Automated (S)TEM Workflow for Process Control

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Outline

- Introduction
- Experimental Setup
- (S)TEM Process Control
- Conclusions

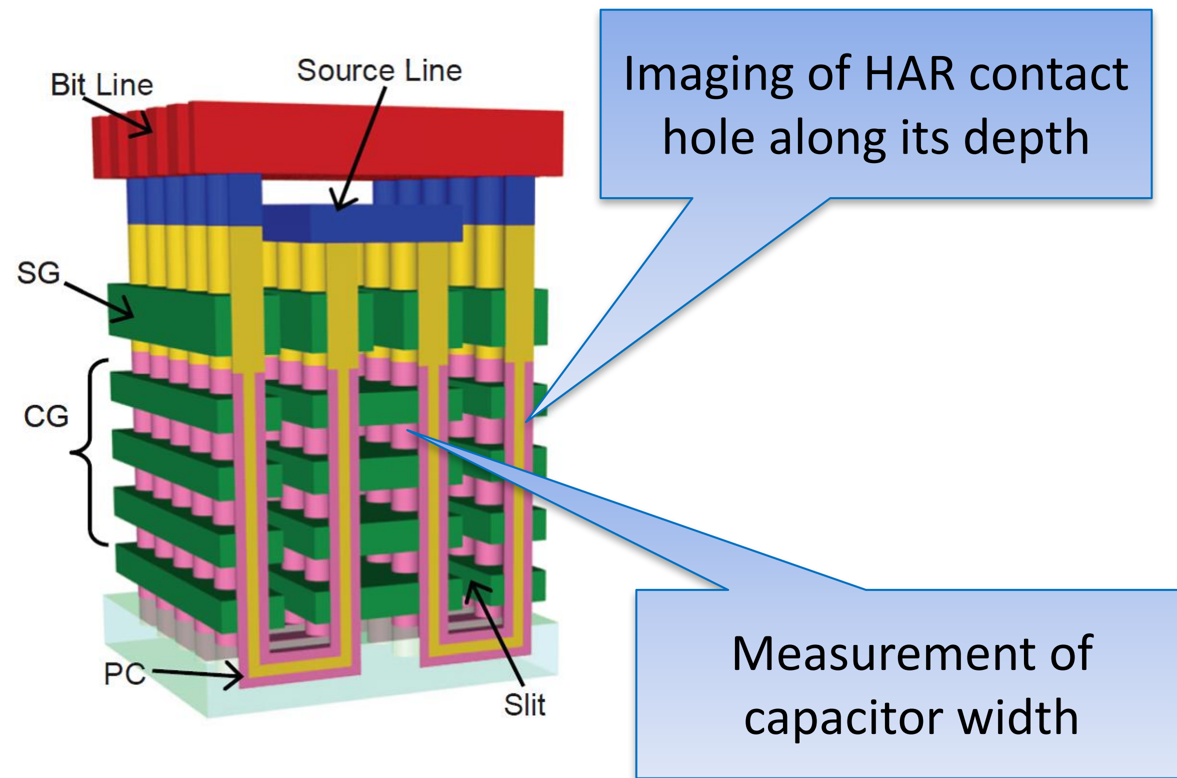
Introduction

Metrology Challenges in the Fab

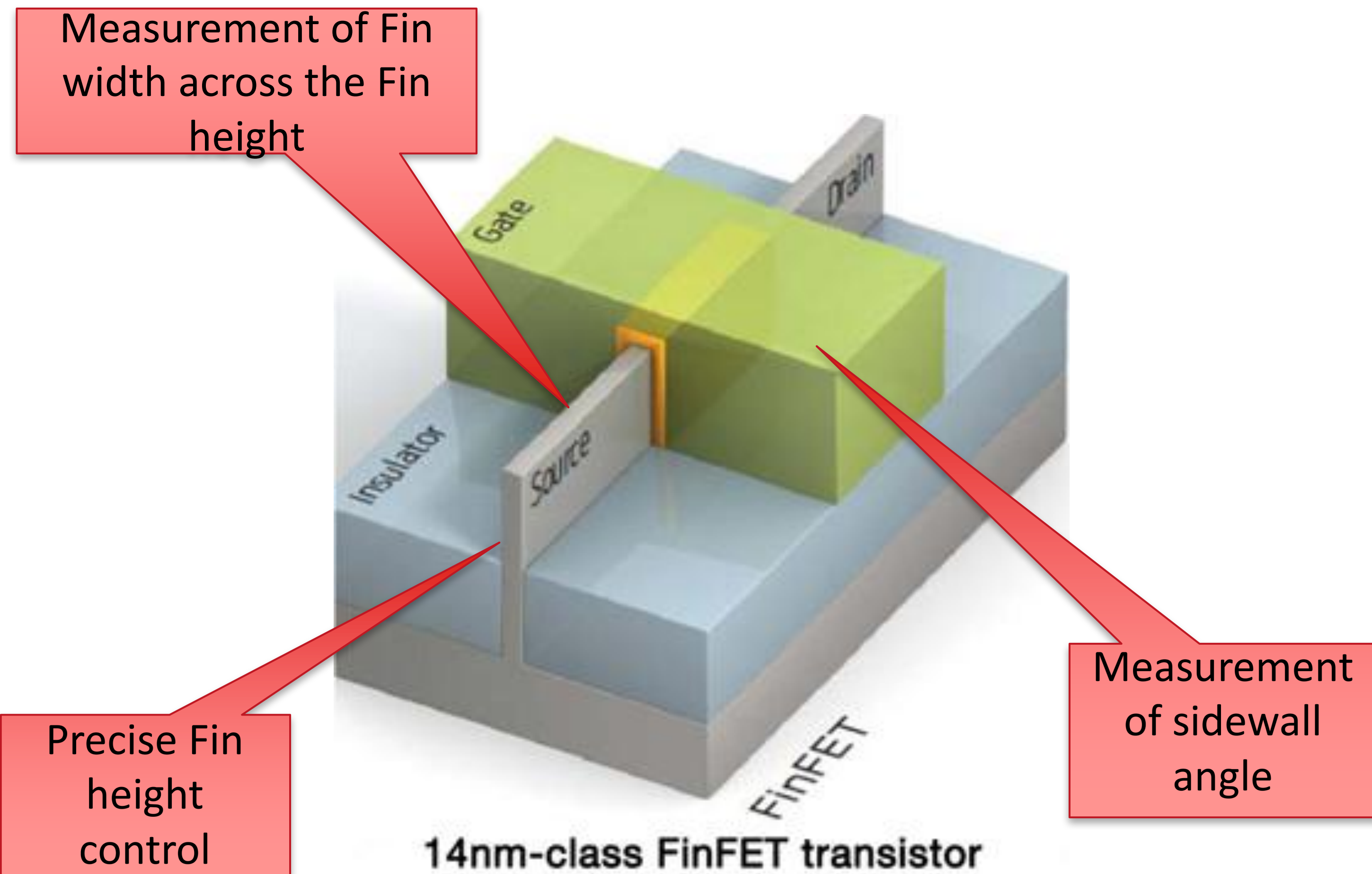
Precise Metrology

More sampling

3D Metrology



Memory

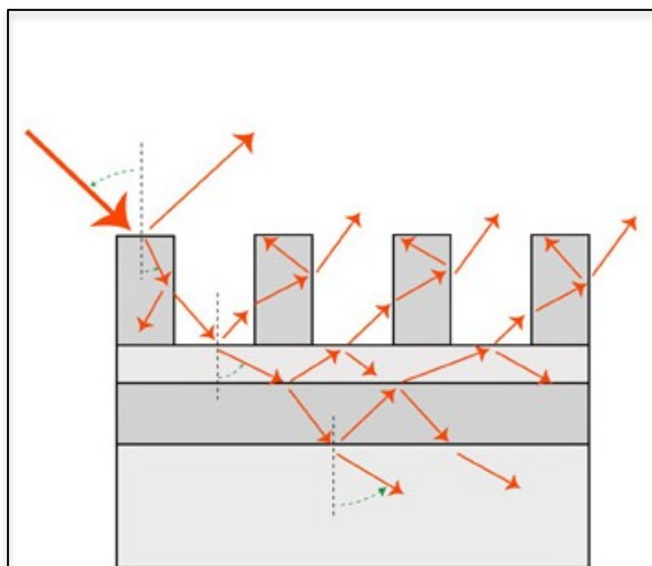
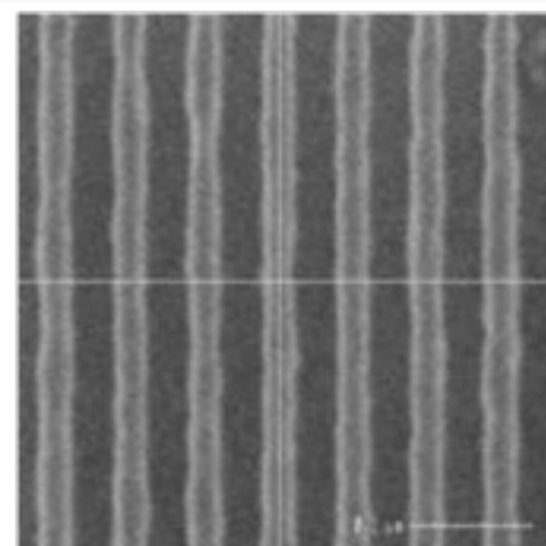
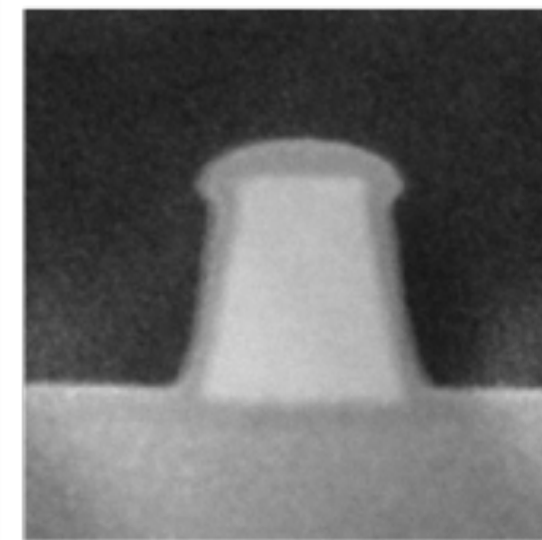


14nm-class FinFET transistor

Logic

Introduction

Most commonly used Metrology techniques

OCD	CDSEM	(S)TEM
		
