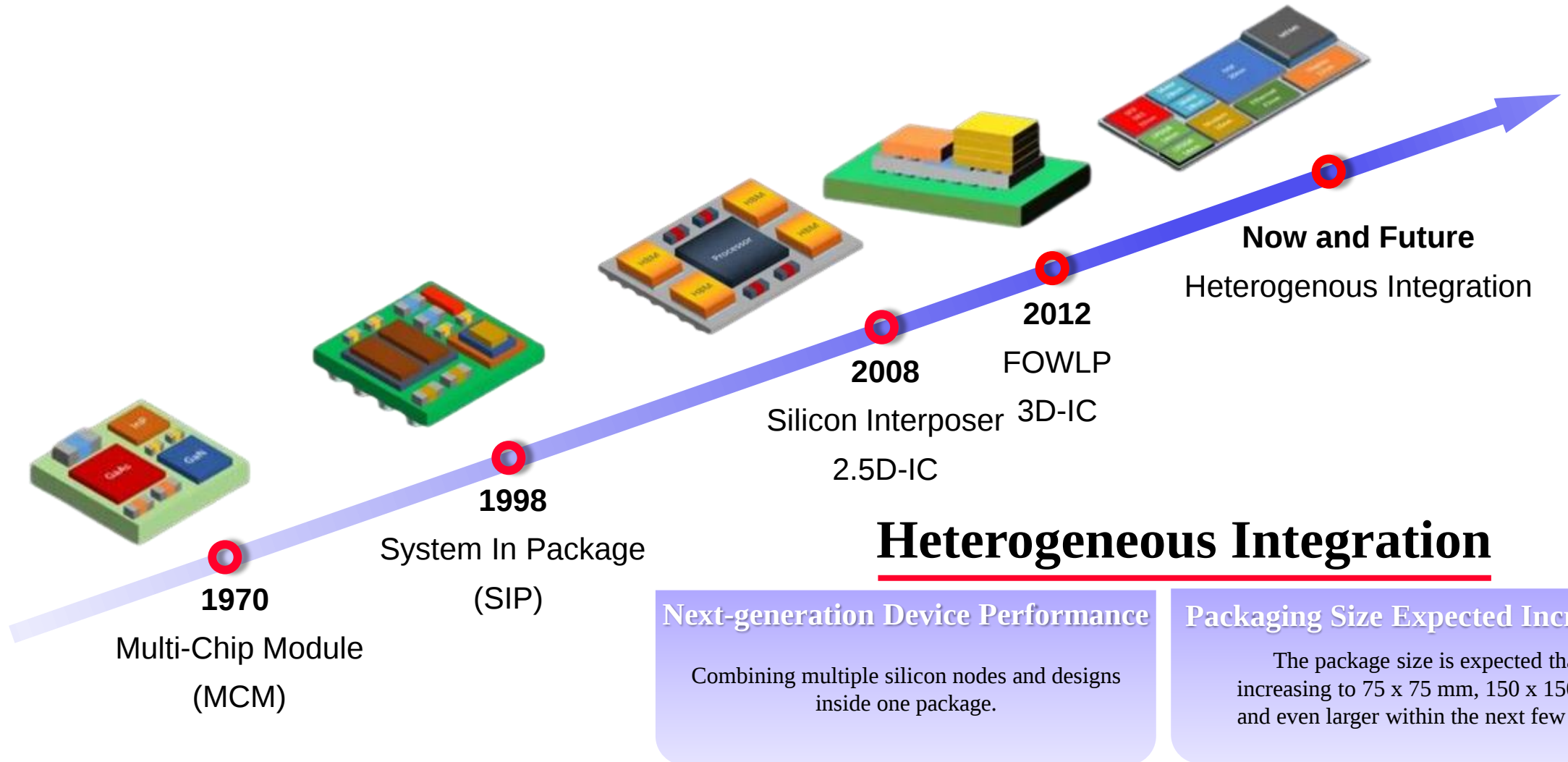


Addressing Advanced IC Substrate Deformation and Pattern Distortion Using an Extremely Large Exposure Field Fine-Resolution Lithography System

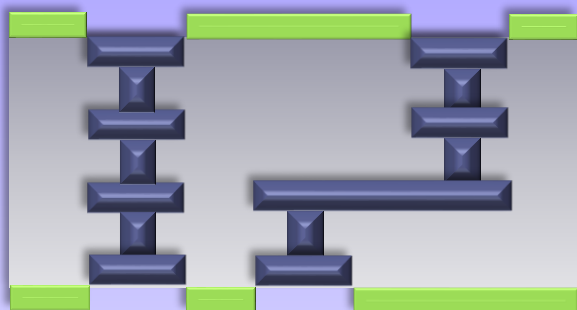
John Chang

Onto Innovation
Wilmington, MA, USA

- Introduction
- Pattern Distortion Components and Correction Method
- Extremely Large Exposure Field Fine-Resolution Lithography
- Overlay Demonstration Results and Discussion
- Summary and Conclusion

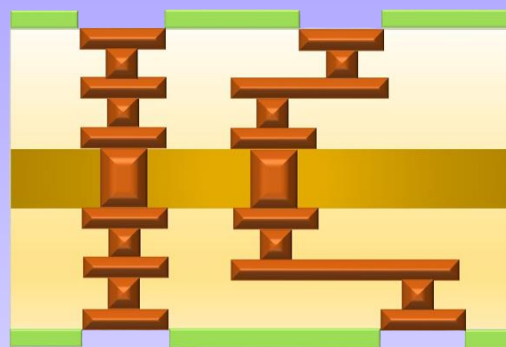


4 Layers Coreless Packaging Structure



Overlay Yield **↑1%**
(per layer)
Product Yield **↑3.71%**

6 Layers Cored Packaging Structure



Overlay Yield **↑1%**
(per layer)
Product Yield **↑5.29%**

Overlay Yield Getting More Challenging

Packaging Layers ↑
(Performance Require)

Overlay Budget ↓
(Fine Resolution Require)

