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ENABLING FINE LINE RDL AND HIGH ASPECT RATIOS FOR CU PILLARS FOR HETEROGENEOUS INTEGRATION

IMAPS – Device Packaging Conference

Fountain Hills, Arizona, March 2 – 5, 2020

Speaker: Fabian Benthaus

Habib Hichri, Markus Arendt, Matthew Gingerella

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OUTLINE

CHALLENGES IN ADVANCED PACKAGING

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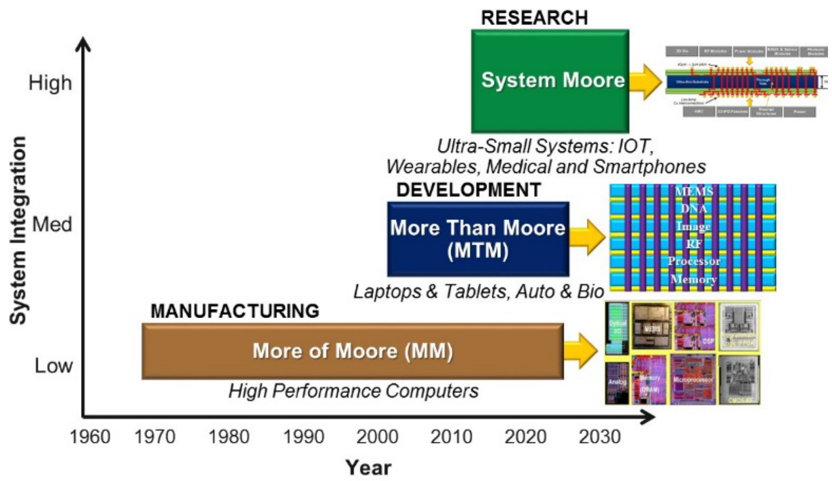

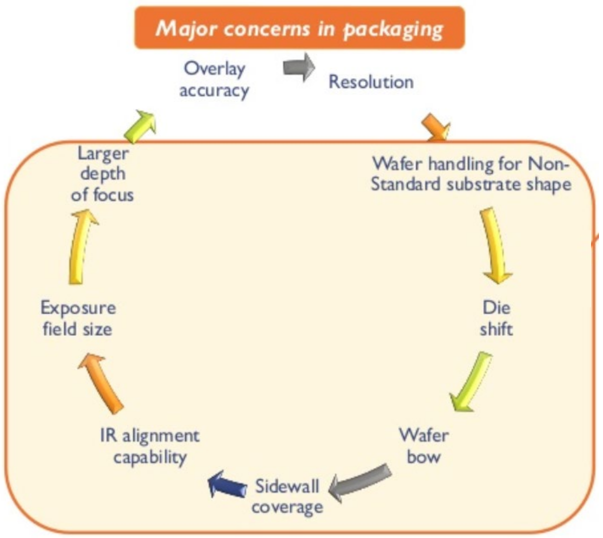

Advanced Packaging Requirements	Translate into AP Litho Tool Requirements
Lower Cost	Lower CoO
Increased Performance	Higher Throughput Tighter Overlay
Increased Functionality	Heterogeneous Integration Packages of any size Scaling of FOWLP wafers

- **Advanced Packaging:**
  - Lower cost, increase performance and functionality through advanced packaging
  - Drive for multi die packages and systems thereof (SiP)
  - Advanced Flip Chip packages, WLP, 3D TSV, hybrid solutions

Yole Développement: Lithography technology and trends for « Semiconductor frontier » held by Amandine Pizzagalli on Semicon West 2016

WHAT IS A FULL-FIELD UV PROJECTION SCANNER?