CD, Profile	CD, LWR	CD, Profile, LWR, any
Depth limited	Top Down View	Any structure
Fastest & Statistics	Fast & Statistics	Slow & No Statistics
Requires Calibration	Requires Calibration	Accurate
Needs modelling	Limited resolution	Destructive

Green: Advantage — Yellow: Average — Red: Disadvantage

Explore. Discover. Resolve.

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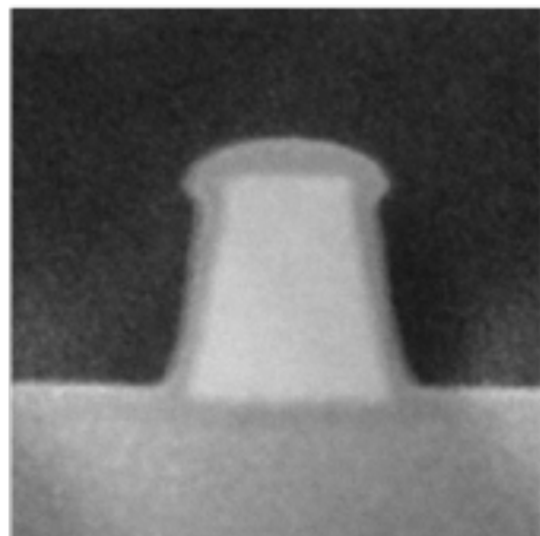
Introduction

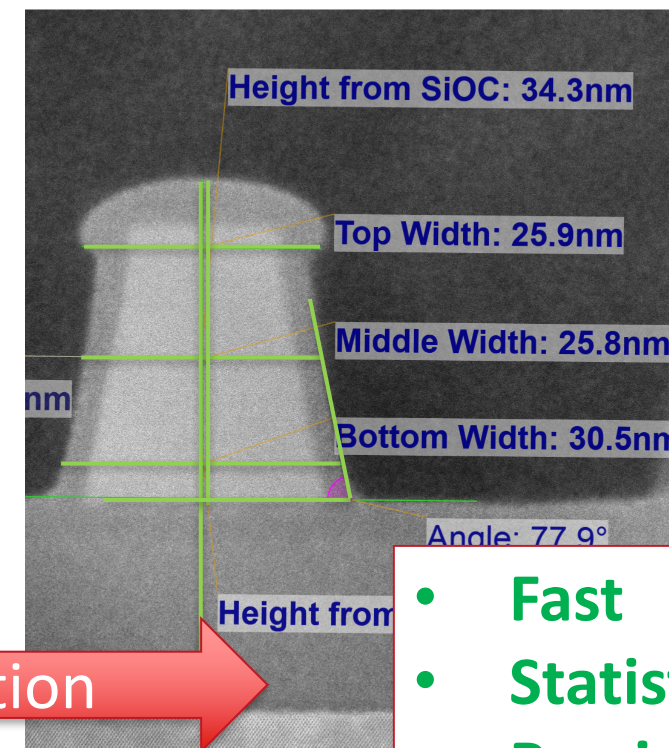
(S)TEM Metrology

(S)TEM



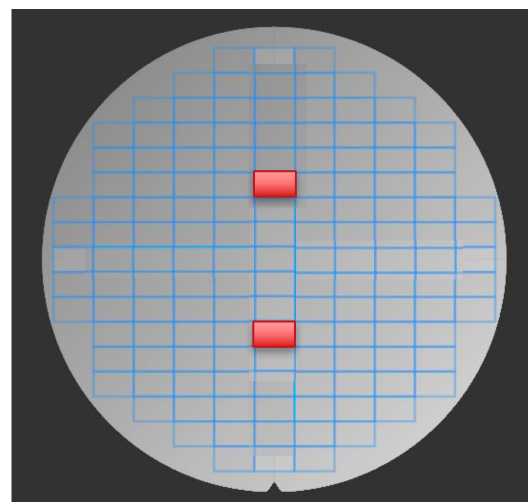
CD, Profile, LWR, any
Any structure
Slow & No Statistics
Accurate
Destructive