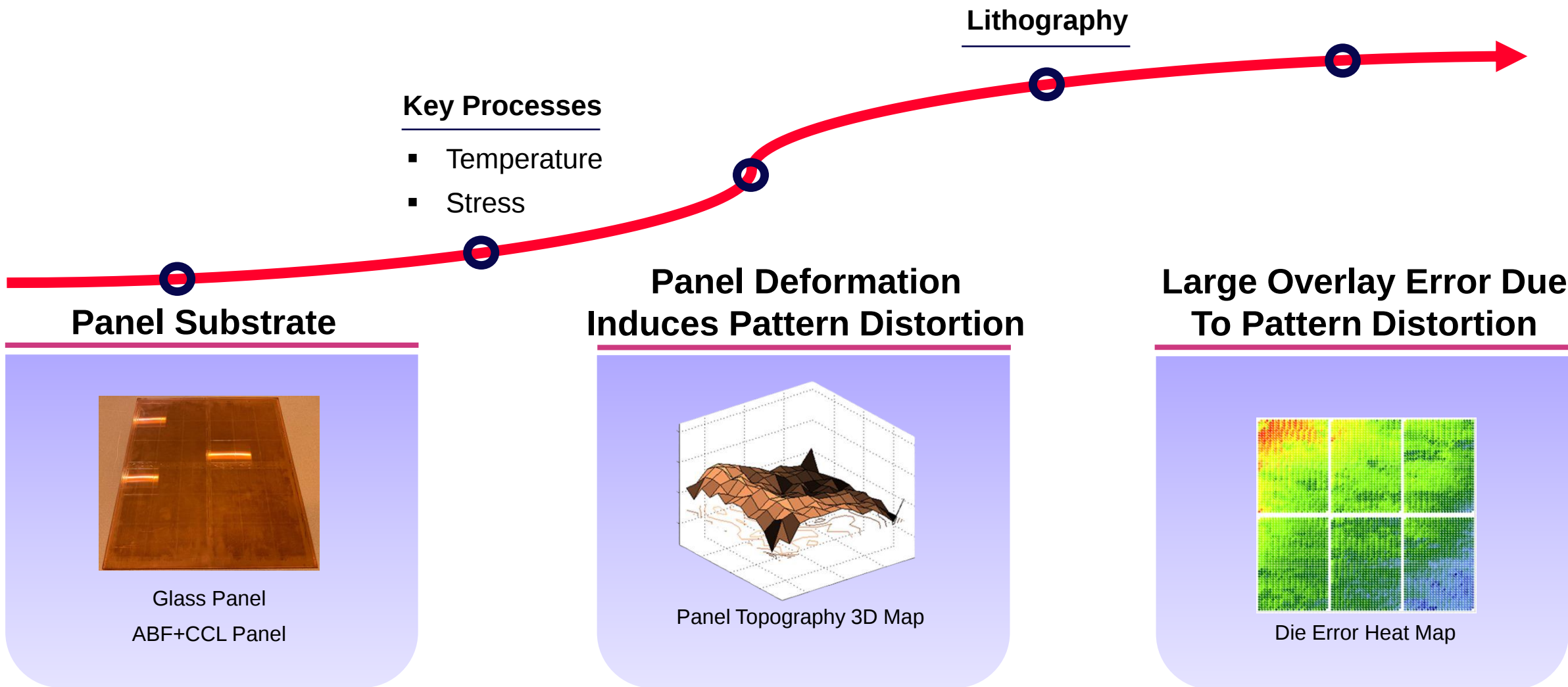


**Lithography Overlay
Yield Challenge**

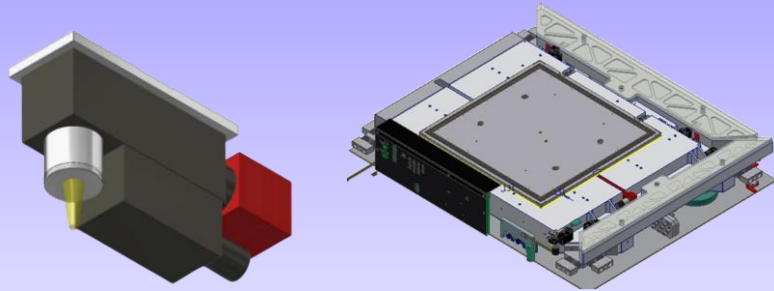
- Introduction
- **Pattern Distortion Components and Correction Method**
- Extremely Large Exposure Field Fine-Resolution Lithography
- Overlay Demonstration Results and Discussion
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Substrate Deformation Induces Pattern Distortion

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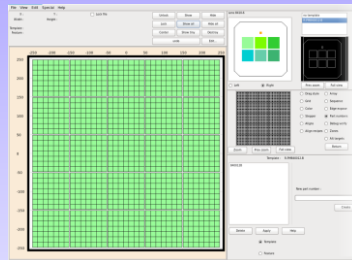
Actual Pattern Position



Reflective Alignment Camera

Grid Stage

Nominal Pattern Position



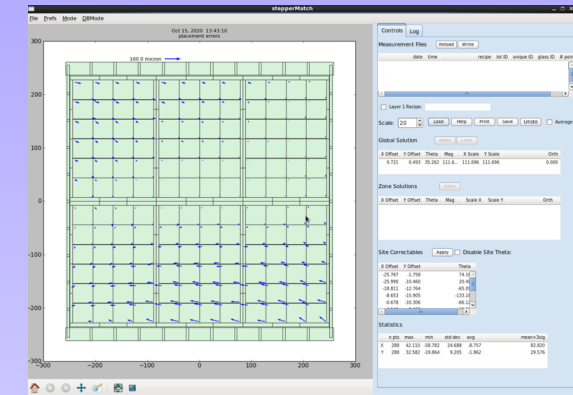
Panel Layout Design

Metrology Data

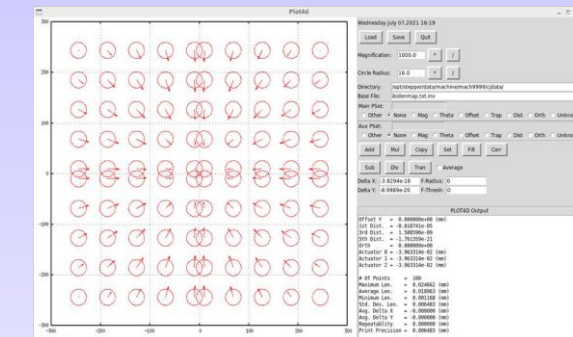


Contains Die Error Info.

Analysis Tool

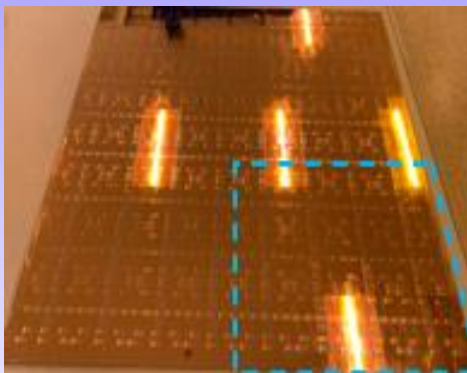


Onto StepperMatch



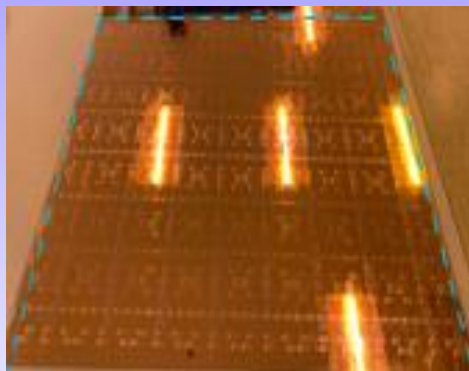
Onto Dolana

Quadrant Scale Distortion Coefficients



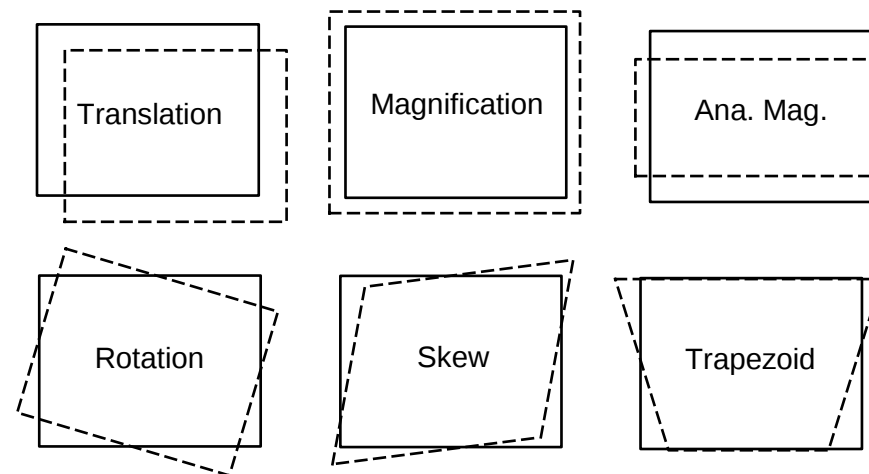
Term	Value
X Tran	-1.76E-03
Y Tran	5.97E-04
Mag	-3.06E-06
Ana Mag	-3.06E-06
Rotation	1.20E-05
Skew	1.20E-05
X Trap	1.67E-07
Y Trap	-6.28E-08

