Innovations in Integrated Metrology

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Evolution of Integrated Metrology based CMP process control

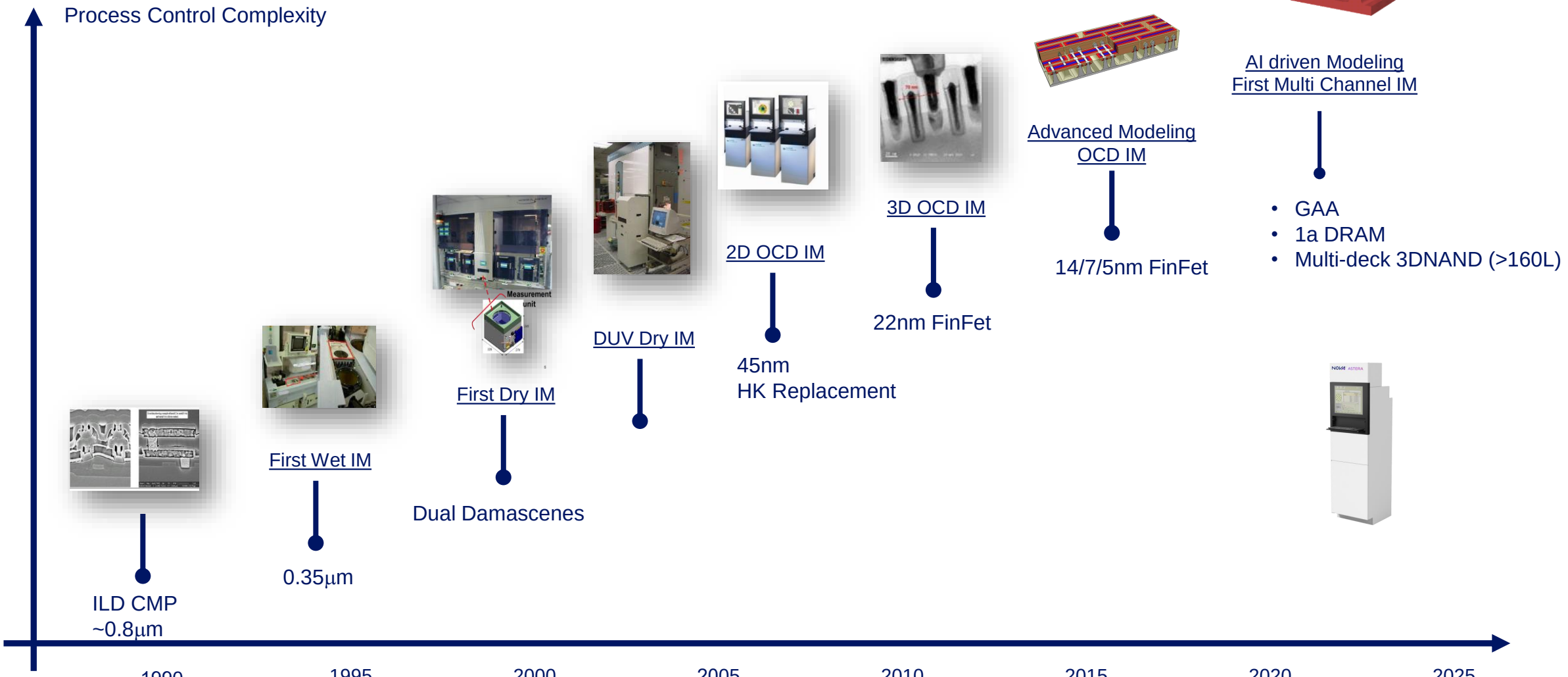
Emerging CMP process control challenges

IM in-die metrology empowered by AI

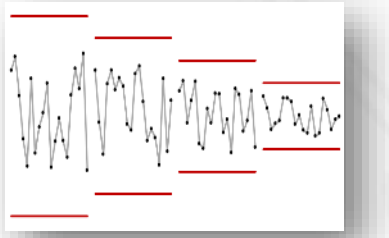
Multi Channel Integrated Metrology and ultra thin residue control