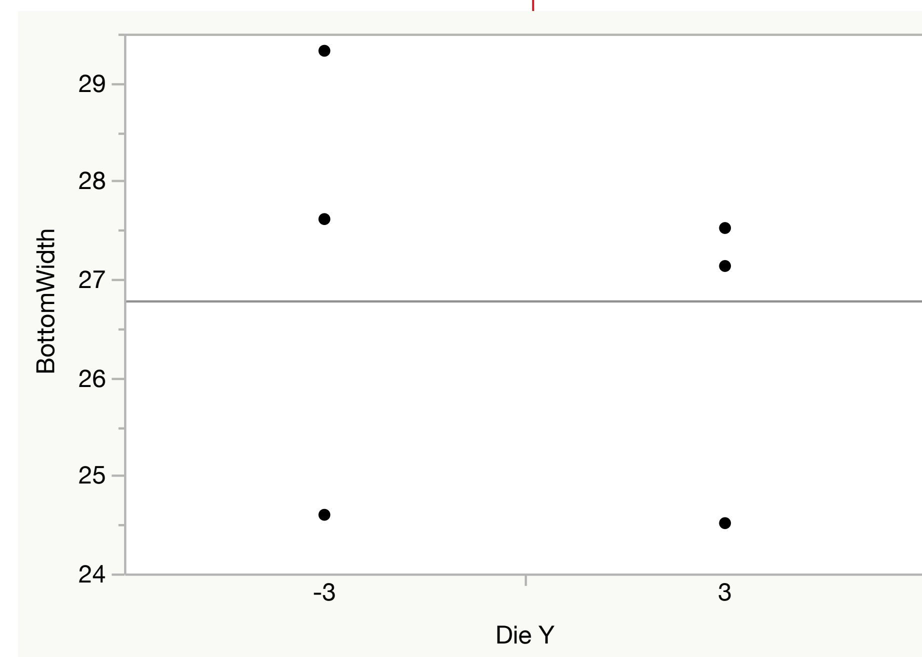
- Highest Resolution
- Accurate [1% Si Lattice]
- Cross-Section or Plan View CD
- Visual / No modeling
- Slow
- No Statistical data
- Not precise



Automation

- Fast
- Statistical Data
- Precision





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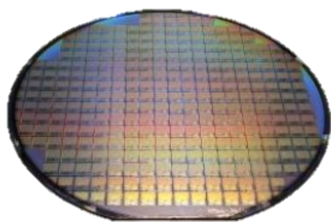
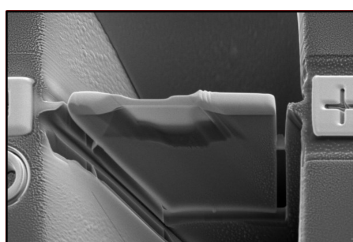
: Advantage : Disadvantage

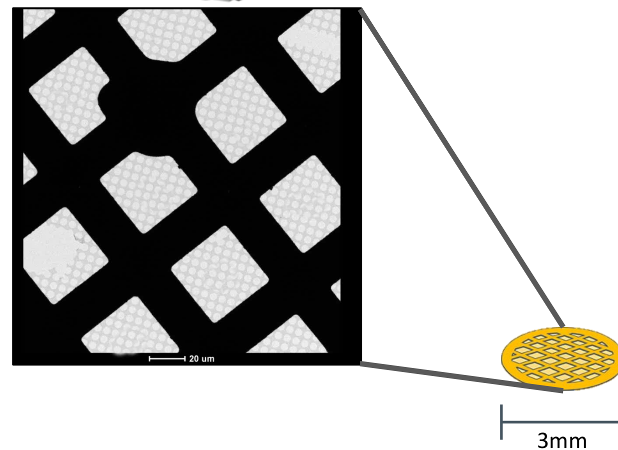
Experimental

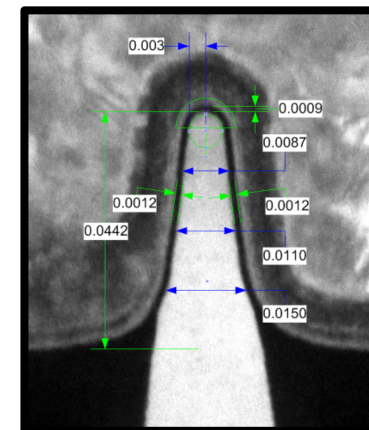
Automated ETM Workflow

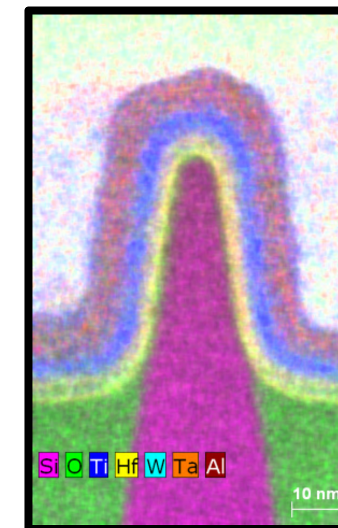
ExSolve 2	**T**EMLink	**M**etrios DX
Automated Sample Prep	Semi-Automated Plucking	Automated (S)TEM (TEM/STEM/EDS/ Metrology)











Row Labels	Distance (nm)
BottomLine	50.0
FinHeight	42.9
FinWidth50Percent	10.3
LeftOxideWidth50Percent	1.5
RightOxideWidth50Percent	1.6
TopOxideWidth	1.8