Panel Scale Distortion Coefficients

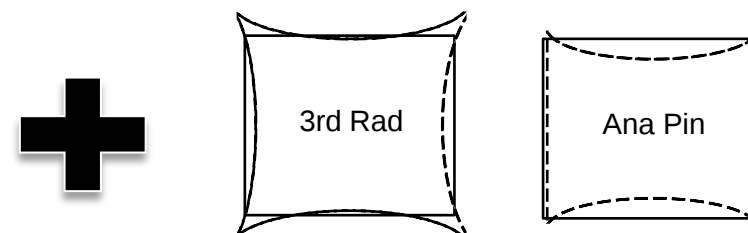


Term	Value
3rd Rad	2.75E-10
Ana	-2.81E-10

Quadrant Scale Distortion Component

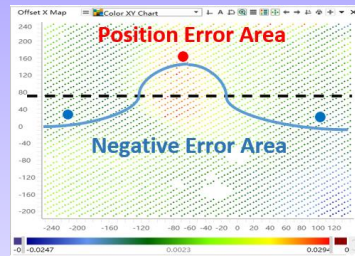


Panel Scale Distortion Component

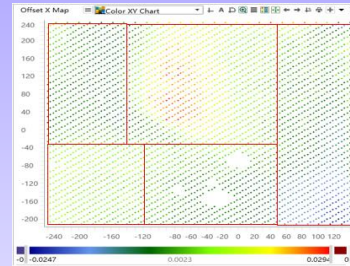


Distortion Coefficient : Used in the equations that describe each term fit.

