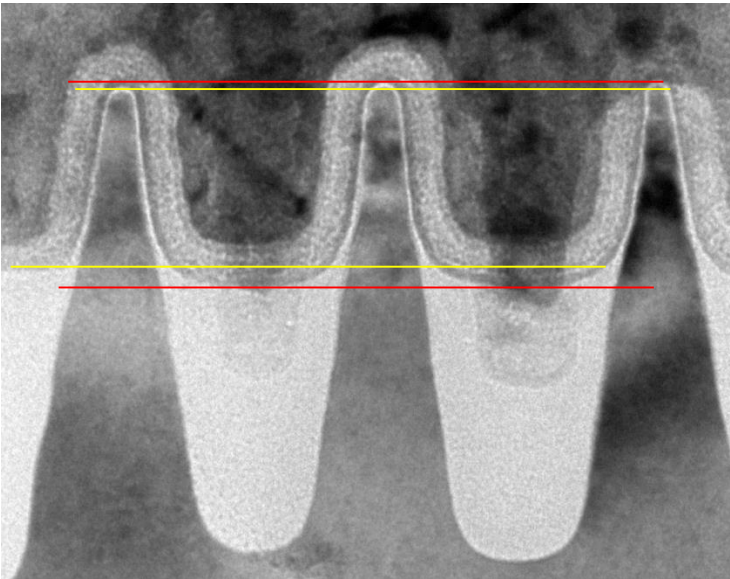


Advantages of Optical Metrology

	Optical Methods	Other Methods
		
Non-destructive	✓	✗
<i>In-line</i> Monitoring	✓	✗
Speed & Cost	✓	✗
Accuracy	✓	✓

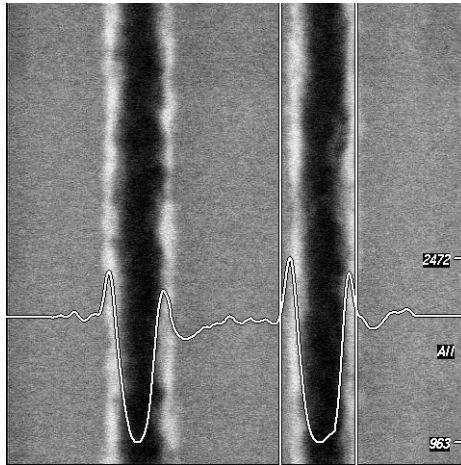
Large Uncertainty of TEM Reference

Representative FinFET TEM Images

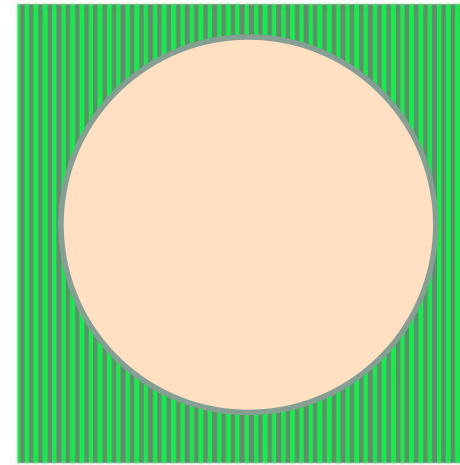


- TEM error ($\pm 3\text{nm}$) can often be larger than the parameter range (2nm) due to image resolution, line to line variation and non-ideality of the structure.

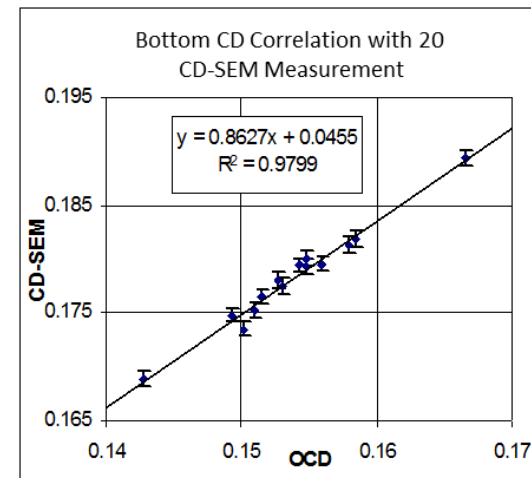
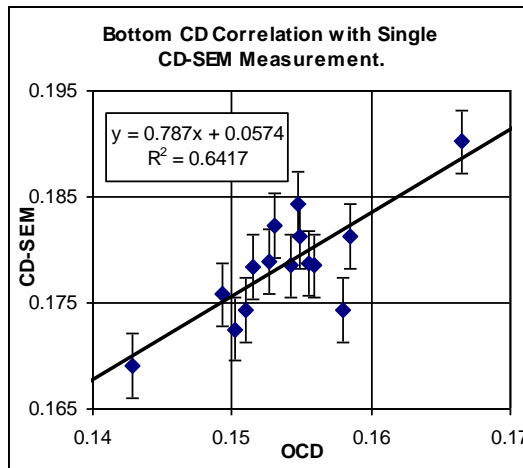
CD-SEM vs. OCD – Small vs. Large Sample Size



CD-SEM



OCD



- OCD target has smaller uncertainty due to large sample size



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advanced process control systems and solutions