Experimental

Tool Precision

Automated
Imaging & Metrology

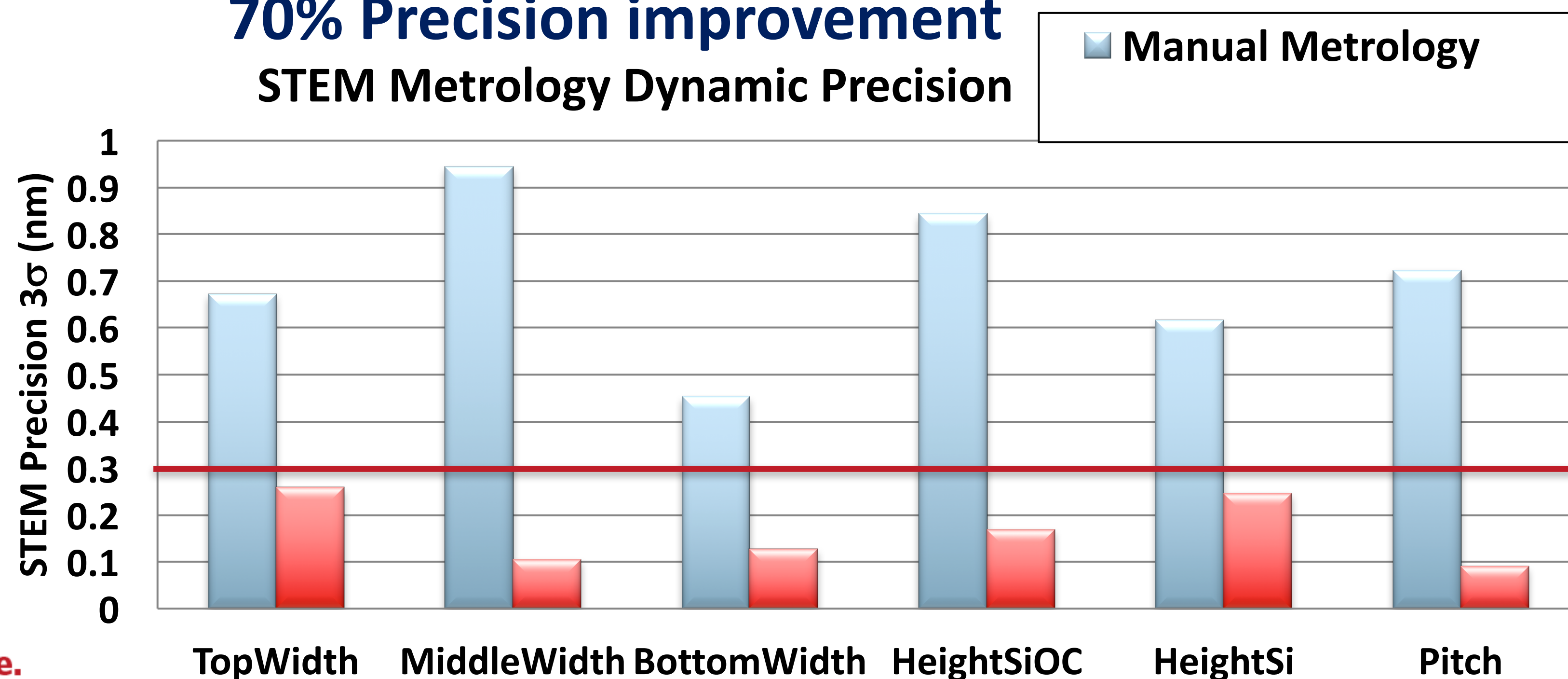
Automated
Calibration

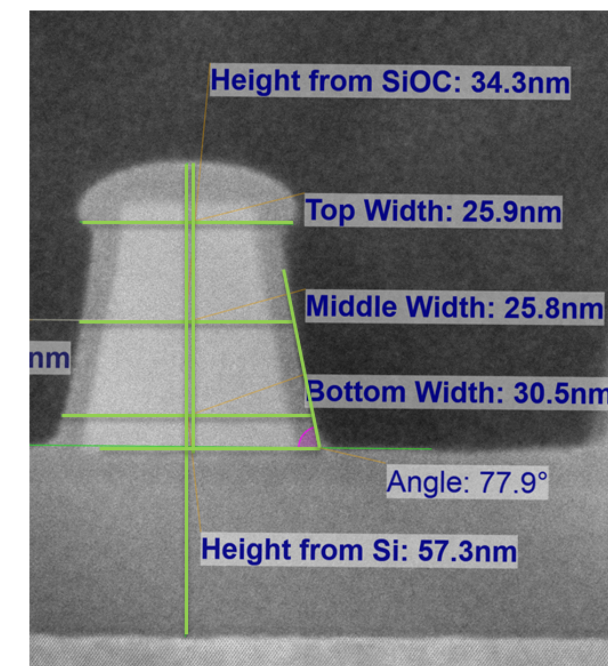
Not Precise
Maybe accurate

Precise
(repeatable)

Accurate
(real size)

<0.3nm 3σ Precision
<1% Accuracy Error





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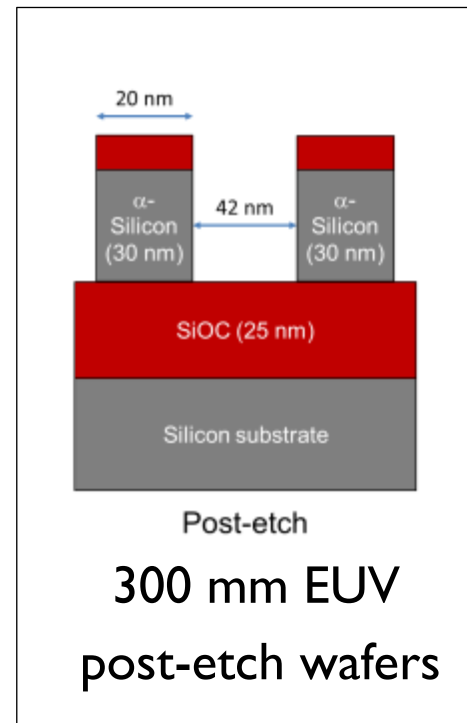
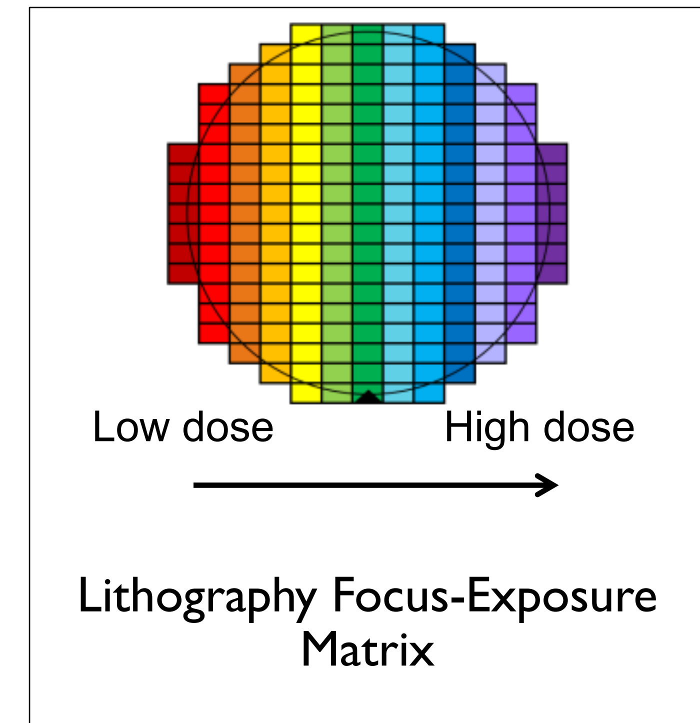
Experimental