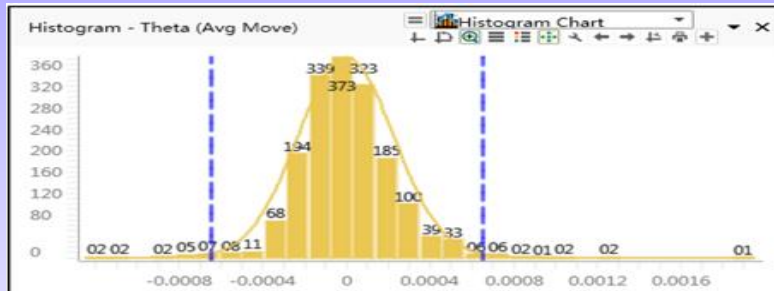
Non-Linear Error In Panel



Non-Linear Error Across Panel



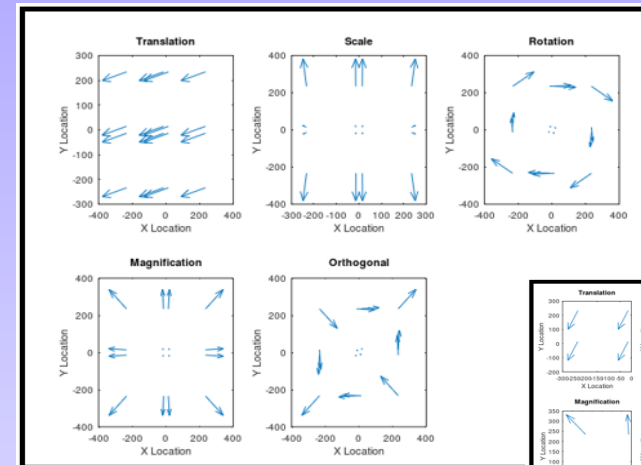
Zone Scale Error



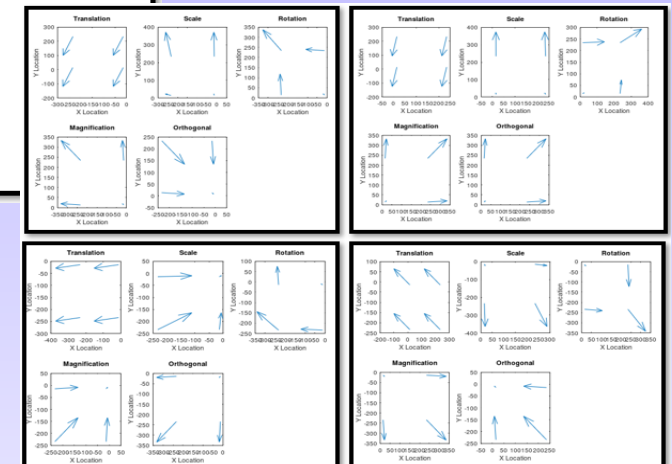
Large Range Rotation Error in Panel

Global Correction vs Zone Correction

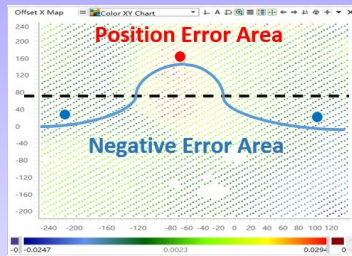
Global Correction Terms



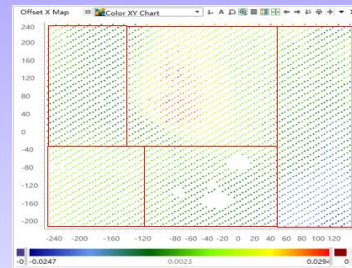
Zone Correction Terms



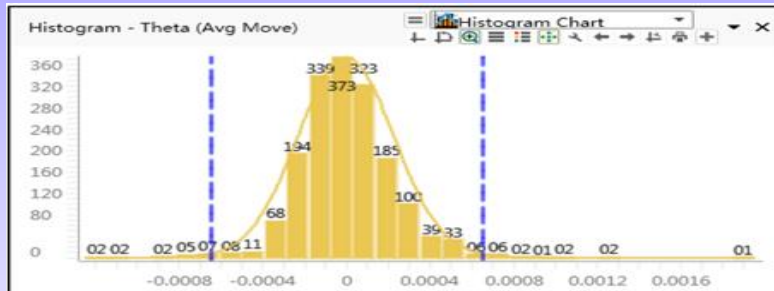
Non-Linear Error In Panel



Non-Linear Error Across Panel



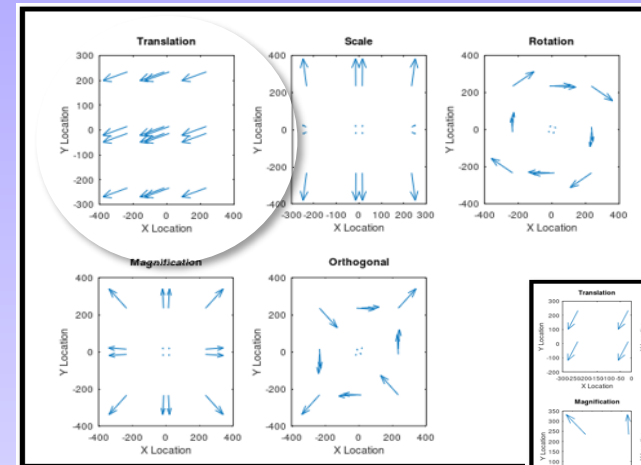
Zone Scale Error



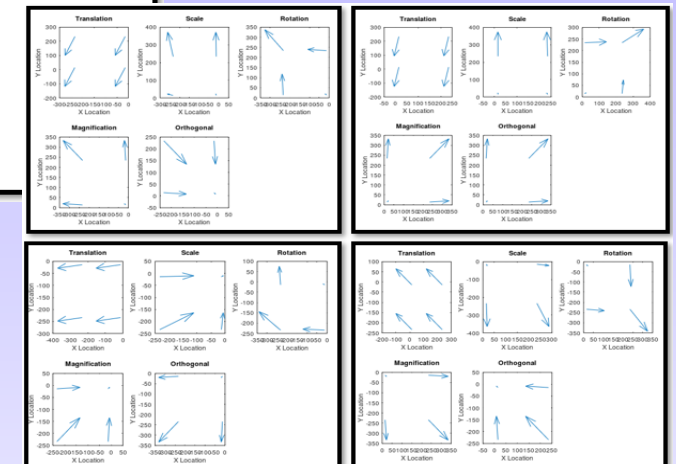
Large Range Rotation Error in Panel

Global Translation Toward Bottom-Left

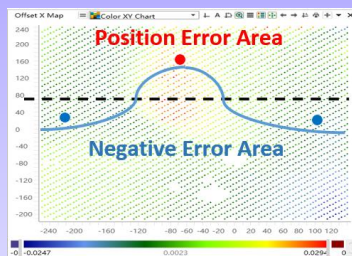
Global Correction Terms



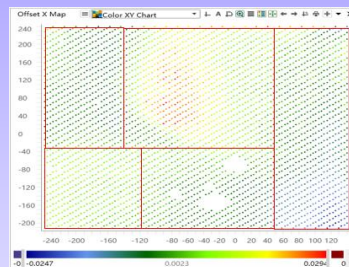
Zone Correction Terms



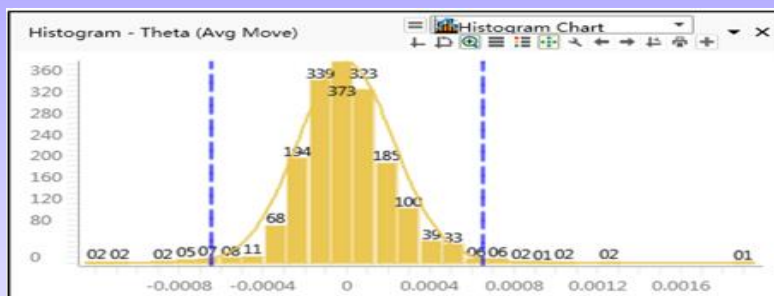
Non-Linear Error In Panel



Non-Linear Error Across Panel



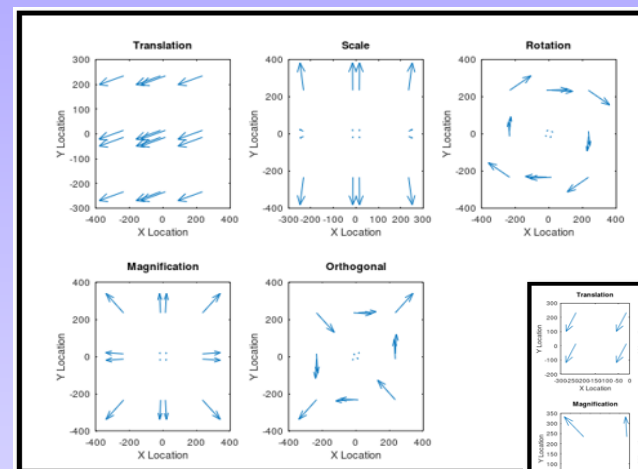
Zone Scale Error



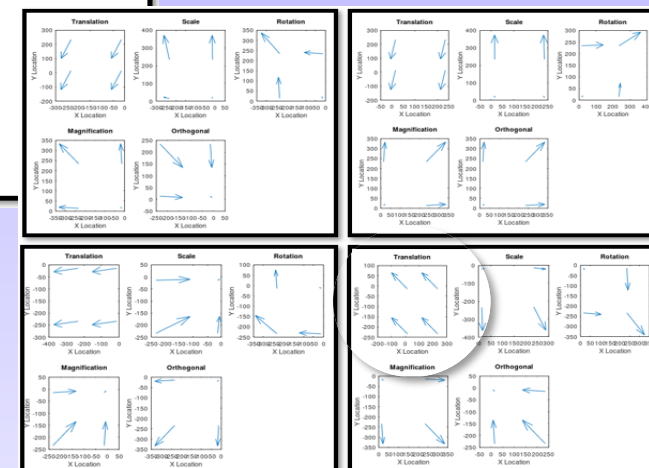
Large Range Rotation Error in Panel

Bottom-Right Zone Translation Toward Top-Left

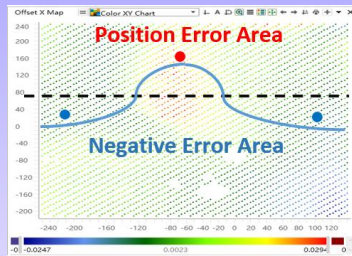
Global Correction Terms



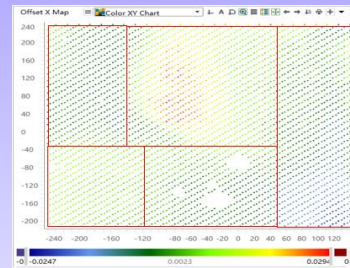
Zone Correction Terms



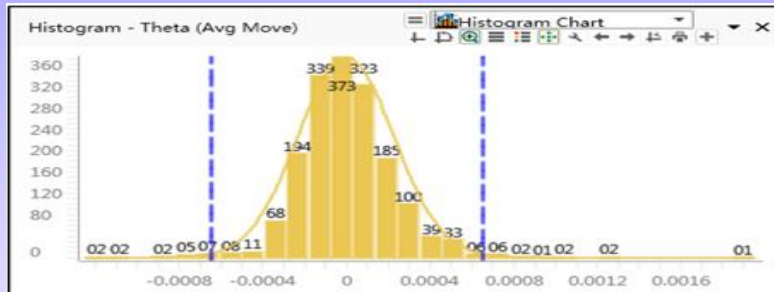
Non-Linear Error In Panel



Non-Linear Error Across Panel



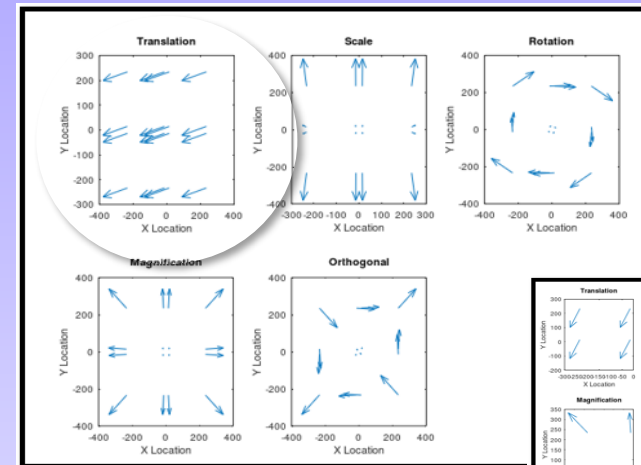
Zone Scale Error



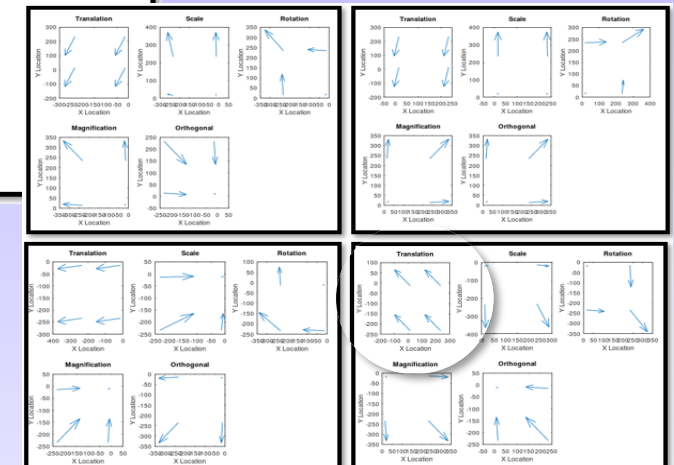