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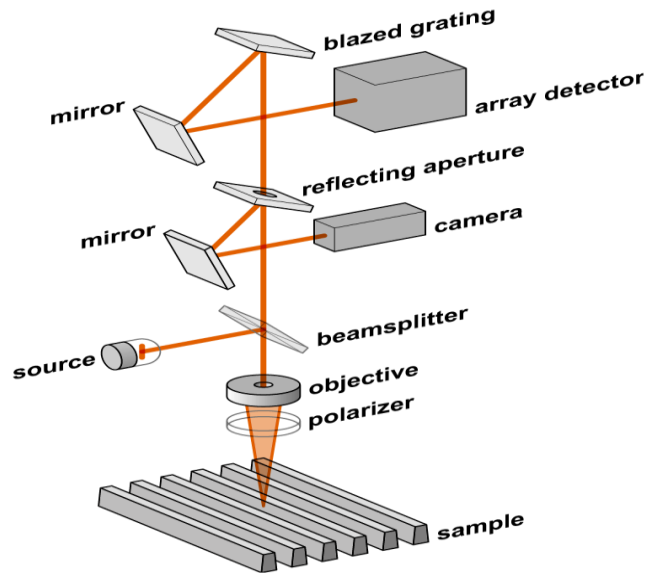
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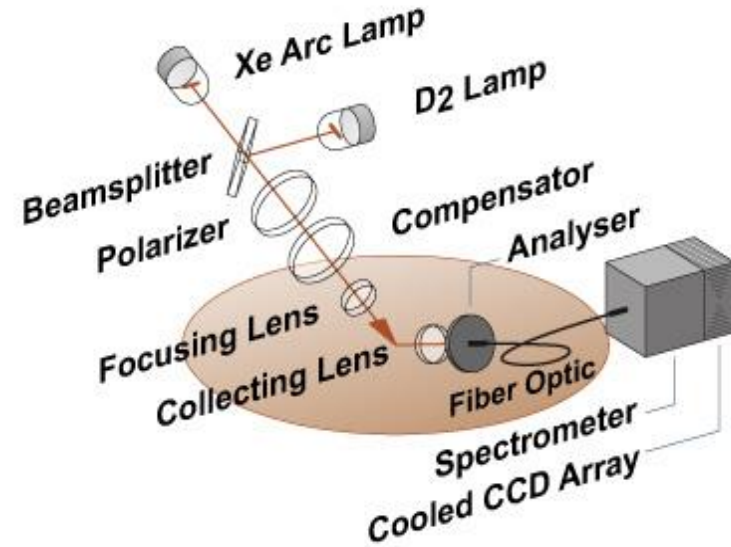
Nanometrics OCD Technologies

OCD Technologies Offered by Nanometrics

NIOCD



Spectroscopic Ellipsometry



■ Spectroscopic Reflectometry

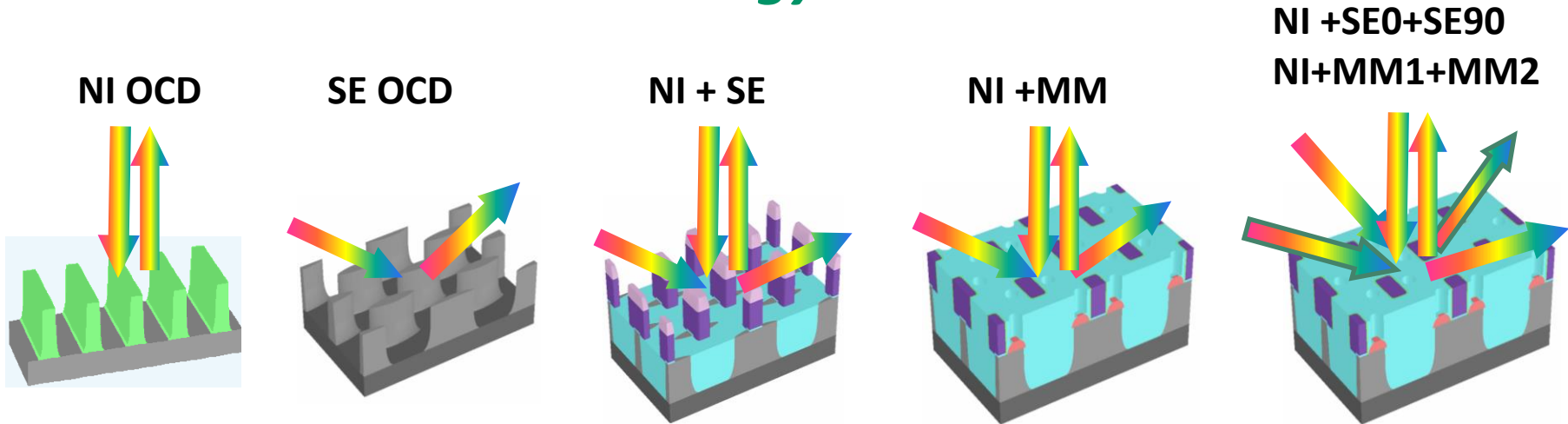
- Polarized broadband incident light
- Multi-wavelength, **normal** incidence
- Measure **intensity** change.

■ Spectroscopic Ellipsometry

- Polarized broadband incident light
- Multi-wavelength, **oblique** incidence
- Measure **polarization** change.

*Note: Mueller is a generalized SE technology.

Nanometrics OCD Technology



	NI OCD	SE (RAE)	SE (RCE)	NI+SE	NI+Mueller	NI+SE0+SE90 NI+MM1+MM2
Data	TE/TM	α, β	N, S, C	TE/TM/N, S, C	TE/TM/15 MM terms	TE/TM, SE or MM for multi-azimuths

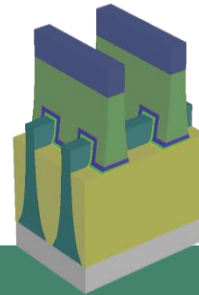
- **Complex technology – MM and Combined techniques – key for solving complex OCD problems**
 - Structure complexity; parameter sensitivity; parameter correlation
- **Nanometrics provide the most complete OCD technology portfolios to meet the metrology challenges**

Leader in OCD Solutions for FinFET and 3D NAND

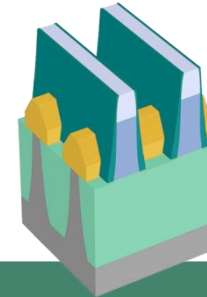
ATLAS II+

SA

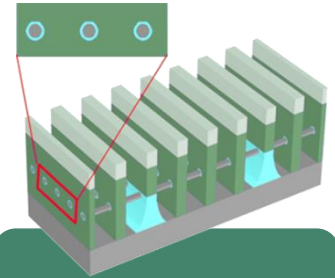
- Process Control for all Critical Steps
- Fab Deployment:
 - Transistor
 - Lithography
 - Contact
 - BEOL



16/14nm: FinFET



10nm:
Replacement Channel



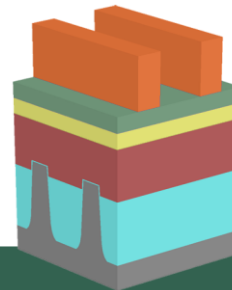
Future: NanoWire

IMPULSE

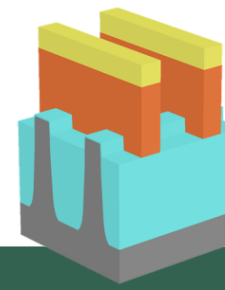
- Integrated Solutions for Critical Lot and Wafer-to-Wafer Control
- Fab Deployment:
 - CMP
 - Track
 - Etch