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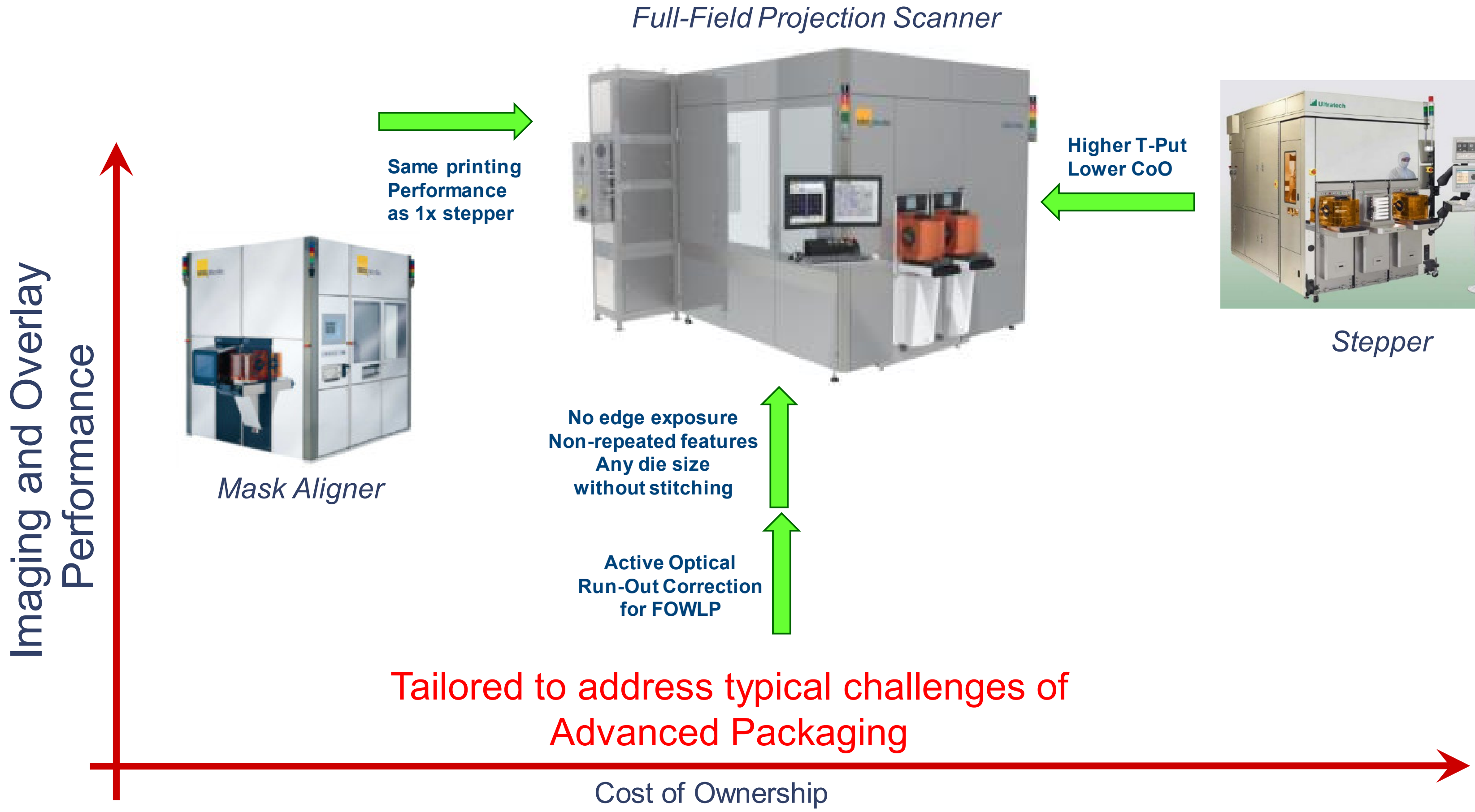
+ UV Exposure Tool Comparison



WHAT IS A FULL-FIELD UV PROJECTION SCANNER?

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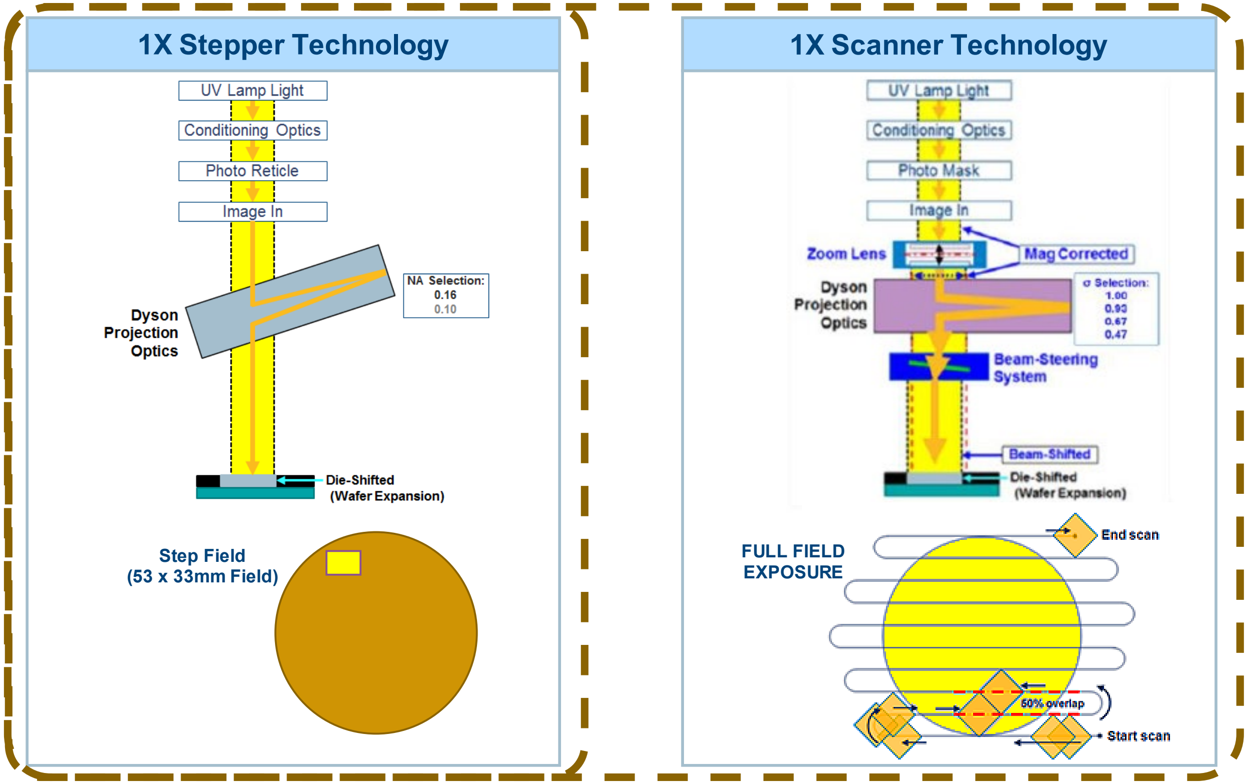
+ Projection Technology Comparison



WHAT IS A FULL-FIELD UV PROJECTION SCANNER?