New process control capabilities enabled by AI

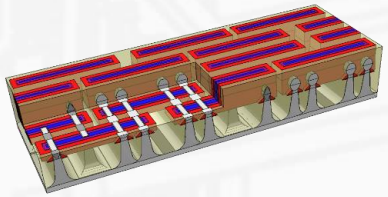
Evolution of IM based process control



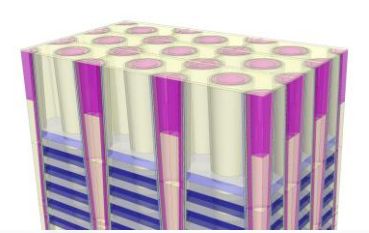
Emerging Process Control challenges



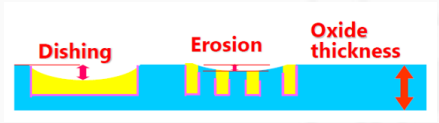
Tighter Specs as design rule shrinks



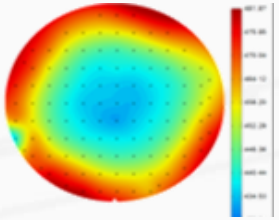
Device vs. Scribe control



Ultra-Thin Residue Control



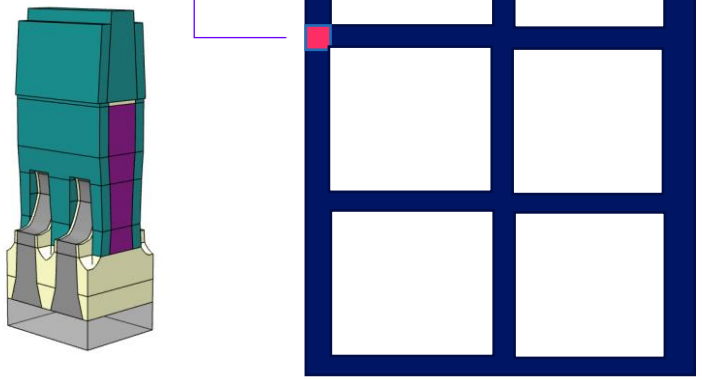
Micro Loading/Local Density effects: Dishing, erosion, hot-spots