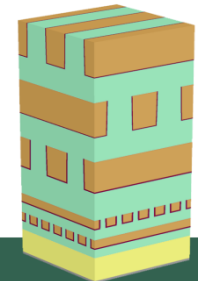
IM



Lithography (Track)



Gate Etch

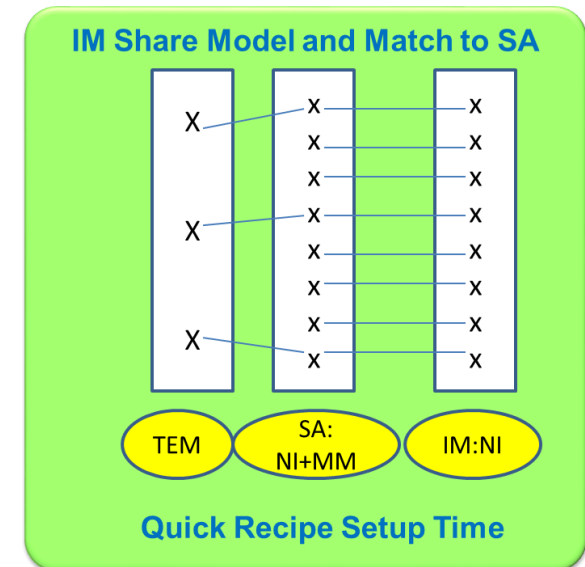
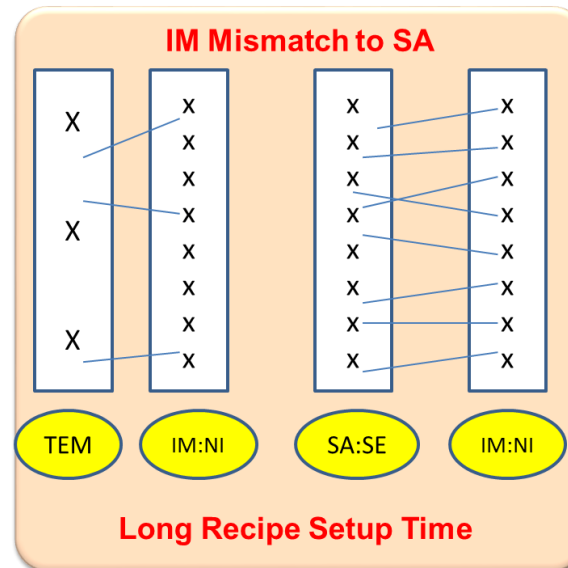


Metal CMP

Good Compatibility of Nano IM with SA for HVM

- Same optical path for IM and SA SR channel
- Extensive TF experience and optical model library enables good thin film matching to any SA systems
- Quick recipe setup as same OCD model SW for IM and SA
- One Time Quick Recipe Set-up for SA and IM in HVM

Thin Film Target (A)	Number of Layers	Skew to SA (A)
600	14	+/-3
800	64	+/-8
520	63	+/-5
2,500	63	+/-5
6,000	63	+/-15





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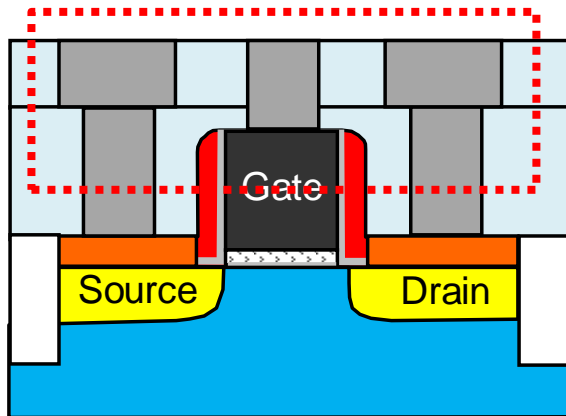
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IM OCD for Cu CMP