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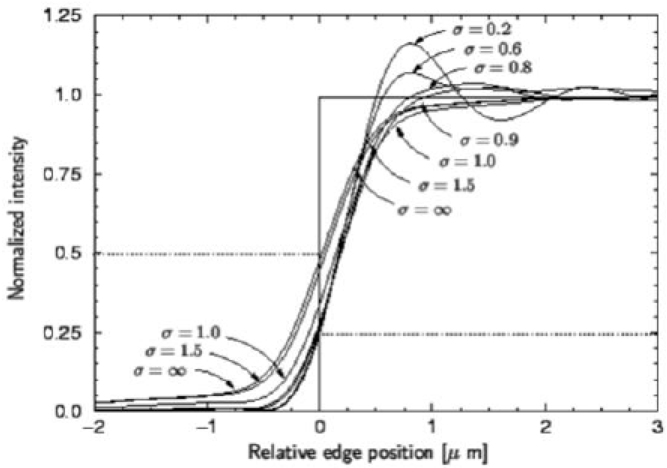
+ Automated variable σ for more process control

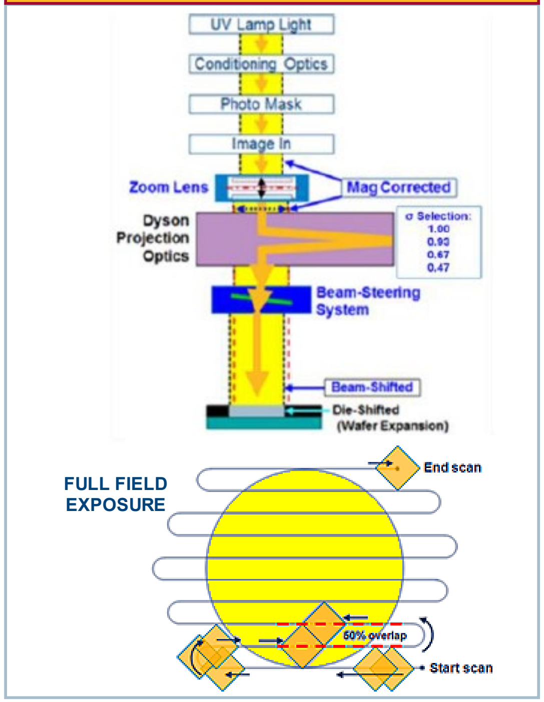
$$DOF = \pm k_2 \lambda / (NA)^2, \quad (1)$$

$$\sigma = \frac{NA_{illumination}}{NA_{image}}. \quad (2)$$

$$R = \frac{k_1 \lambda}{NA\,(1+\sigma)}. \quad (3)$$



R. Rogoff, 1996. Photolithography using the areal illuminator in a variable NA wafer stepper, Santa Clara: SPIE Symposium on Microlithography.



WHAT IS A FULL-FIELD UV PROJECTION SCANNER?

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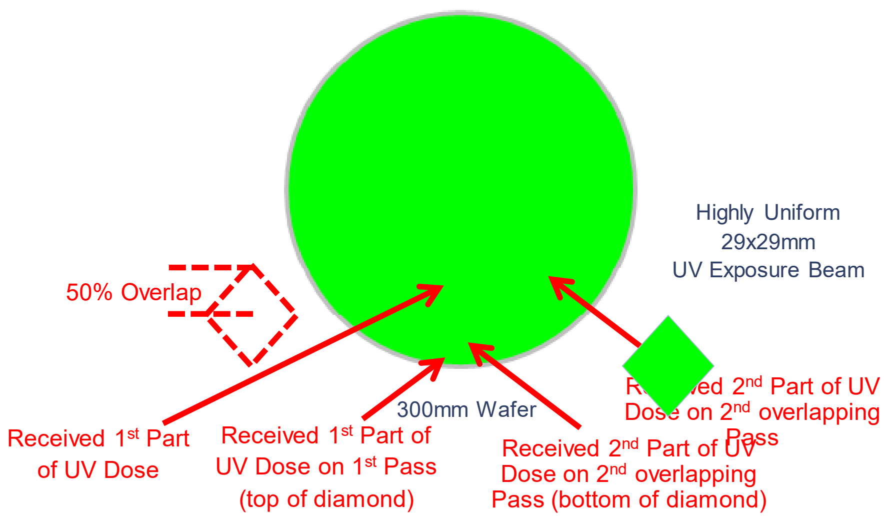
High Throughput Scanning Technology