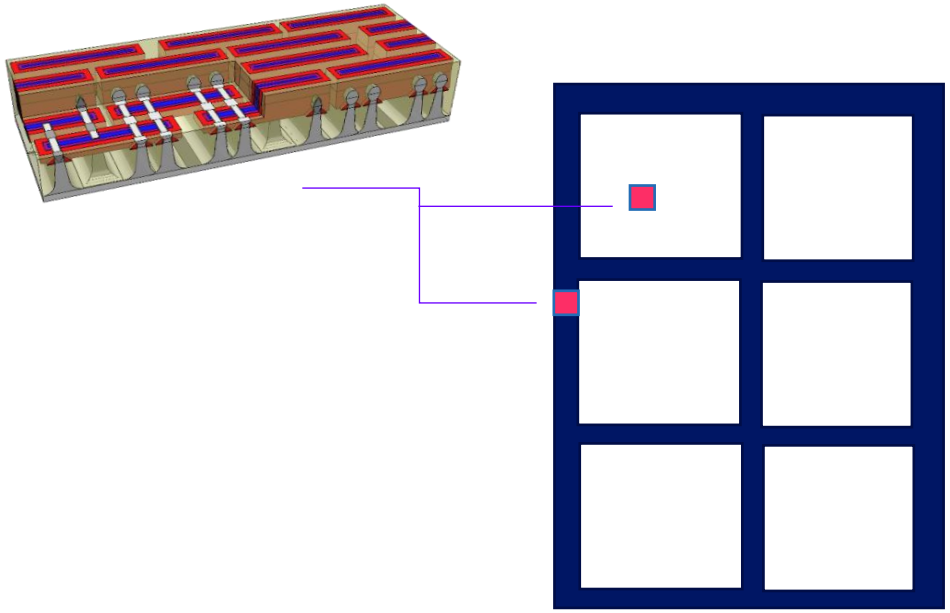
High Sampling, WiW, WtW and CoO control

Moving in-Die/on Device Measurement

Traditional Measurement



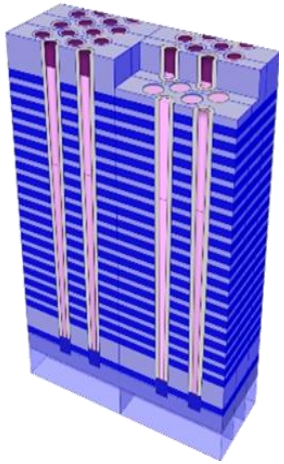
Desired Measurement

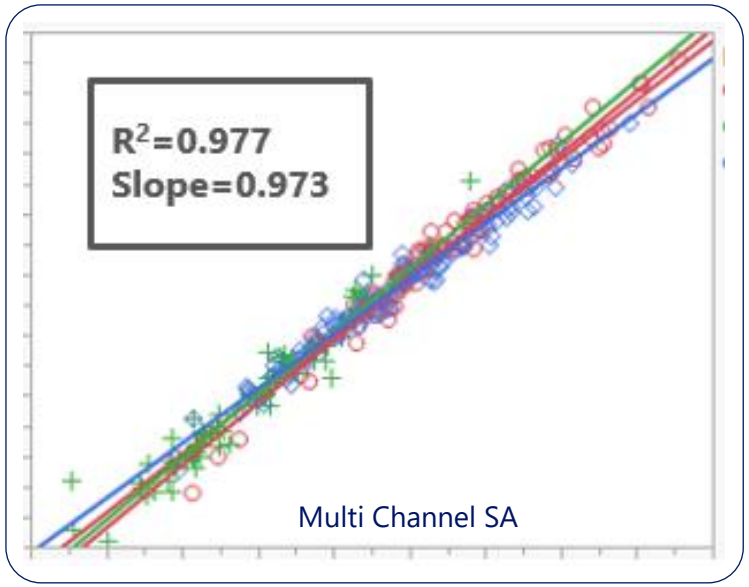


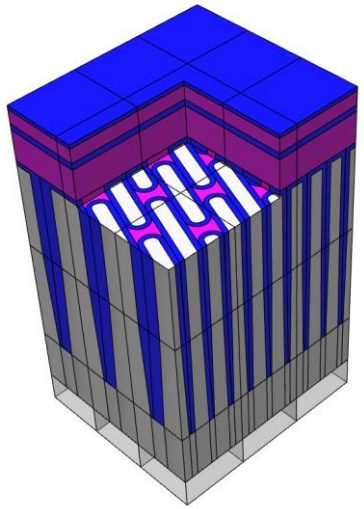
Motivation

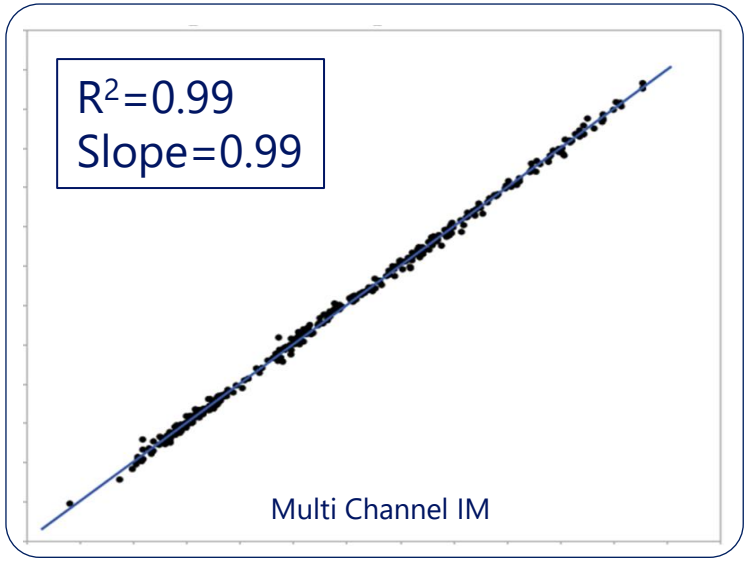
- Improved correlation to yield
- Improved WID and Edge control