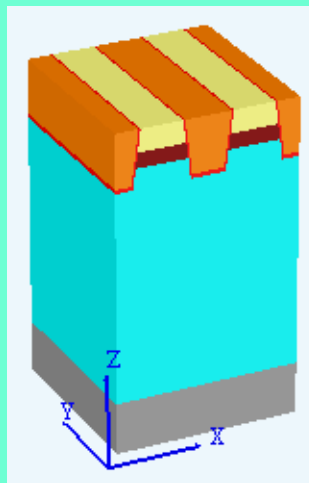
OCD For Cu Structure Measurement



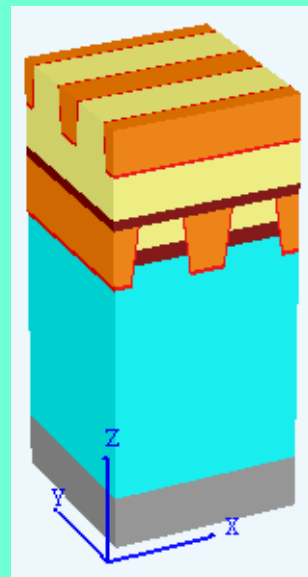
Parameters

Cu Height, CDs, film thickness, dishing, erosion, under layer geometries

M1



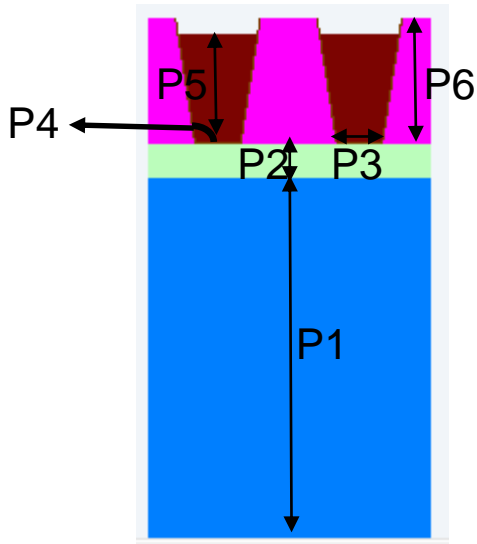
M2



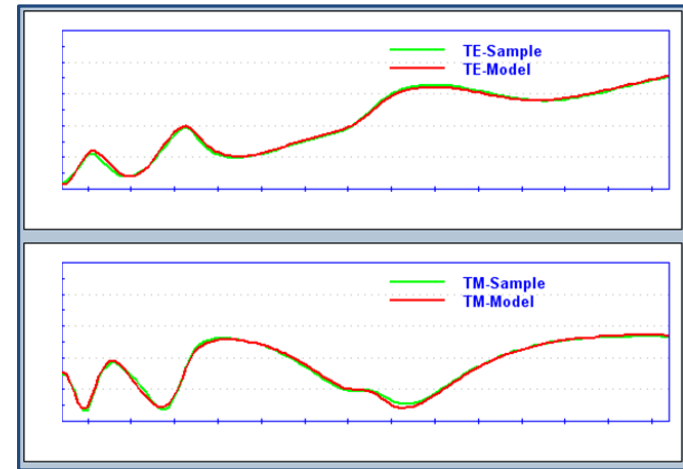
M3



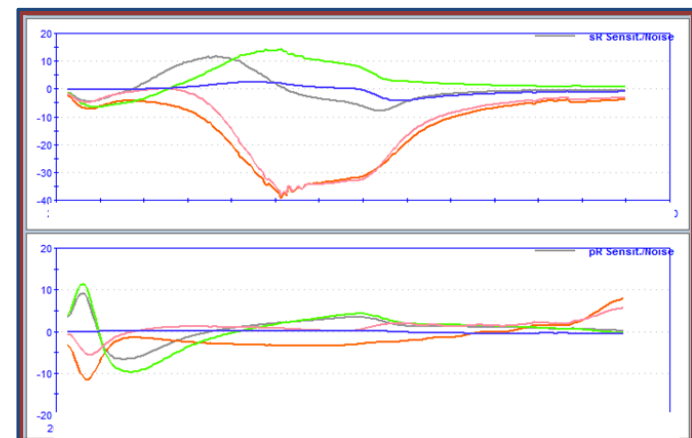
OCD Model and Fitting -- M1 Structure Measurement



Model & Fitting



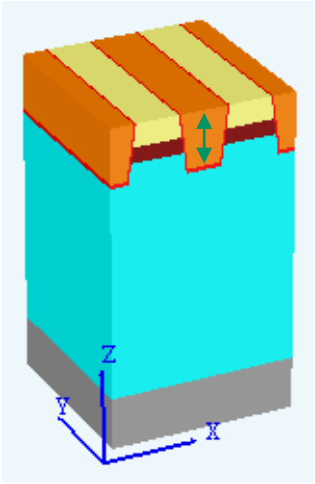
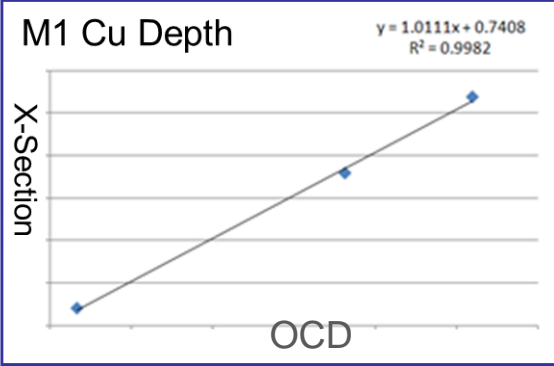
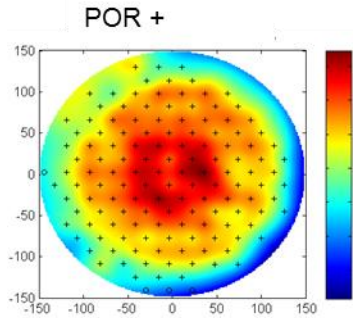
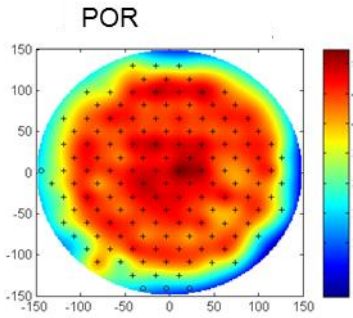
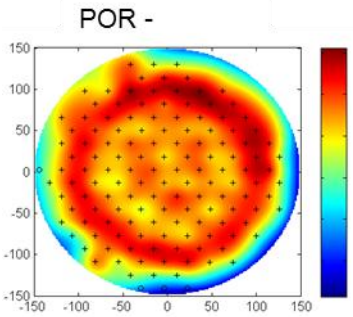
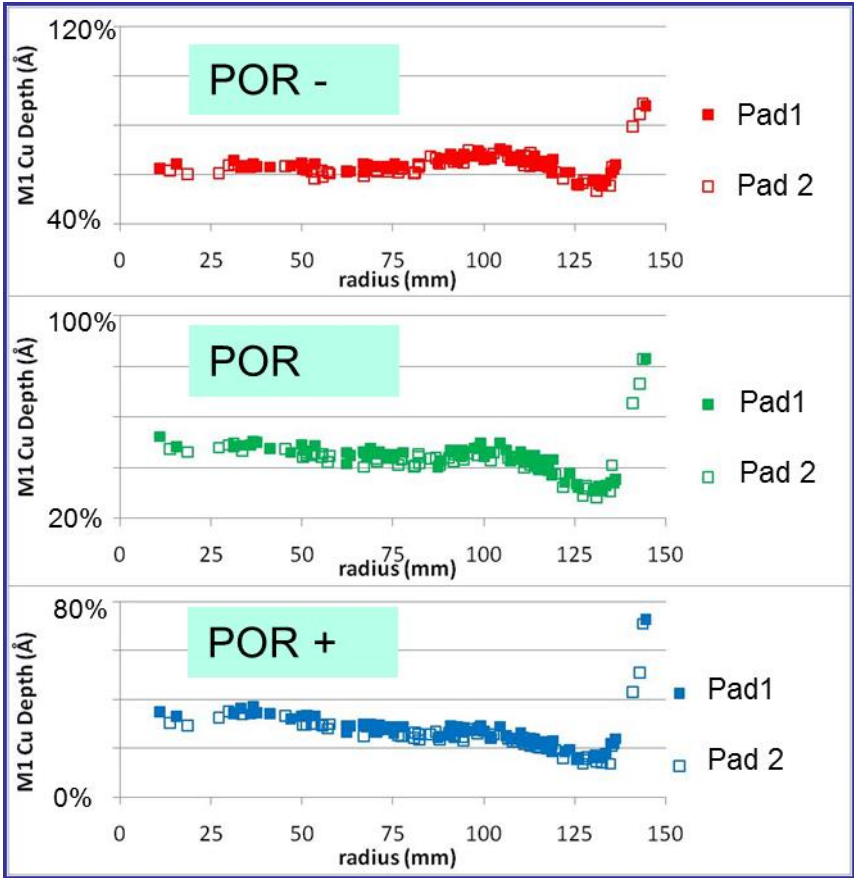
Sensitivity