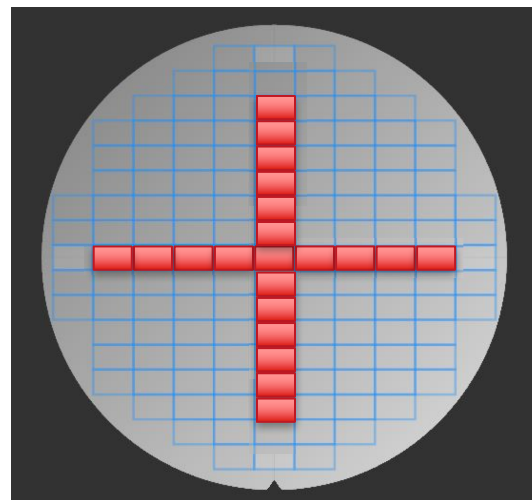
Wafer	Photo Resists	Exposure	Focus
Wafer 18	EUV Resist A	Increases Left to Right	Constant
Wafer 16	EUV Resist B	Increases Left to Right	Constant



300 mm EUV post-etch wafers



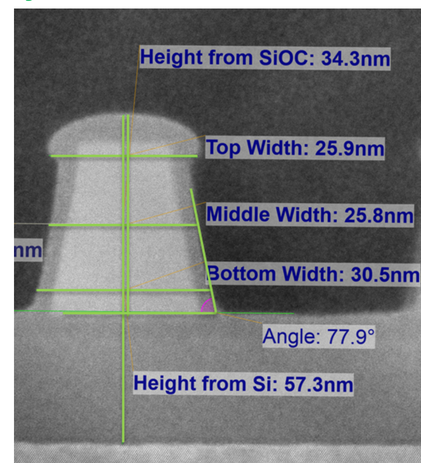
Lithography Focus-Exposure Matrix



Lithography Exposure

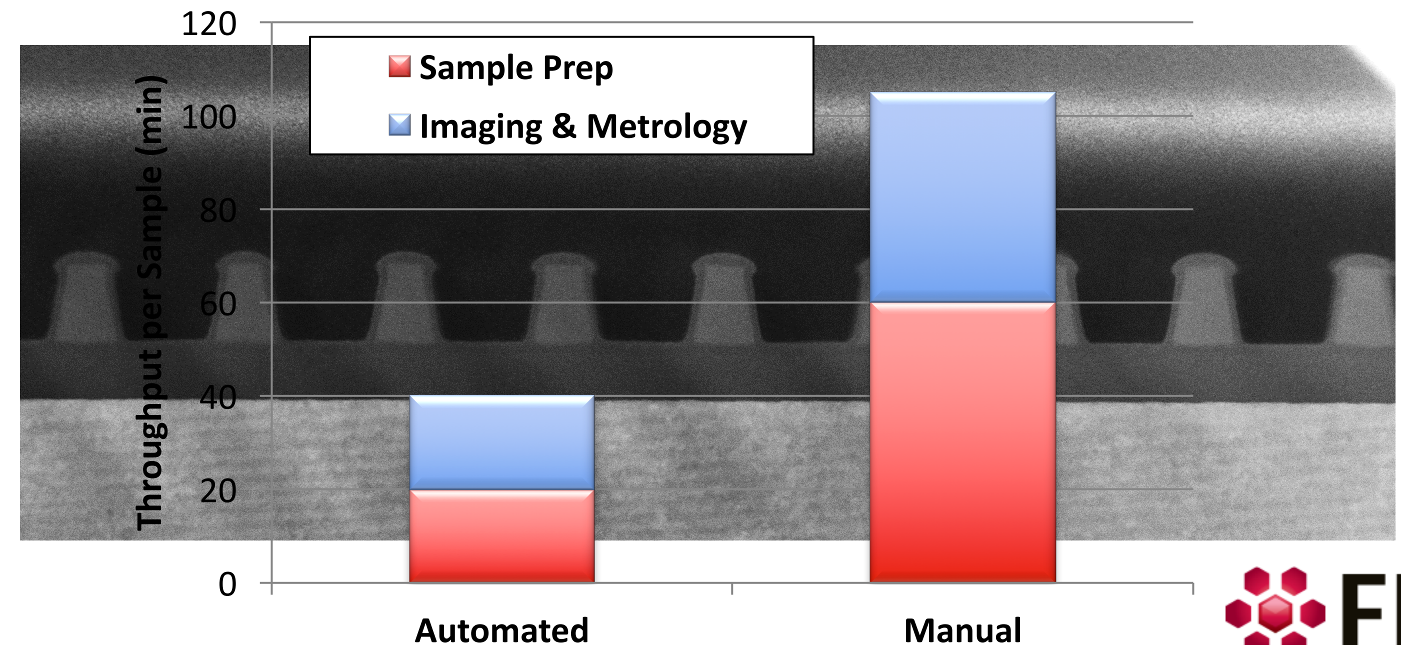
- 2 wafers
- 21 samples/wafer
- 6 images/sample
- 45 devices/sample
- 7 CDs/device

~13,000 Data Points!



Total time (42 samples): 21 hours [Automated]

Total time (42 samples): 58 hours [Manual] + overhead



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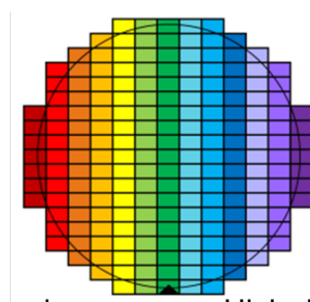
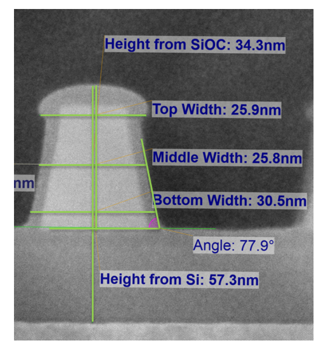
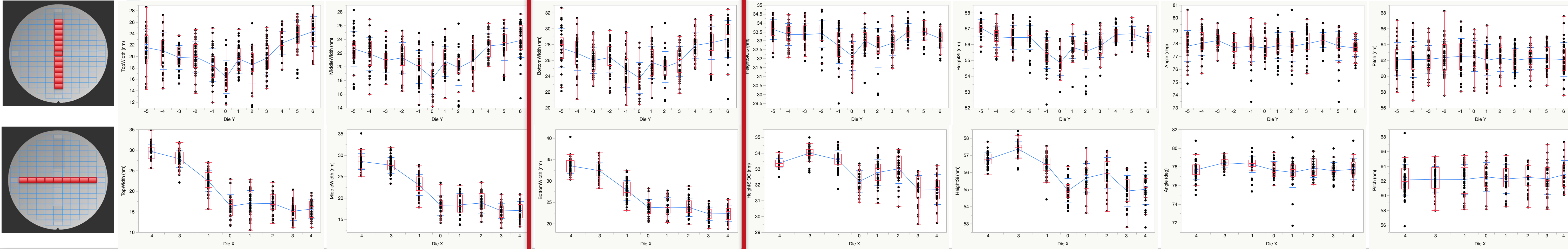
(S)TEM Process Control