Solution: Integrated Metrology Empowered by AI





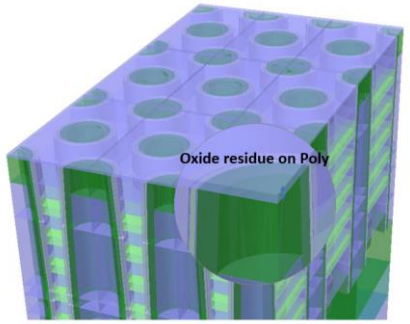


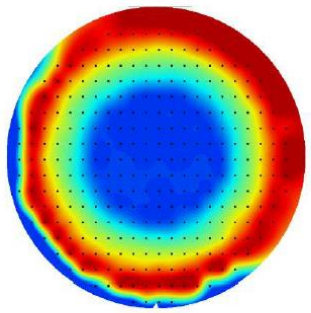


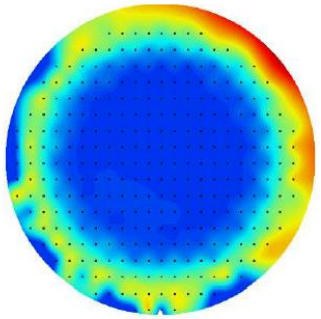
- In-die measurement in IM form factor
- Limited amount of destructive reference
- Improved CMP Cpk thru APC
- Economical CoO for HVM

In-die ultra thin residue control

- Post CMP residues results are highly related to incoming variation. Significant yield loss can be expected due to:
  - electrical opens in the device degrading chip yield
  - electrical shorts
- Due to different density between scribe-line and in-die, scribe-line based residue control results in insufficient metrology for remaining resides
- Due to lack of robust metrology for in-die, traditionally simplified scribe-line structure is used




In-Die Target


Scribe-line Target

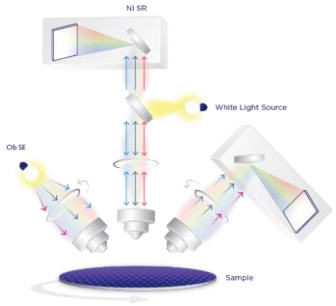
Multi Channel IM – ASTERA Prime

Unique product architecture

- New platform combining Normal Incident & Oblique Channels
- New light source with improved SNR
- New Stage for most accurate navigation

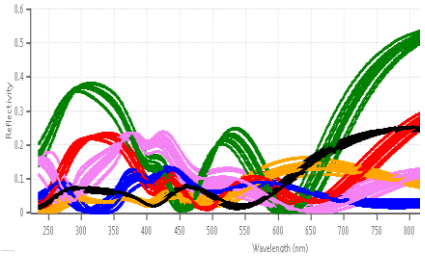
Best in class metrology performance enabled by HW

- Standalone level accuracy
- Best sensitivity and parameters de-correlation
- Repeatability & Tool matching improvement

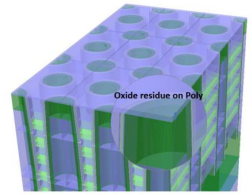


Shorten R&D Time To solution

- Accurate model-based solution
- Fast adaptation to CIP changes (<1day)
- Eliminate the need to measure on SA



In-die ultra thin residue detection metrology



Challenge

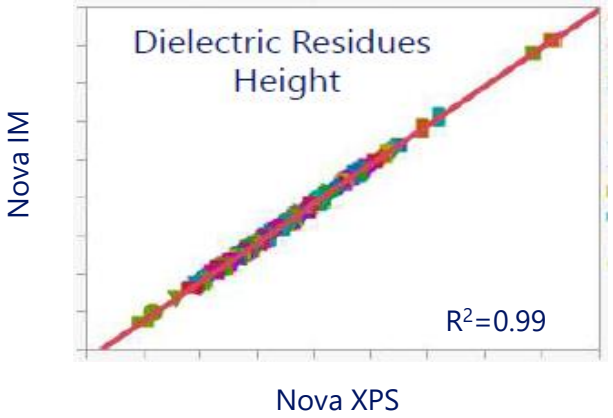
In die detection of remaining dielectric or metal layer post CMP process

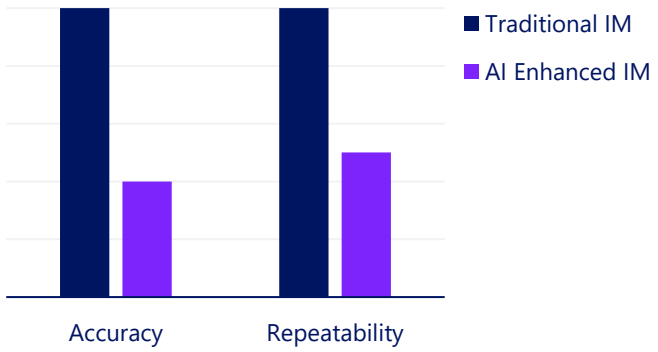
- Ultra thin layer on complex stack
- Complex modeling and long time to solution
- Low sensitivity for traditional NI Channel