Floating Parameters

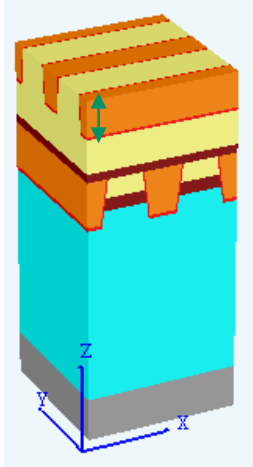
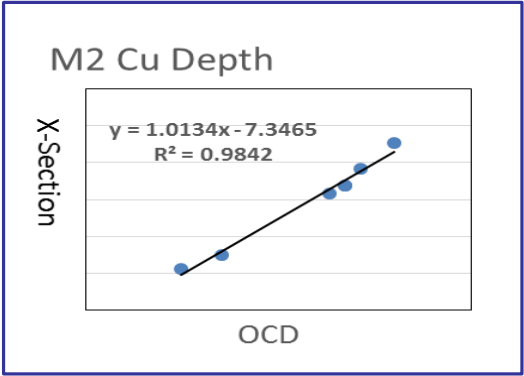
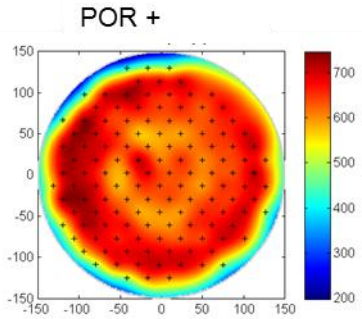
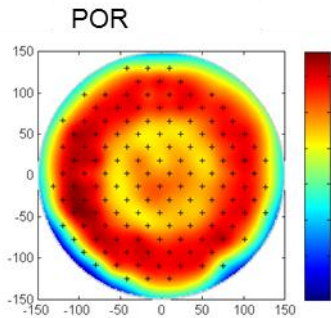
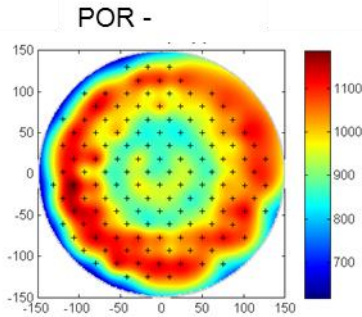
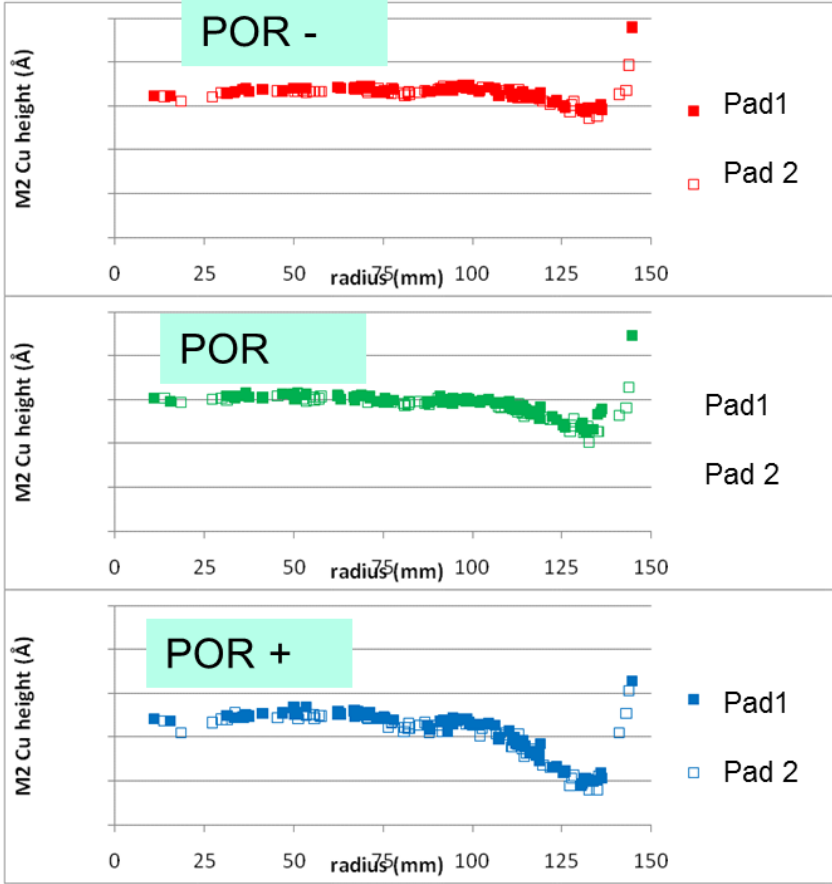
P1 Thickness1
P2 Thickness2
P3 Cu BCD
P4 Cu SWA
P5 Cu Height
P6 Thickness3