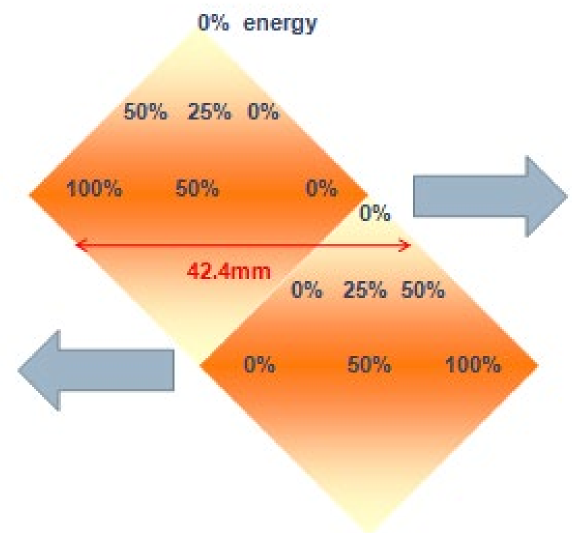
Scanning technique results in excellent image uniformity across 300mm wafer

- *No stitching*
- *No edge exposure / edge protection*
- *Dies of any size*
- *Throughput is not affected by step field fill factor*

Full Dose Applied Over 2-Overlapping Passes

- Passes apply Complimentary Doses
- Pass-1 Dose + Pass-2 Dose = 100% Dose





WHAT IS A FULL-FIELD UV PROJECTION SCANNER?

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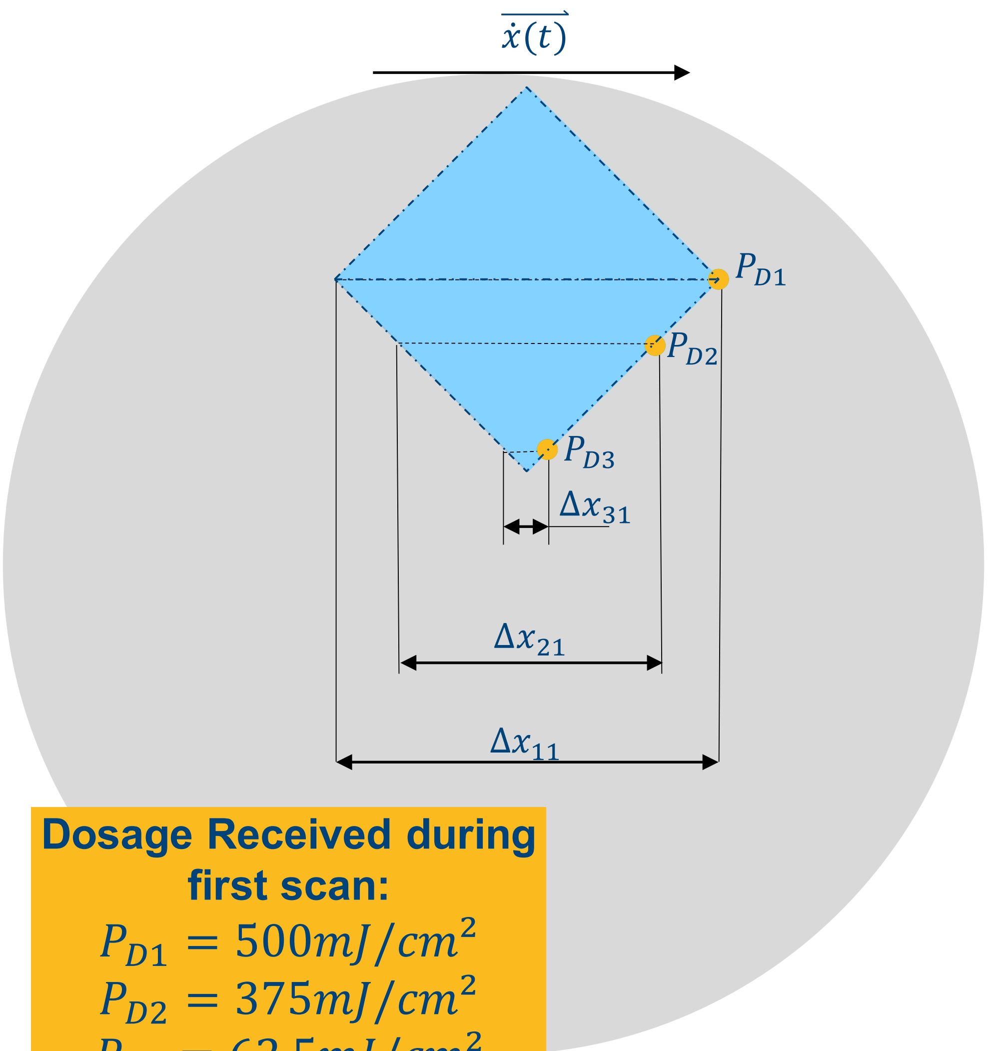
+ First scan path:



Dosage Received during first scan:

$P_{D1} = 500mJ/cm^2$

$P_{D2} = 375mJ/cm^2$

$P_{D3} = 62.5mJ/cm^2$

What we know:

- Lamp intensity I: 5000mW/cm²
- Required exposure dose: e.g. 500mJ/cm²
- Beam width:
  - Δx_{11}: 40mm
  - Δx_{21}: 30mm
  - Δx_{31}: 5mm

How fast we need to scan so point P_{D1} receives 500mJ/cm²

$$\overrightarrow{\dot{x}(t)} = \frac{\Delta x_{11}}{P_{D1}} \cdot I = 400mm/s$$

What dosage receives P_{D2} and P_{D3} when scanning at 400mm/s during first scan

$$P_{D2} = \frac{\Delta x_{21}}{\overrightarrow{\dot{x}(t)}} \cdot I = 375mJ/cm^2$$

$$P_{D3} = \frac{\Delta x_{31}}{\overrightarrow{\dot{x}(t)}} \cdot I = 62.5mJ/cm^2$$

WHAT IS A FULL-FIELD UV PROJECTION SCANNER?