Solution

Enhancing IM capability by MC IM metrology and AI

- <20A sensitivity on IM platform
- Fast time to solution supporting aggressive R&D cycle
- Every wafer detection for excursion elimination
- High sampling for WiW and edge residue control





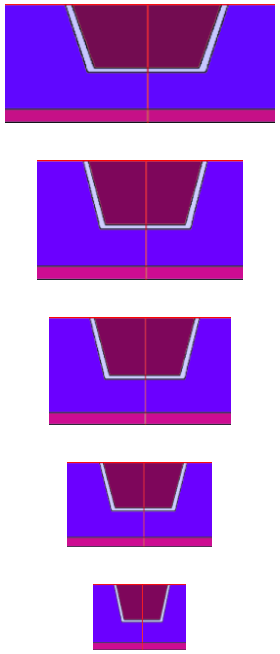
Extending CMP Control Beyond Optical Metrology

1. Metal CMP resistivity control

2. In-die Dishing/Erosion monitoring

Metal CMP Resistivity Control

Interconnect scaling with advancing technology node



E-test Resistivity Dependence	Parameters of interest
Copper Area	TCD, BCD, Trench Height
+Liner Area	+ Liner Thickness and Shape +Non trapezoid Cu Area
+ Copper grain size, Liner properties, Cobalt capping	+Copper & Liner Material Cap thickness
+Structure density	Non-periodic e-test site

Challenge

EOL Electrical test
- Long info turn
- No early excursion prevention

In-line Electrical test
- Low Throughput and productivity
- Q-time violation
- Defects due to contact-based measurement
- Low statistics & high CoO

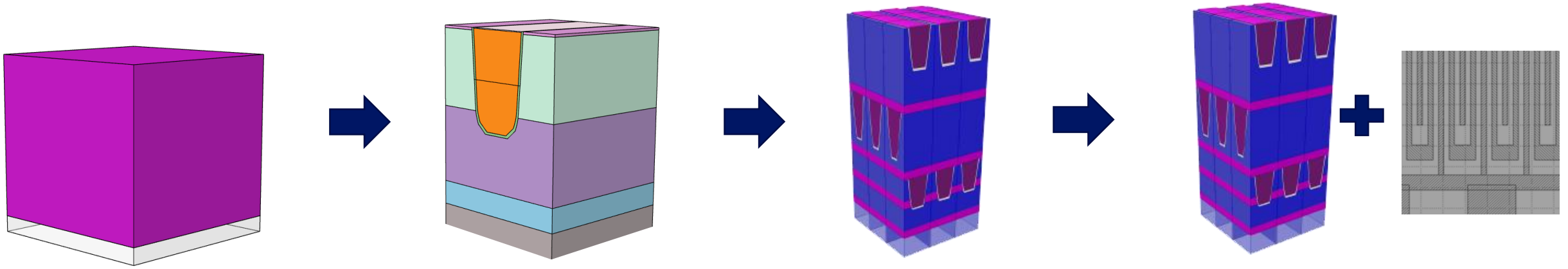
In-line OCD
- Model inaccuracies due to multiple variables
- Poor correlation between metro cell and e-test site

Solution

In-line IM Metrology based Machine Learning

- Excellent correlation to EOL e-test
- High throughput and excellent CoO
- No Q-time concern
- Done directly on e-test site/in-die