Wide Range Rotation Error in Panel

Global Correction Cannot Fully Correct The Error

Global Correction Terms



Zone Correction Terms



- Introduction
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Extremely Large Exposure Field With Fine Resolution Lithography Tool in The Study

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Substrate size	Up to 510mm x 515mm
Resolution	3μm
Exposure Field Size	250mm x 250mm
System Overlay	Mean + 3 Sigma < 1.5μm
Magnification	2.2X
Magnification Compensation	400PPM
Anamorphic Mag. Compensation	100PPM
NA	> 0.06
Wavelengths	I-Line
Alignment Method	EGA and Zone correction
Overlay Corrections Ability	Translation, Rotation, Magnification, Anamorphic magnification, Skew and Etc.

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Extremely Large Exposure Field With Fine Resolution Lithography Tool in The Study

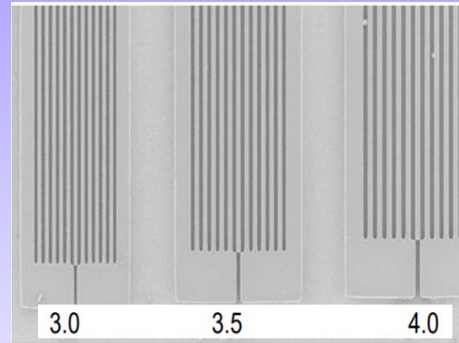
IMAPS 19th Conference on DEVICE PACKAGING | March 13-16, 2023 | Fountain Hills, AZ, USA

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Lithography Tool Standard Resolution Results

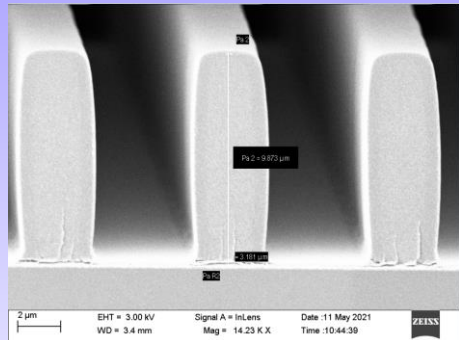
IMAPS 19th Conference on DEVICE PACKAGING | March 13-16, 2023 | Fountain Hills, AZ USA

3μm Resolution Resolved



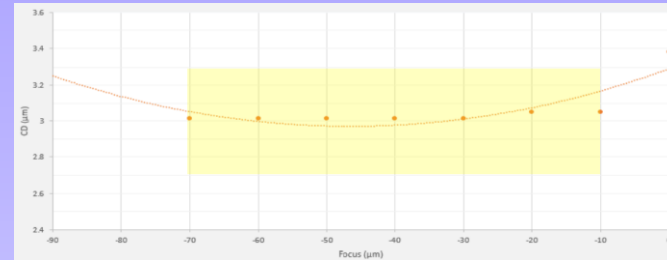
3μm L/S with 10μm DFT

3μm Cross Section



3μm L/S with 10μm DFT

60μm Depth Of Focus

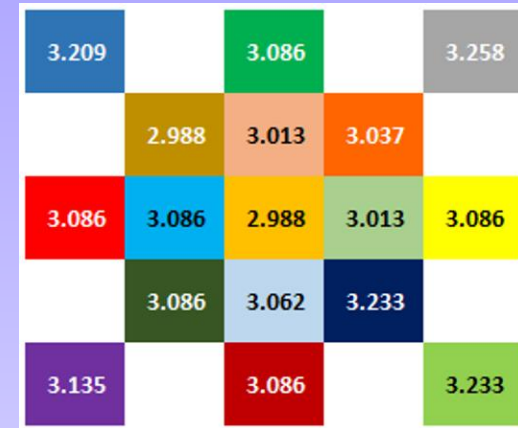


60μm DOF
(3μm LS with 10μm DFT)