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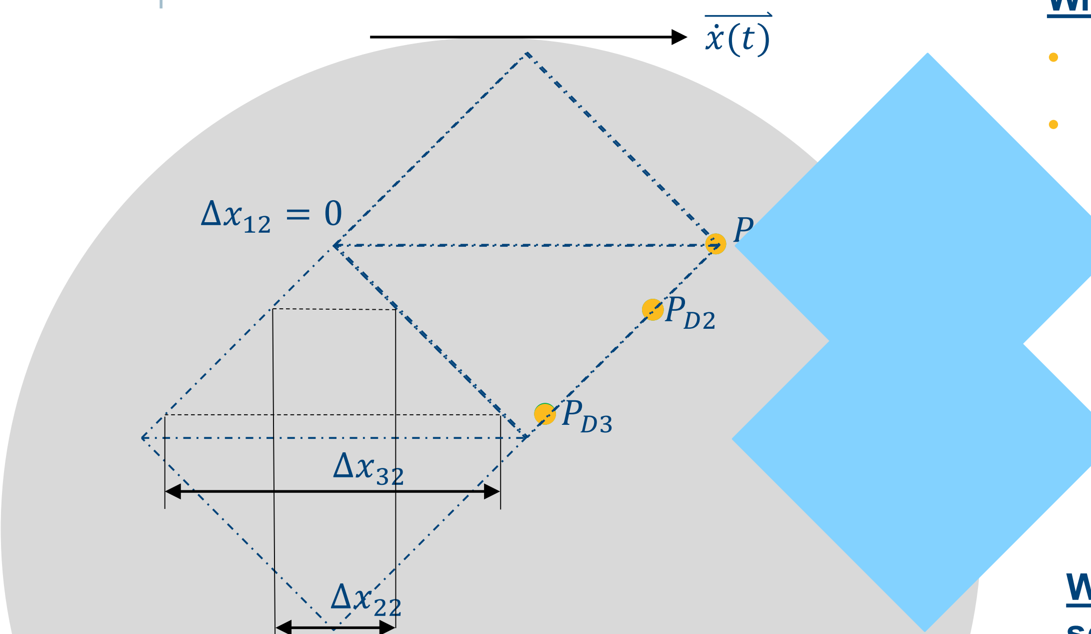
+ Second scan path:



What we know:

- Lamp intensity I: 5000mW/cm²
- Required exposure dose: e.g. 500mJ/cm²
- Beam width:
  - Δx_{12}: 0mm
  - Δx_{22}: 10mm
  - Δx_{32}: 35mm
- **Scan speed: 400mm/s**

What dosage receives P_{D1}, P_{D2} and P_{D3} when scanning at 400mm/s during second scan:

$$P_{D1} = \frac{\Delta x_{12}}{\overrightarrow{\dot{x}(t)}} \cdot I = 0\ mJ/cm^2$$

$$P_{D2} = \frac{\Delta x_{22}}{\overrightarrow{\dot{x}(t)}} \cdot I = 125mJ/cm^2$$

$$P_{D3} = \frac{\Delta x_{32}}{\overrightarrow{\dot{x}(t)}} \cdot I = 437.5mJ/cm^2$$

Dosage Received during first scan:

$$P_{D1} = 500mJ/cm^2$$
$$P_{D2} = 375mJ/cm^2$$
$$P_{D3} = 62.5mJ/cm^2$$

Dosage Received during second scan:

$$P_{D1} = 0\ mJ/cm^2$$
$$P_{D2} = 125mJ/cm^2$$
$$P_{D3} = 437.5mJ/cm^2$$

Total received dosage during two paths:

$$P_{D1} = P_{D2} = P_{D3} = 500mJ/cm^2$$

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WHAT IS A FULL-FIELD UV PROJECTION SCANNER?