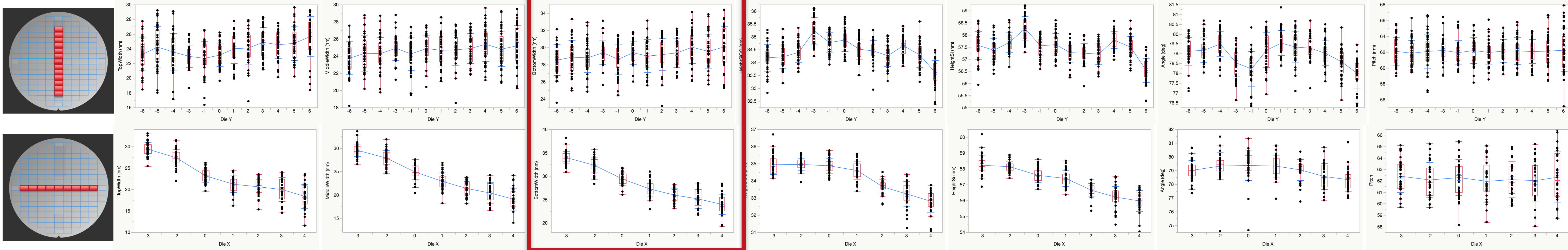




Wafer 18 --- EUV Resist A

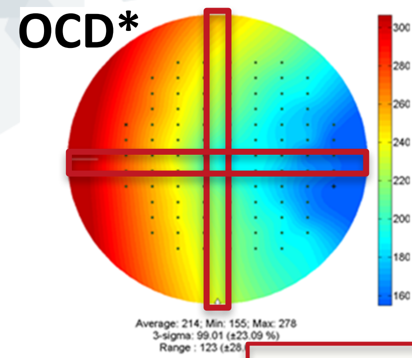


Wafer 16 --- EUV Resist B

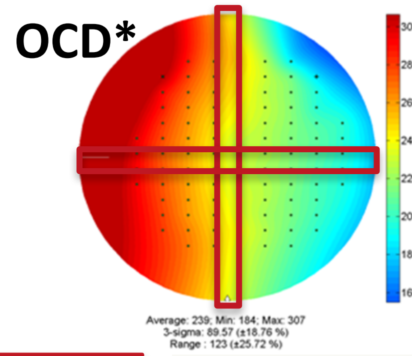


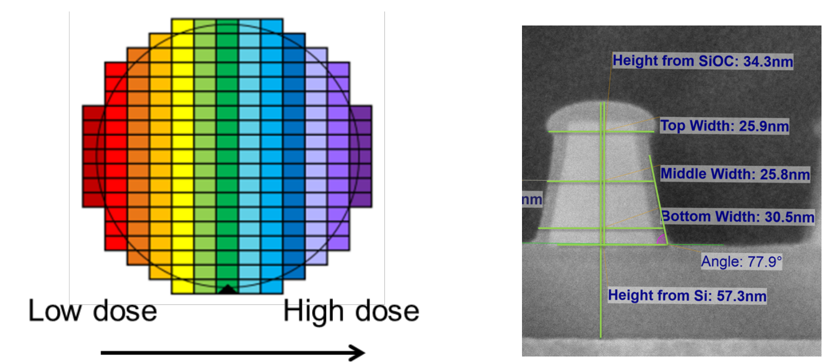
(S)TEM Process Control

OCD*



OCD*

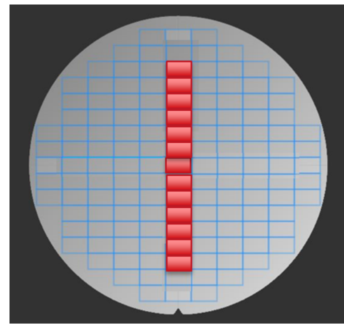




Wafer 18
EUV Resist A

Wafer 16
EUV Resist B

Constant Focus

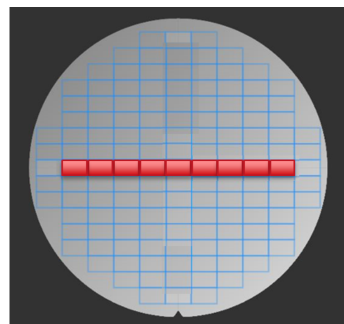


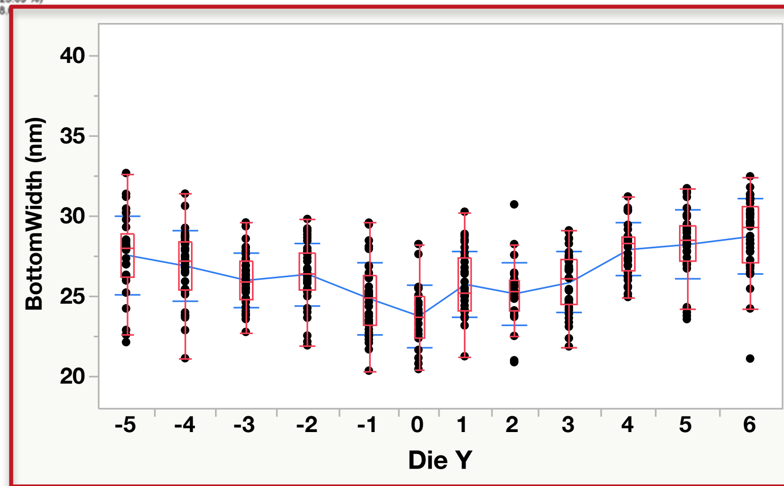
Low Dose → High Dose

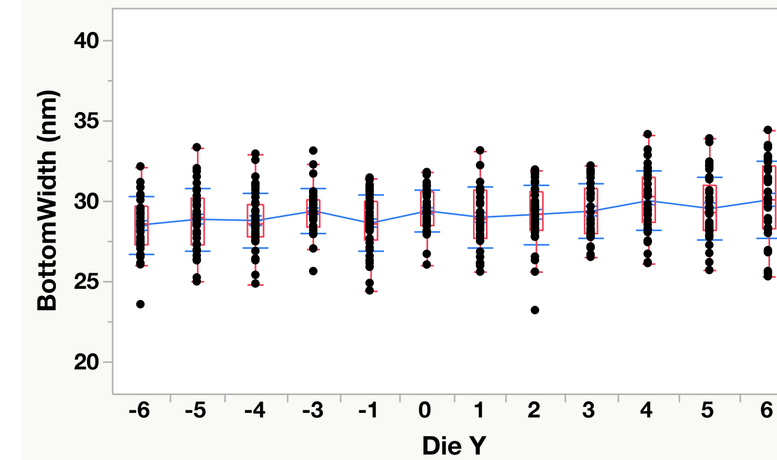
Lithography Exposure