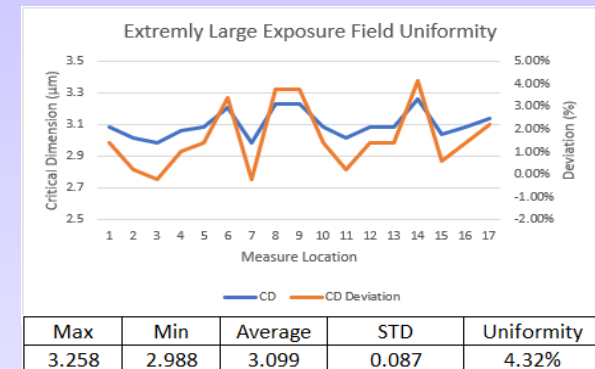


Focus Matrix of 3μm Line/Space

4.32% CD Uniformity in Panel

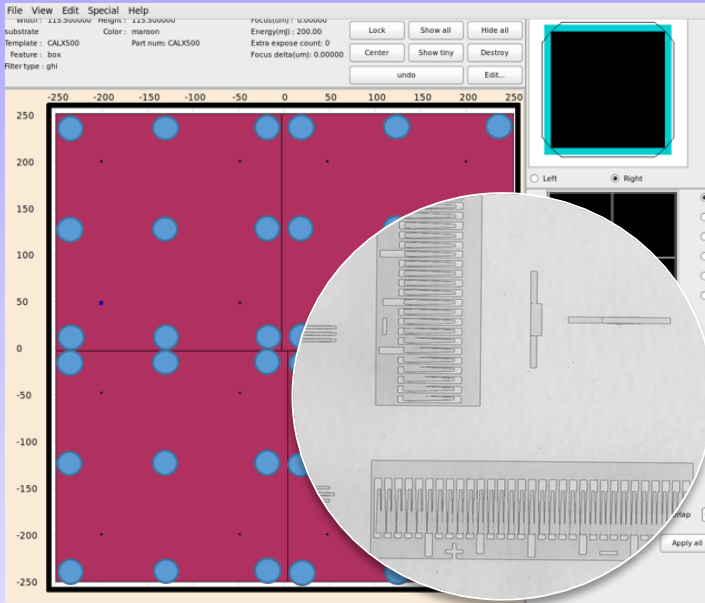


CD Values in a 250 mm x 250 mm Field



3μm with 10μm DFT CD deviation Chart

9 Pts a Zone, 36 Pts Measurement a Panel

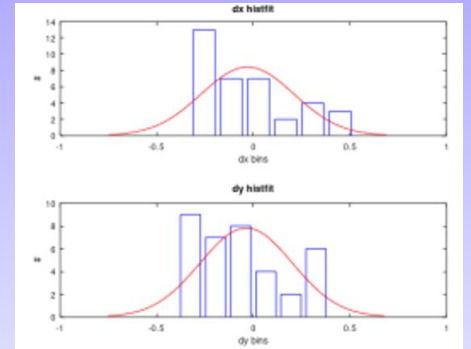


Overlay Error Measurement Location

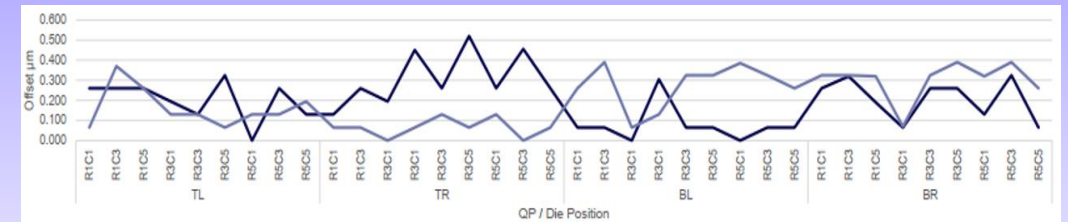
Lithography Tool Overlay Results < 1.5 μ m

OVL	Dx	Dy
Max	0.52	0.39
Min	-0.32	-0.39
Mean	0.2	0.2
Std	0.24	0.24
Mean+3 σ	0.91	0.91

Overlay Error Table



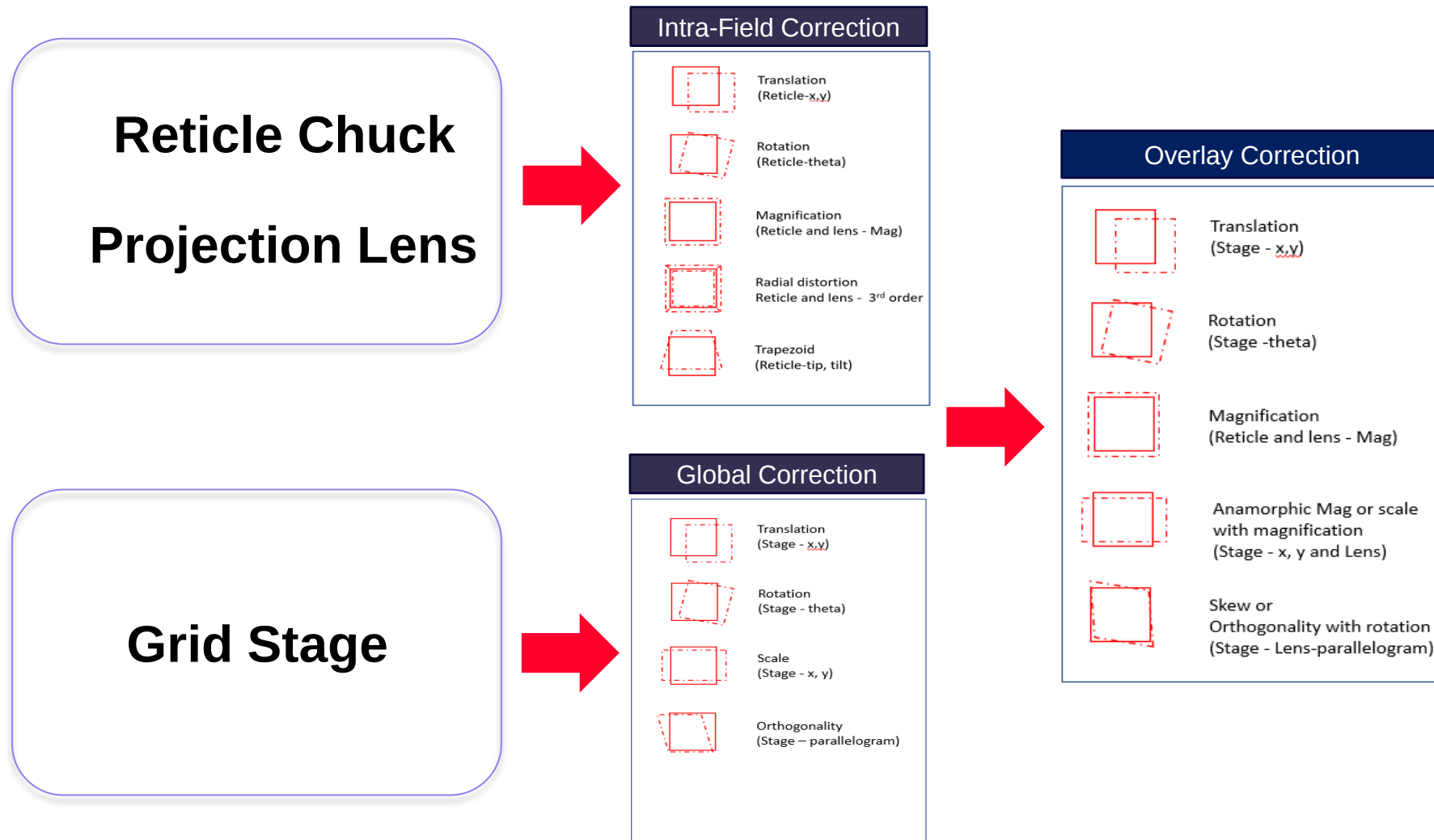
Overlay Error Histogram



Overlay Error Chart

Lithography Tool Overlay Correction Capability

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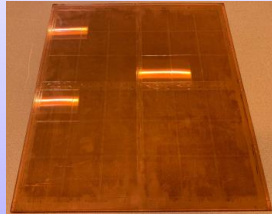
- Introduction
- Pattern Distortion Components and Correction Method
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- **Distortion Correction Demonstration, Results and Discussion**
- Summary and Conclusion