Evolution of IM Capabilities in BEOL CMP

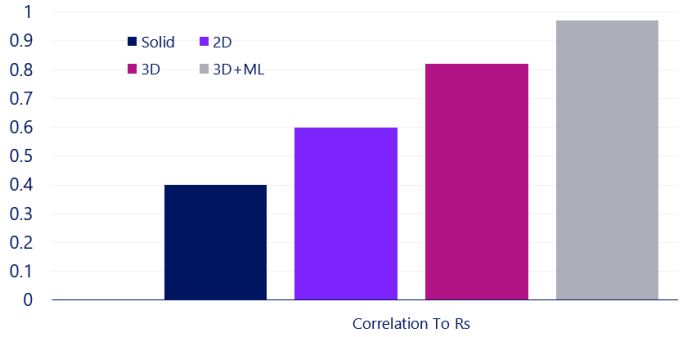


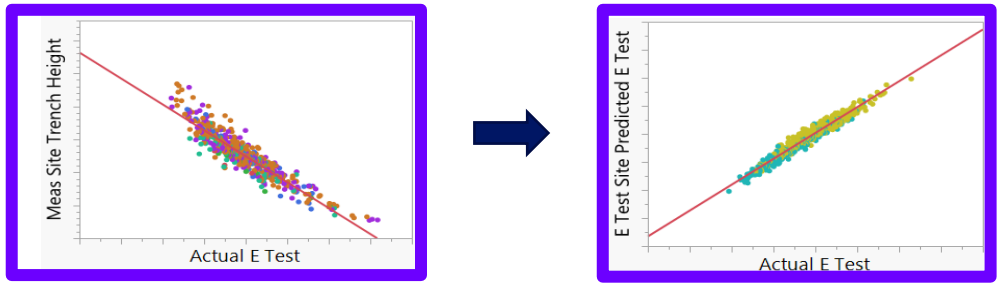
Solid Site on Scribe line

2D OCD

3D OCD

3D OCD+Machine Learning





Combination of 3D OCD and Machine learning:
Improve correlation to electrical test > 0.9, while enable on device measurement

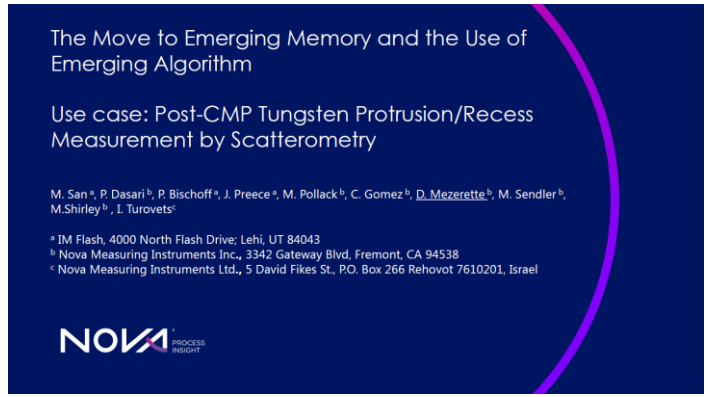
In-die Dishing/Erosion Monitoring

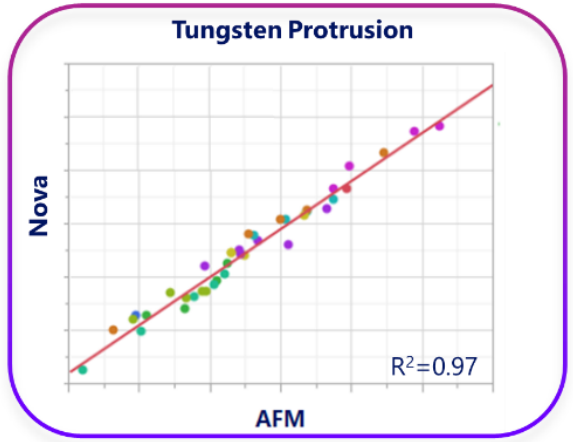
Challenge

- Local Density effects polish rate on different in-die structures
- Scribe measurement pads doesn't represent in-die behavior accurately
- Alternative measurement is either destructive (TEM) or slow (In-line AFM)

Solution

- Machine Learning model combining IM signal with AFM labeling
  - Allows every wafer in-die dishing/erosion monitoring
  - Excursion prevention and CMP quality control





Summary

- Continuous increase of process complexity and spec tightening pose new challenges of CMP process control beyond traditional thickness monitoring.
- In-Die based W2W control is essential for yield performance in advanced tech nodes. IM metrology empowered by AI proven to be able to do such control.
- Every wafer thin residue control in-die is a major factor in yield control and is enabled by Multi-Channel IM and AI algorithms.
- AI-driven solutions beyond traditional OCD metrology, such as dishing & erosion monitor and in-line e-test prediction.

Last, but not least - Acknowledgments

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Thank You

NOVA PROCESS INSIGHT