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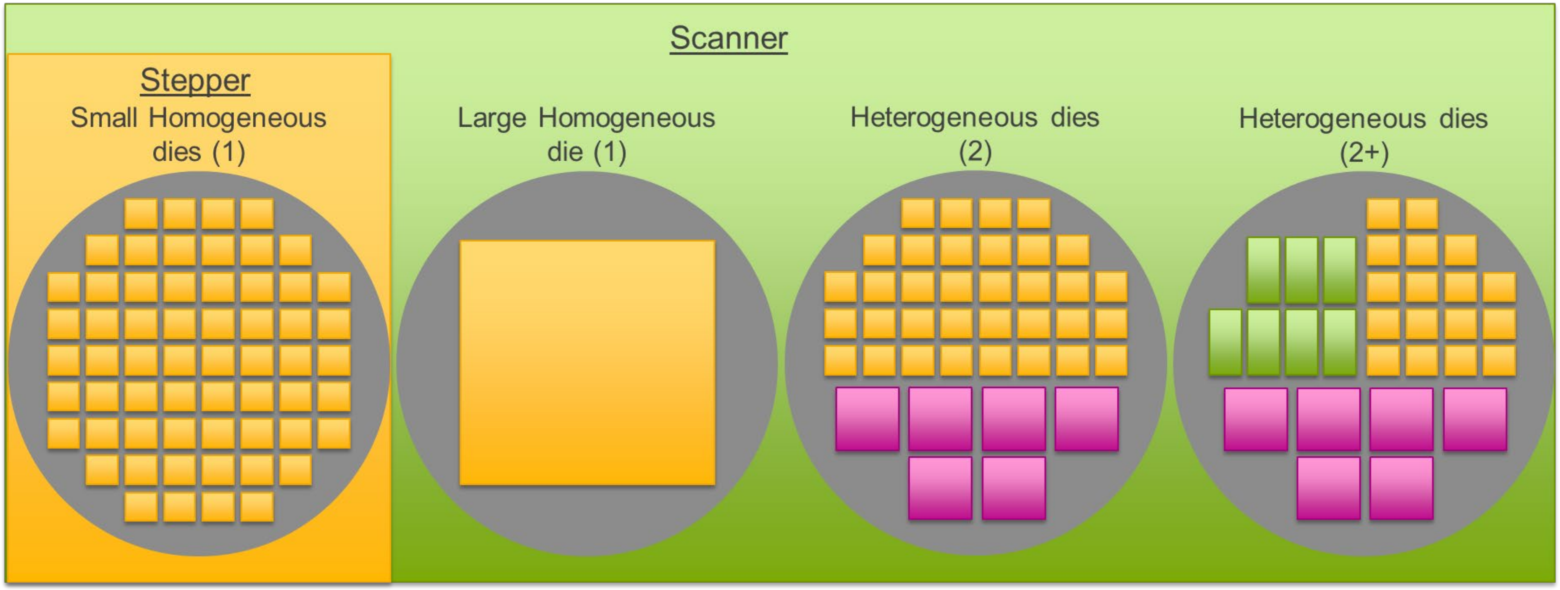
+ Similar full-field benefits as Mask Aligner with 1x projection performance
  - *Full field exposure of 1:1 mask enables non-repeating patterns*
  - *This becomes important with the increasing introduction of heterogeneous integration!*



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CHALLENGES FOR HETEROGENEOUS INTEGRATION

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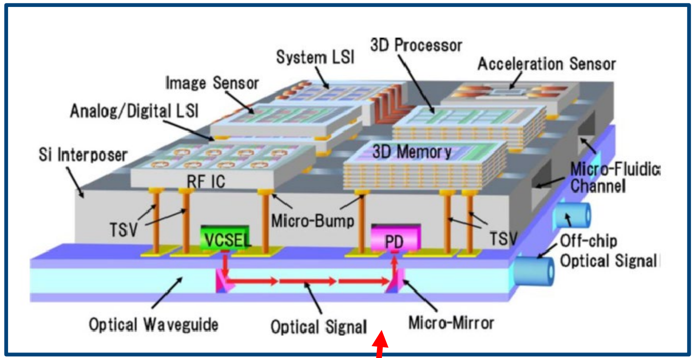
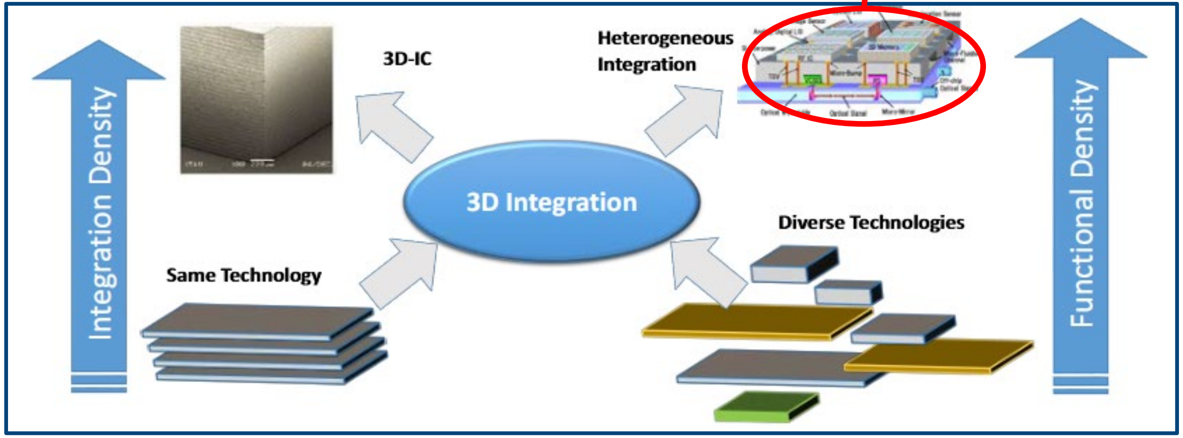
Larger Die and Higher Packaging Complexity driven by **Heterogeneous Integration – More-than-Moore – Fan-Out WLP**