Process Flow of Performance Demonstration

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Control Group

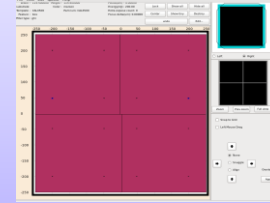
Experiment Group



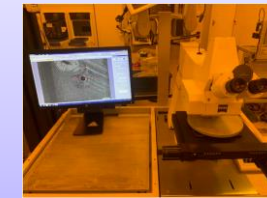
Core CCL+ABF Stacked
510mm x 515mm



Exposure Tool
Pattern Printing



Exposure Layout
250 x 250 mm a Shot
Zone Correction



Optical Microscope
OVL Checking



SEM
CD Checking

Test Vehicle

Lithography Process

Results Inspection

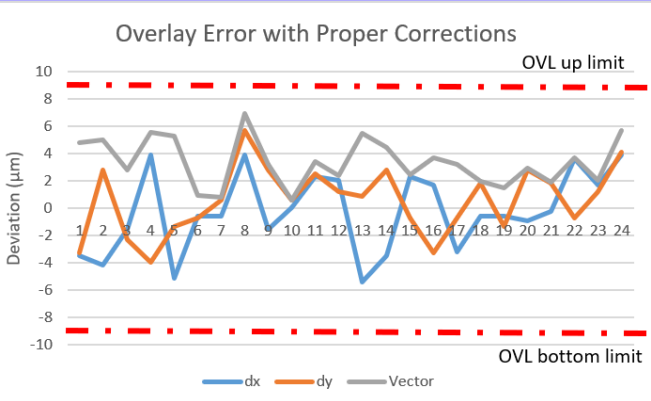


Laminator
Laminating Dry Film



Developer
Immersion Type Conveyor

Experiment Group : Overlay Results with Proper Corrections

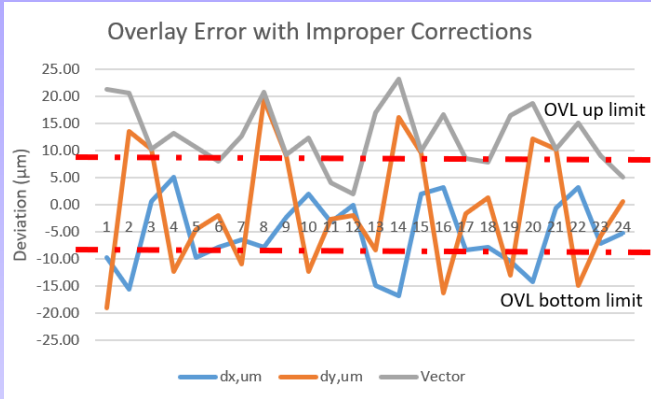


Experiment Group Overlay Deviation Chart

OVL	DX	DY	Vector
Max.	3.94	5.72	6.94
Min.	-5.42	-3.94	0.58
Average	-0.24	0.57	3.37
STD	2.89	2.47	1.74

Experiment Group Overlay Results Table

Control Group : Overlay Results with Improper Corrections

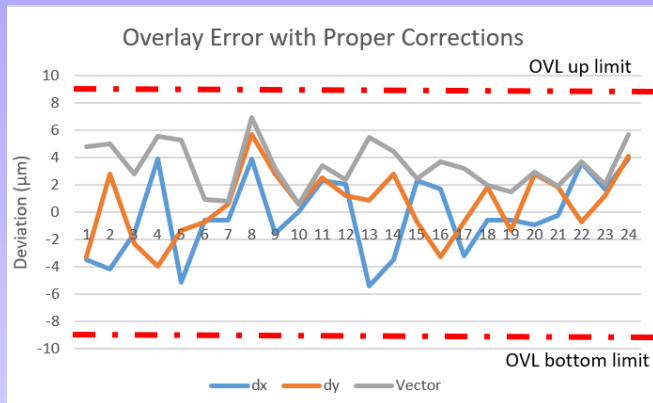


Control Group Overlay Deviation Chart

OVL	DX	DY	Vector
Max.	5.16	19.35	23.26
Min.	-16.77	-19.06	1.94
Average	-5.47	-0.95	12.67
STD	6.46	11.26	5.76