M1 Cu Height Measurement



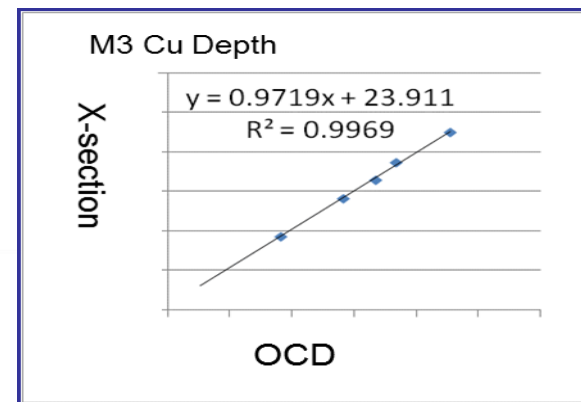
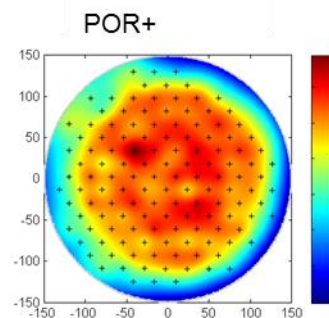
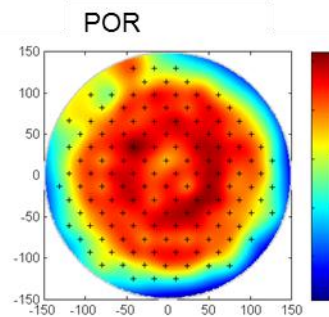
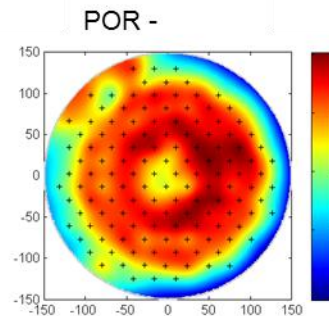
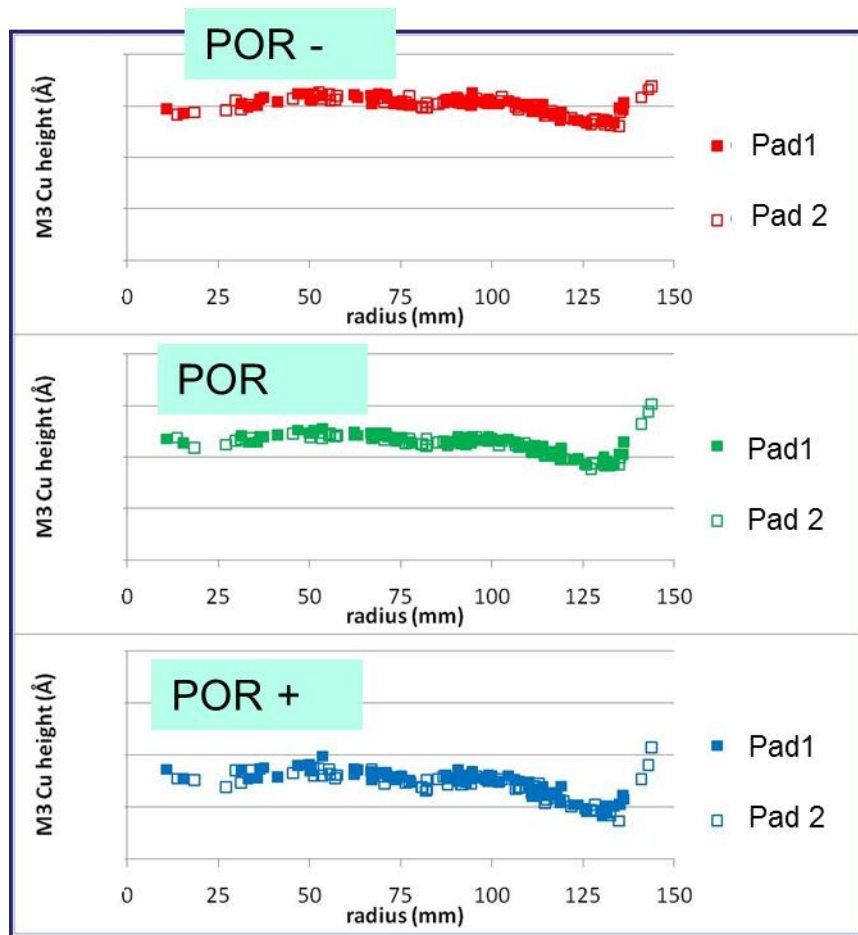
- Clear DOE split of Cu Height
- Consistent wafer-to-wafer distribution

M2 Cu Height Measurement



- Clear DOE split of Cu Height
- Consistent wafer-to-wafer distribution

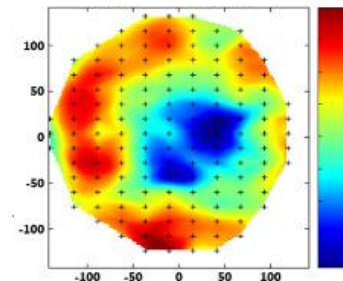
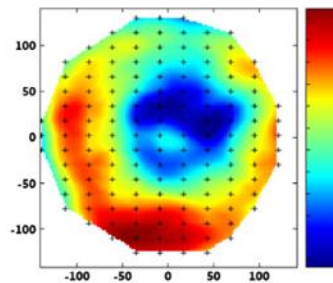
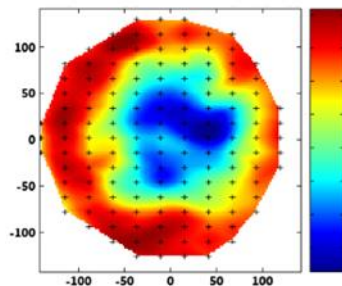
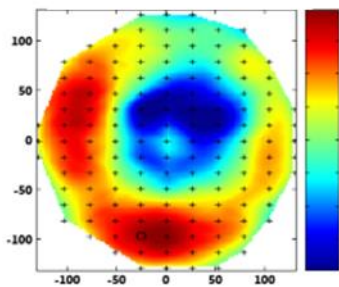
M3 Cu Height Measurement