Dr. Burhan Bayraktaroglu, Heterogeneous Integration Technology, May 19, 2017

INDUSTRY LITHO LIMITATIONS

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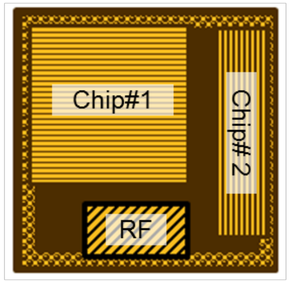
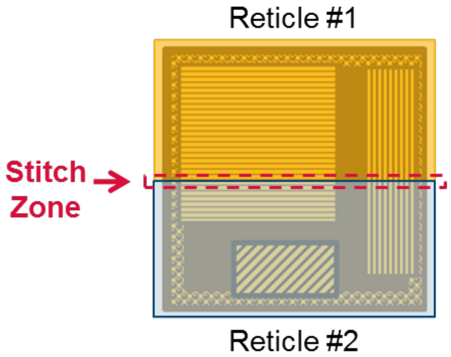
- Existing 1X Projection Litho Tools were not designed to pattern Larger Heterogeneous Integration packages:
  - Users are forced to perform Reticle Stitching with the limited size imaging fields available

Heterogeneous Integration



UV Stepper Reticle Stitching



- Stepper reticle stitching is required for die/package sizes: 30~35 mm²
- Reticle stitching is prone to multiple error factor
- Stitching can lower yield

1X PROJECTION STEPPER – MORE YIELD LOSS POTENTIAL

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+ RETICLE STITCHING :

- So many ERROR Combinations

1X PROJECTION STEPPER – STITCHING DEFECTS

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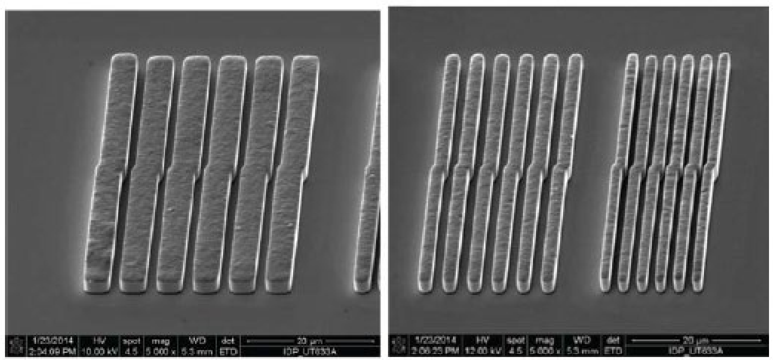
RETICLE STITCHING :

- **Too many extra chances for Shorts, Opens and Pattern Irregularities**



(a) Pitch = 6 µm (b) Pitch = 4 µm and 3 µm

Figure 11. Electroplated metal lines at stitch with (a) 4 µm line and 2 µm space and (b) 4 µm and 3 µm pitches equal line and space pitches. Both cases have a lateral offset of 0.25 µm.

"Taken to the extreme, a large overlap can create an electrical short and a large gap can create an electrical open."

- W. Flack et al., Ultratech, Inc.

Flack, W. et al. (2014), Large Area Interposer Lithography (pg.4). Ultratech Inc., retrieved from Google March 2019.

ELIMINATE STITCHING

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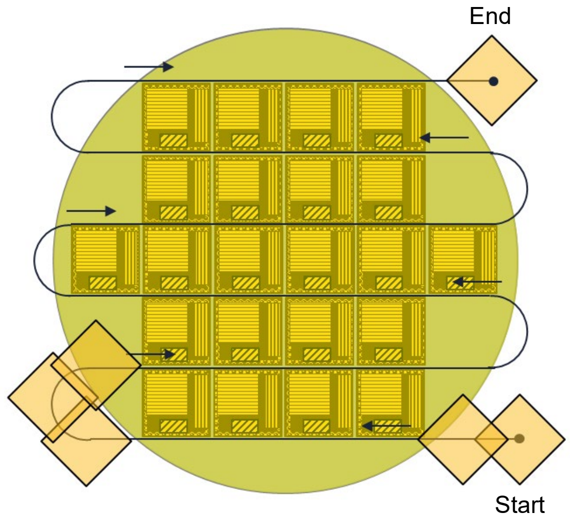
+ Full-Field Projection Scanner Technology:

- Eliminates the need to stitch
- Enables more complex and advanced die and package designs

Full-Field Scan Exposure



Benefits

+ No Stitching
+ No additional chances for stich related Yield Loss
+ Enables fast imaging of more complex patterns
+ Unlimited die and package sizes