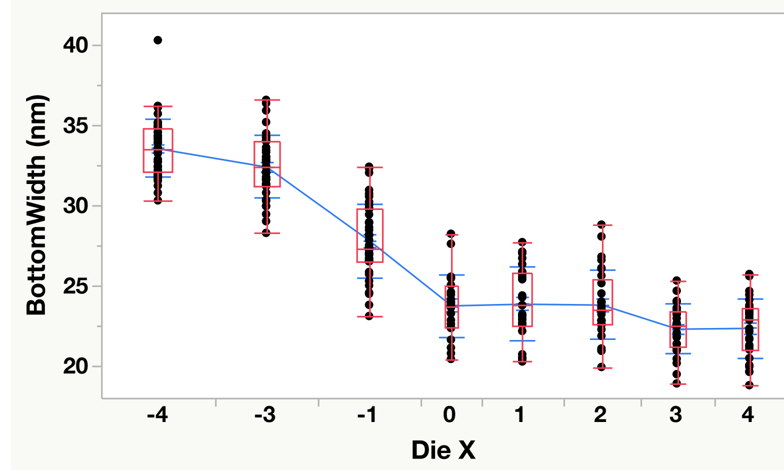
Low Dose → High Dose

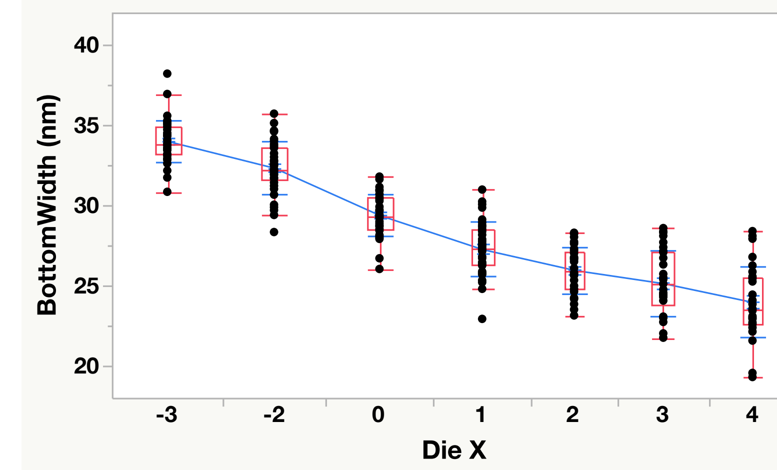
Constant Focus

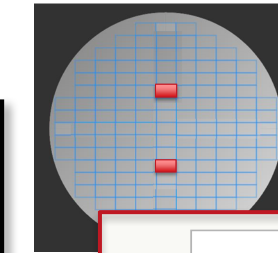


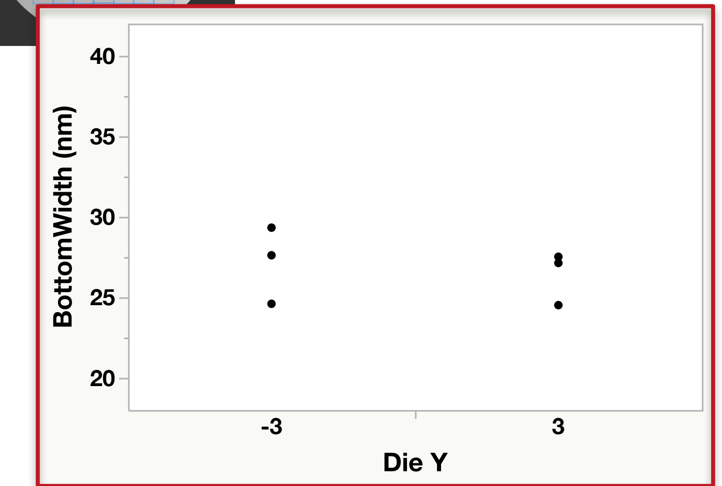












Manual

Limited amount of data from Manual (S)TEM workflow may lead to erroneous decisions in production.

Automation

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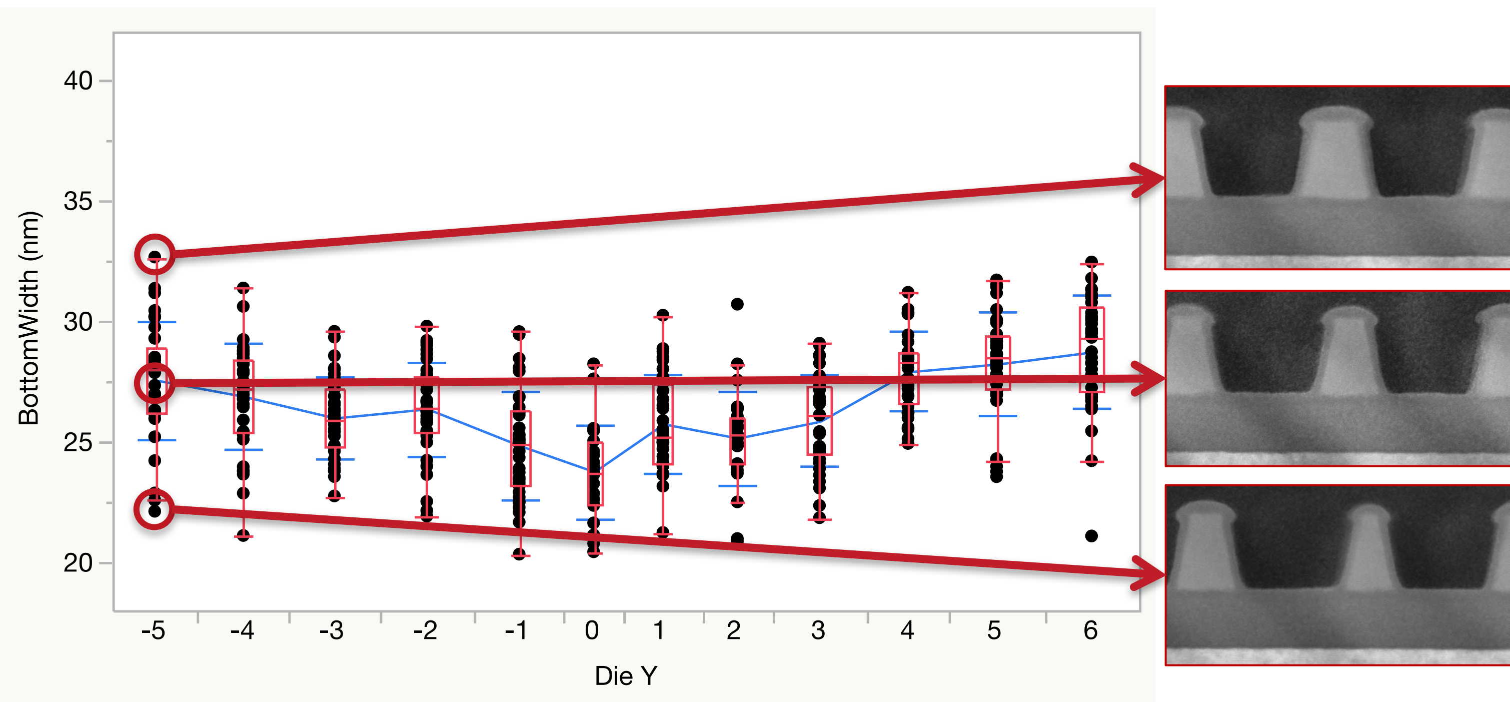
*H. Johanesen et al., "CD metrology for EUV lithography and etch" Advanced Semiconductor Manufacturing Conference (ASMC), 2015 26th Annual SEMI