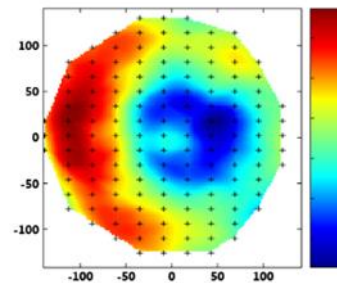
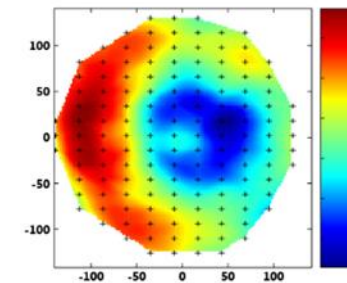
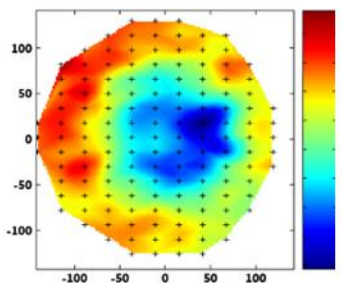
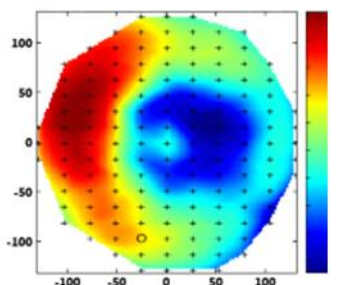
- Clear DOE split of Cu Height
- Consistent wafer-to-wafer distribution

Erosion Measurement -- Top Oxide Wafer Map Plots

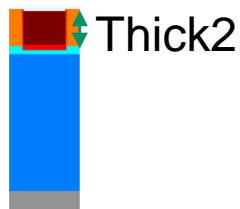
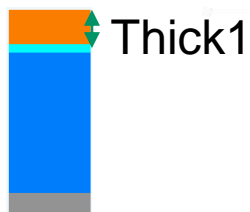
W1



W2



Pitch Increase

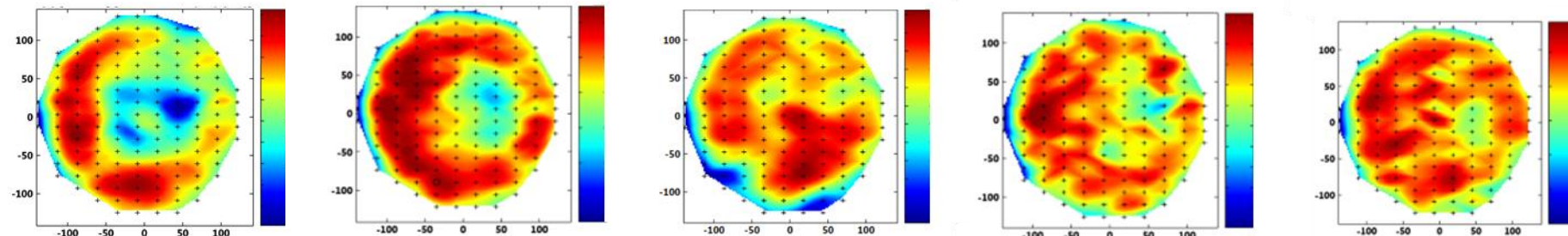


Erosion=Thick1-Thick2

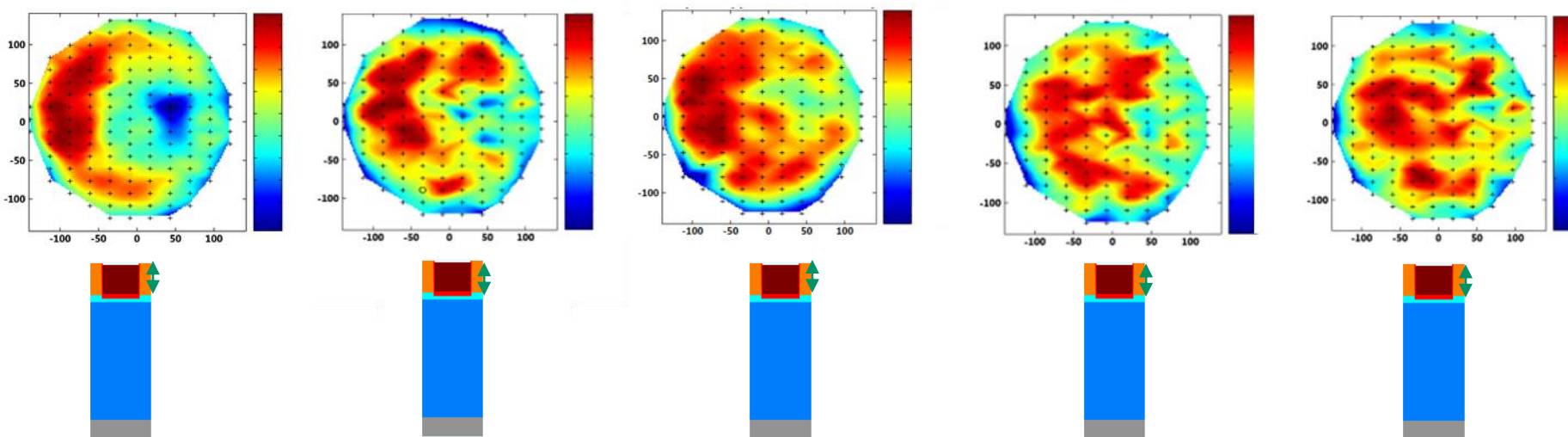
Consistent wafer-to-wafer distribution of top oxide