Control Group Overlay Results Table

Experiment Group : Overlay Results with Proper Corrections

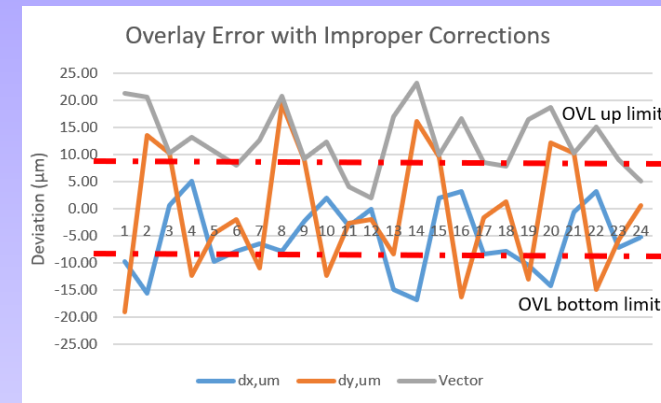


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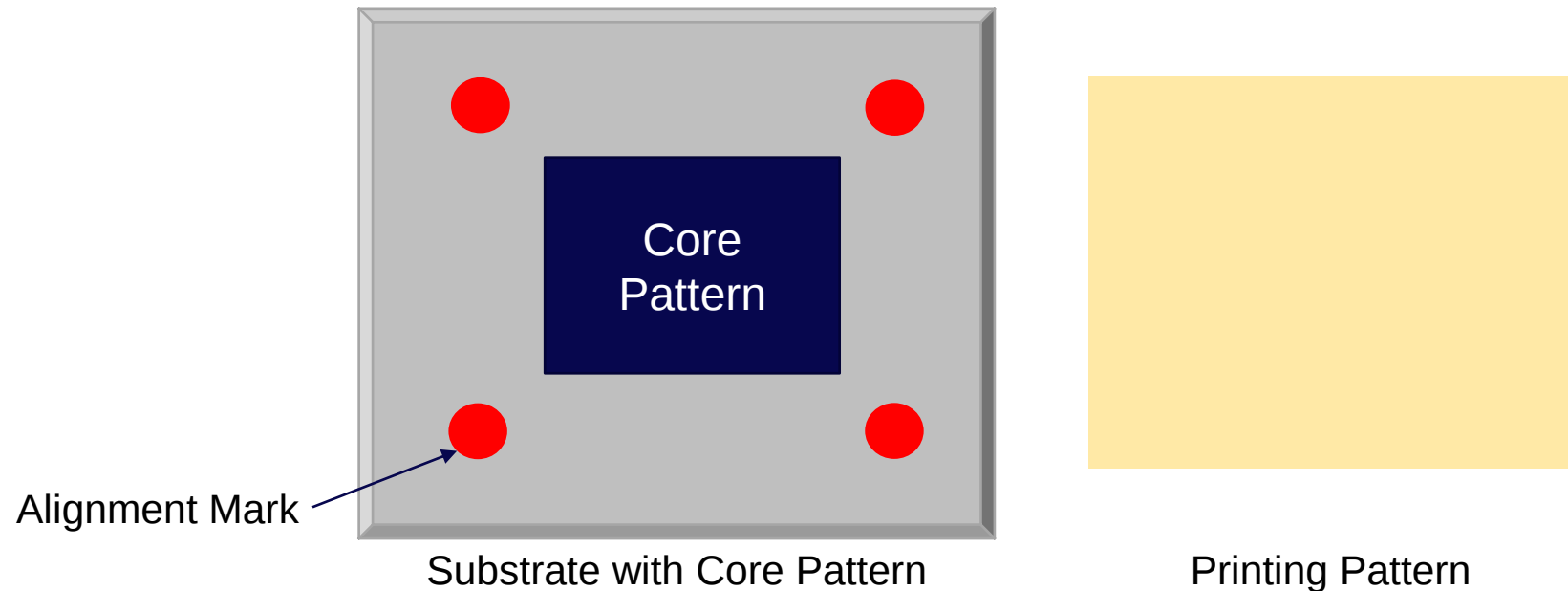
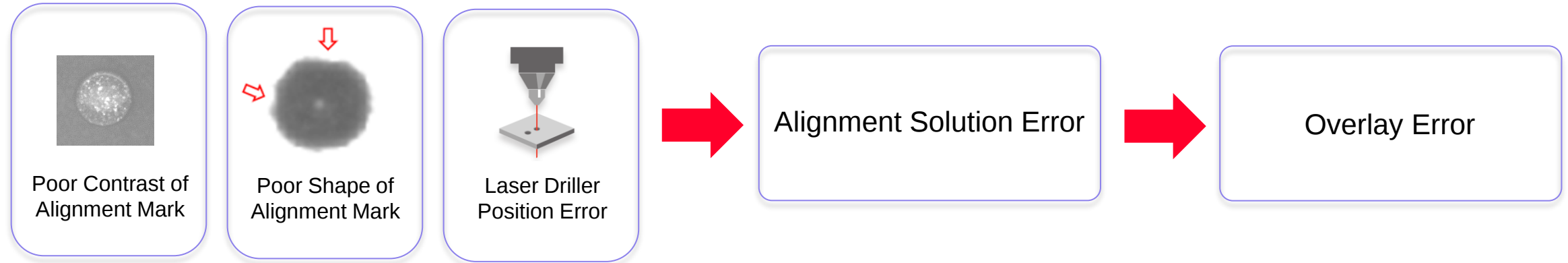


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Average	-5.47	-0.95	12.67
STD	6.46	11.26	5.76

Control Group Overlay Results Table

Alignment Solution Error Induces Overlay Residual Error



Additional Compensation Can Address Alignment Solution Error and Improve Overlay Significantly

Panel 1

Max Overlay Error

40.86% ↓

Original Overlay Results

Max OVL Vector
9.3 μm

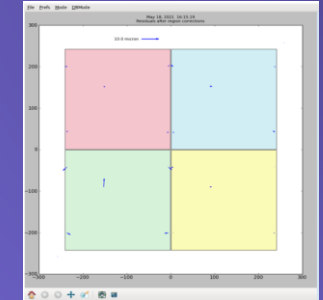


Overlay Correctables

Region Correctables							Apply
X Offset	Y Offset	Theta	Mag	Scale X	Scale Y	Orth	
-0.516	-1.163	7.241	-20.133	8.949	-49.215	-9.849	
3.031	2.901	5.402	-21.353	-10.444	-32.263	-5.357	
3.676	3.290	8.510	-18.092	-13.422	-22.762	8.332	
0.452	-3.612	10.164	-25.837	-1.869	-49.805	21.418	

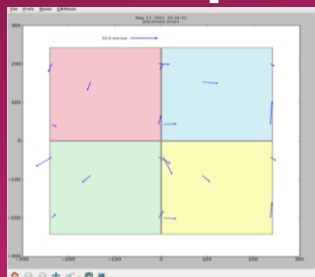
With Additional Compensation

Max OVL Vector
5.5 μm



Original Overlay Results

Max OVL Vector
10.3 μm

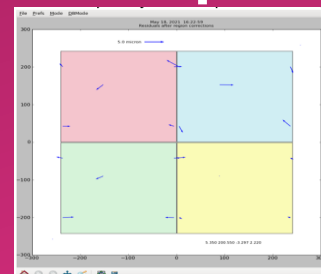


Overlay Correctables

Region Correctables							Apply
X Offset	Y Offset	Theta	Mag	Scale X	Scale Y	Orth	
-0.194	-1.031	6.183	-7.934	24.171	-40.039	-11.590	
2.773	-1.097	29.176	-30.896	-11.058	-50.734	29.008	
2.322	1.225	24.465	-25.479	-4.940	-46.017	12.714	
0.904	-0.968	19.838	-7.406	10.863	-25.674	17.501	

With Additional Compensation

Max OVL Vector
3.9 μm



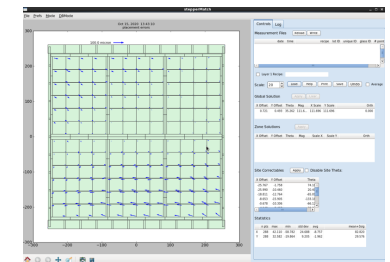
OVL error **6.4 μm** ↓

OVL error **3.8 μm** ↓

Panel 2

Max Overlay Error

62.14% ↓



Steppermatch can be used to analyze the correctable errors and predict the overlay results with the correctables applied.

- Introduction
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- **Summary and Conclusion**

Summary and Conclusion

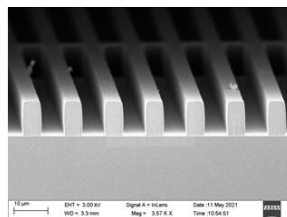
Overlay Yield Product Yield

1%↑ 5.29%↑

In 6 Layers Packaging

Overlay Matters

3μm / 60μm DOF



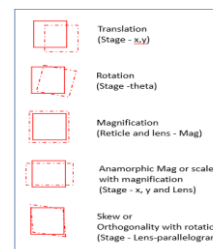
STD Overlay

< 1.5μm

Panel Uni.

4.32%

Correction Capability

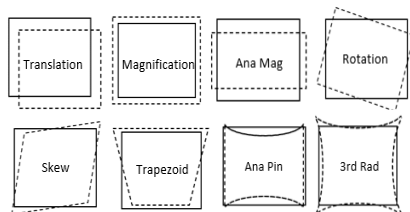


Extremely Large Exposure Field Fine Resolution Lithography

- Correction Ability
- Zone Correction
- Add. Compensation

Conclusion

Pattern Distortion Components



Pattern Distortion and Correction Method

Zone Correction Needed

- Non-linear Error
- Zone Level Error
- Huge Range Rotation Error

Overlay **With** Proper Corrections

Max Overlay Error

6.94μm

Overlay **Without** Proper Corrections

Max Overlay Error

23.26μm

Overlay Demonstration Results



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DEVICE PACKAGING
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Thank You

谢谢 | 謝謝

Danke

ありがとう

감사합니다

Obrigado

Merci

innovation®
onto

John Chang
John.Chang@ontoinnovation.com