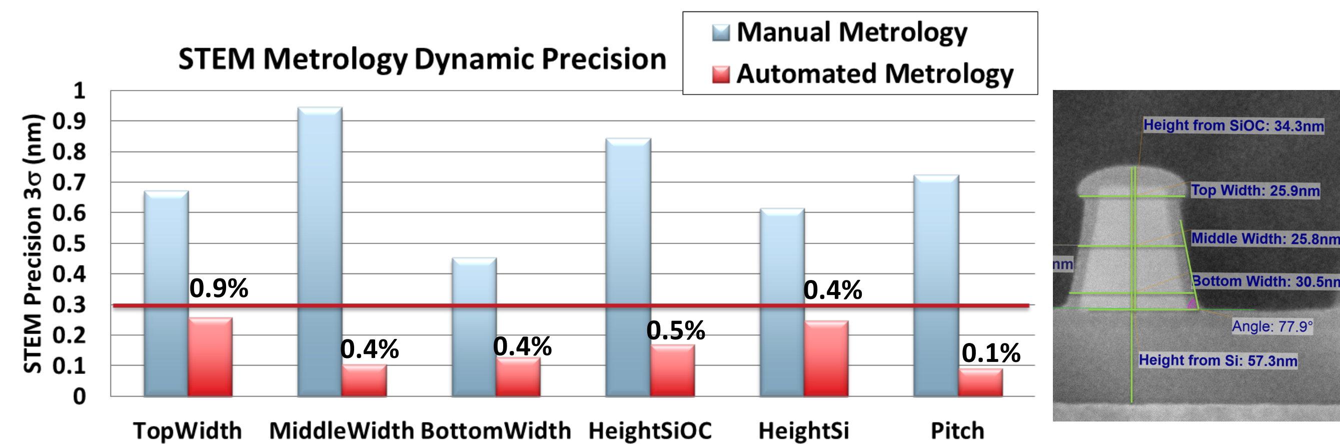
(S)TEM Process Control

Process Variation

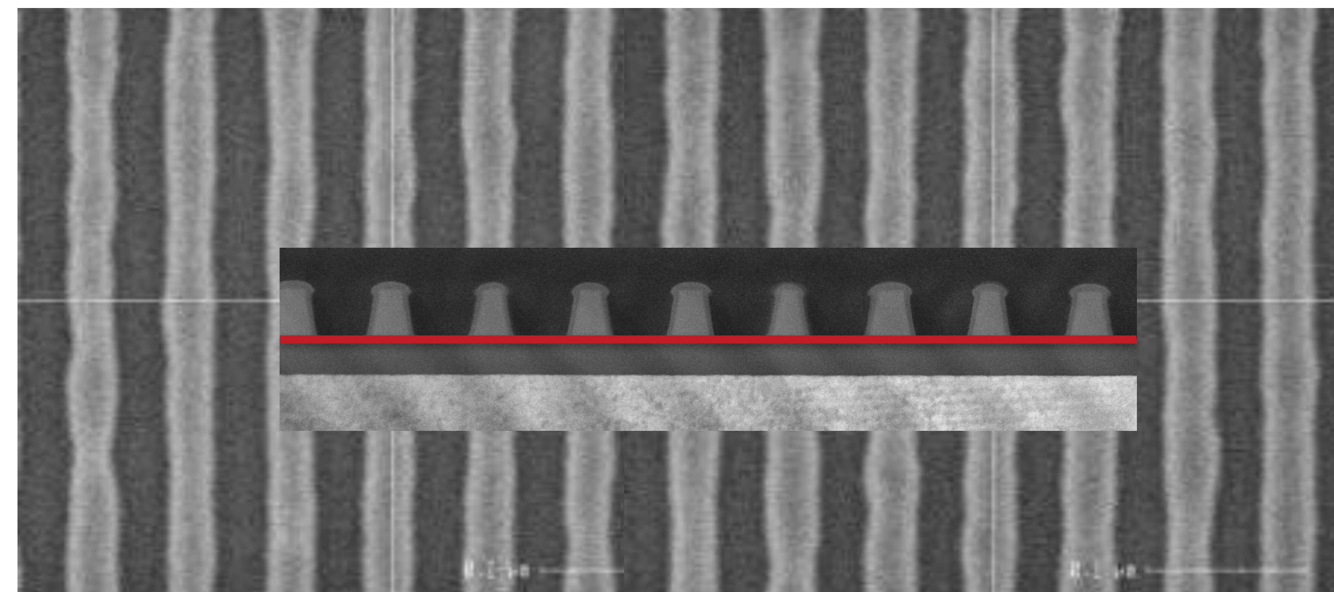


Process Variation >6nm due to large LWR
Tool Measurement Variation <0.3nm

Tool Precision:



Dynamic Precision:	<0.3nm 3σ	<1% Nominal CD



Conclusions

- (S)TEM metrology provides precise and accurate measurements for 3D CD.
  - <1% Accuracy, <0.3nm 3σ Precision
- ETM Workflow allows fully automated (S)TEM metrology in the fab
- Statistically relevant (S)TEM data with high throughput provides new solutions for process control of 3D devices
- Fast and large amounts of data from ETM workflow improves the accuracy of OCD modeling.

Acknowledgements

- Hayley Johanesen
- Anne Kenslea
- IMEC – For providing the wafers
- More details on OCD, LWR and (S)TEM
  - H. Johanesen et al., “CD metrology for EUV lithography and etch” Advanced Semiconductor Manufacturing Conference (ASMC), 2015 26th Annual SEMI

Thank You