Erosion Measurement --Top Oxide Wafer Map Plots

W1



W2

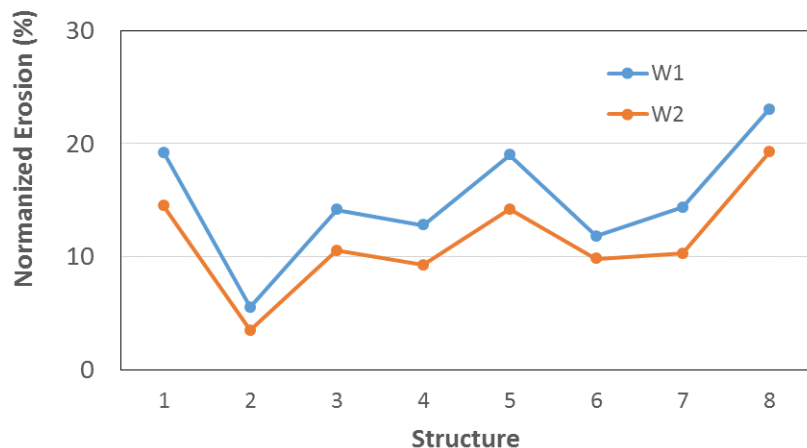


Pitch Increase

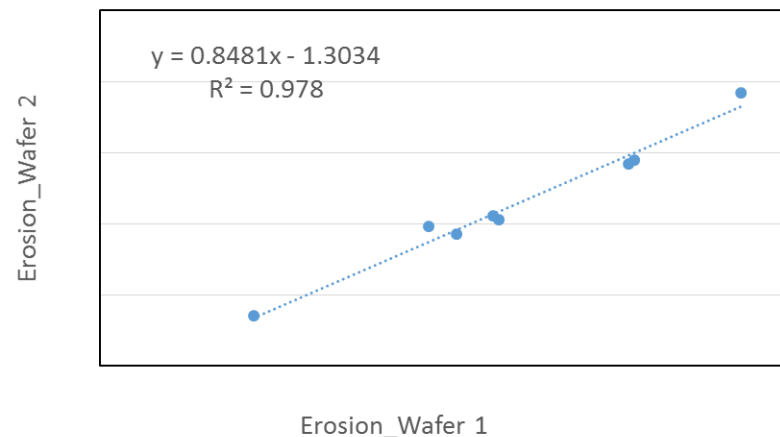
- Top oxide distribution is consistent from wafer-to-wafer
- Within wafer distribution gradually changes with the change of pitch

Erosion Measurement – Wafer-to-Wafer Comparison

Erosion on Different Structures



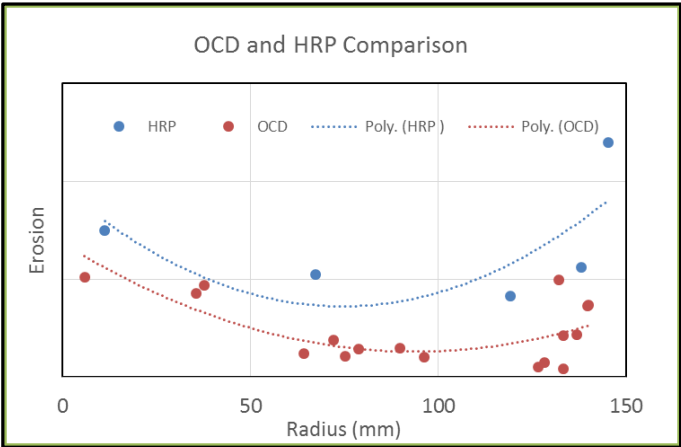
Erosion Correlation on two Wafers



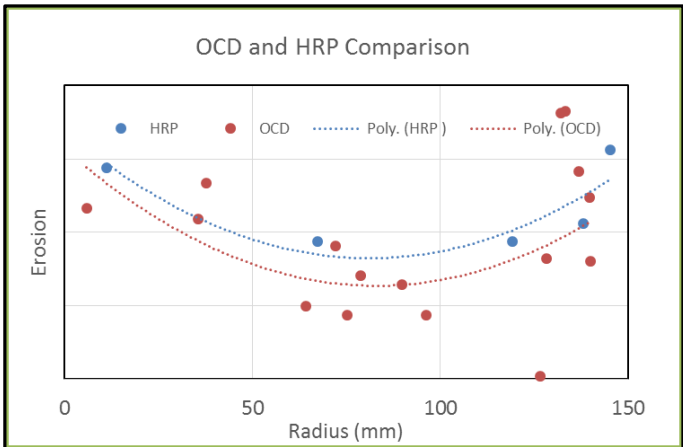
- Consistent erosion wafer-to-wafer trend trend for different pattern density and pitch
- Good erosion correlation b/w different wafer

Erosion Measurement – OCD vs. Surface Topography Tool (HRP)

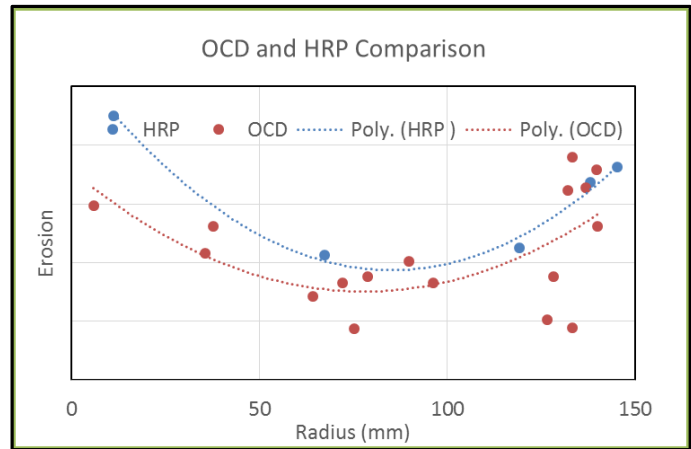
50% Pattern Density



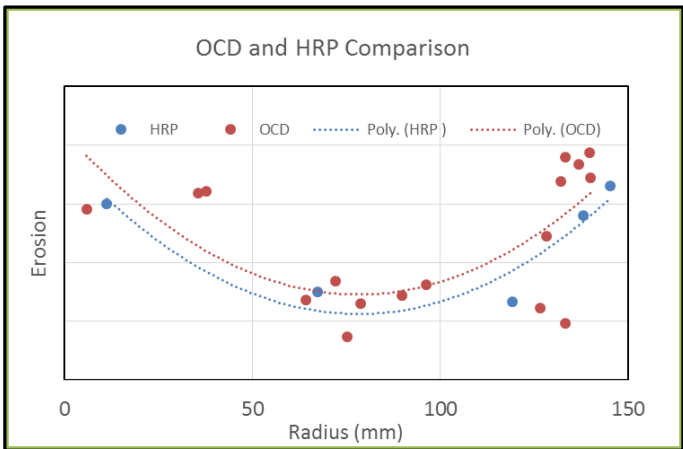
60% Pattern Density



80% Pattern Density (small pitch)



80% Pattern Density (large pitch)



■ Consistent within wafer trend for different pattern density and pitch

Summary

- **OCD is the right candidate to meet the strong demand for advanced process monitoring & control.**
- **Nanometrics provides the most complete OCD technology portfolios to meet the metrology challenges.**
 - Standalone NI+SE/MM provides process control for all Critical Steps
 - Integrated TE/TM critical lot and wafer-to-wafer Control
 - Good compatibility of IM with SA for HVM
- **Successful applications of IM OCD for Cu CMP**
 - Direct Cu grating profile and underlayer measurement from M1 to M3
 - Thorough erosion behavior study on pattern density and pitch



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