HETEROGENEOUS INTEGRATION & LARGE DIE SOLUTION

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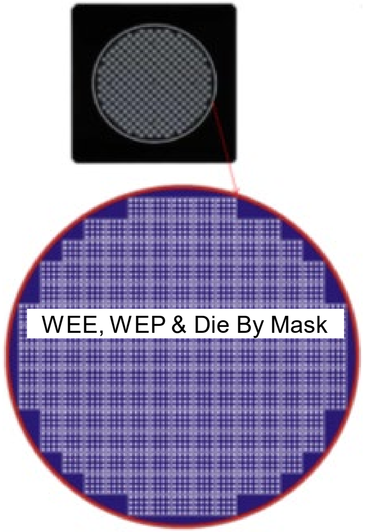
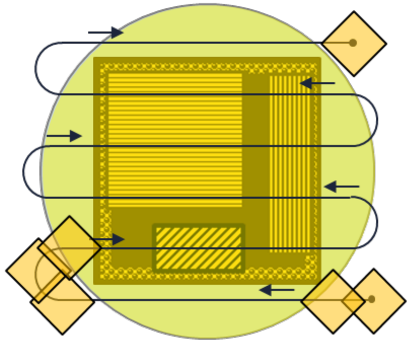
Limitless design and patterning capabilities

- Allows Dies of any size and patterning of Non-repeated Features (i.e. edge ring)
- Throughput is not die size or wafer layout dependent

No edge exposure
No edge protection



GO LIMITLESS!



+ No Die Size Limits
+ New Design Possibilities – No Stitching
+ No Edge WEE & WEP Fussing

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UV PROJECTION SCANNER CAPABILITIES

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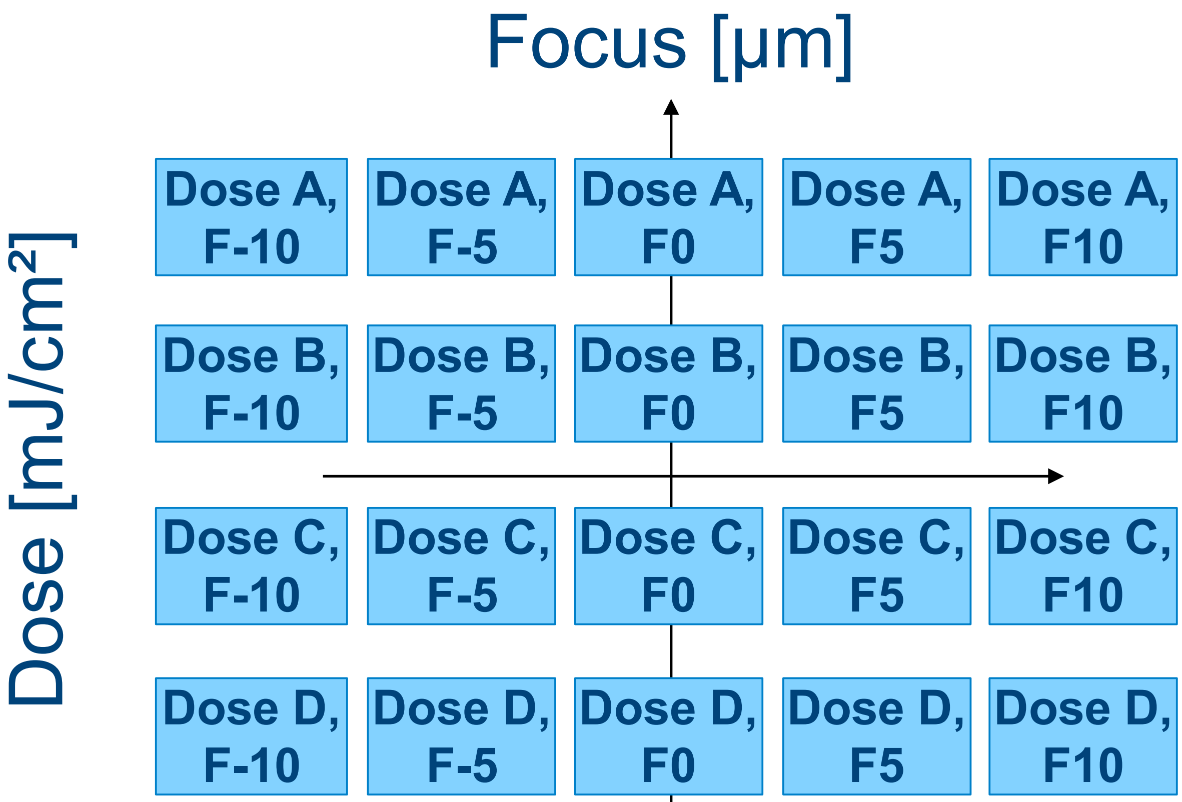
- Focus Exposure Matrix (FEM) as useful evaluation tool to determine full process window and stability of new processes
- Principal can be adopted in an evaluation matrix to check not only dose and focus but also wavelength, and apertures (σ)



UV PROJECTION SCANNER CAPABILITIES

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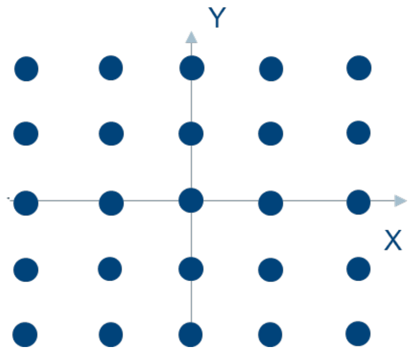
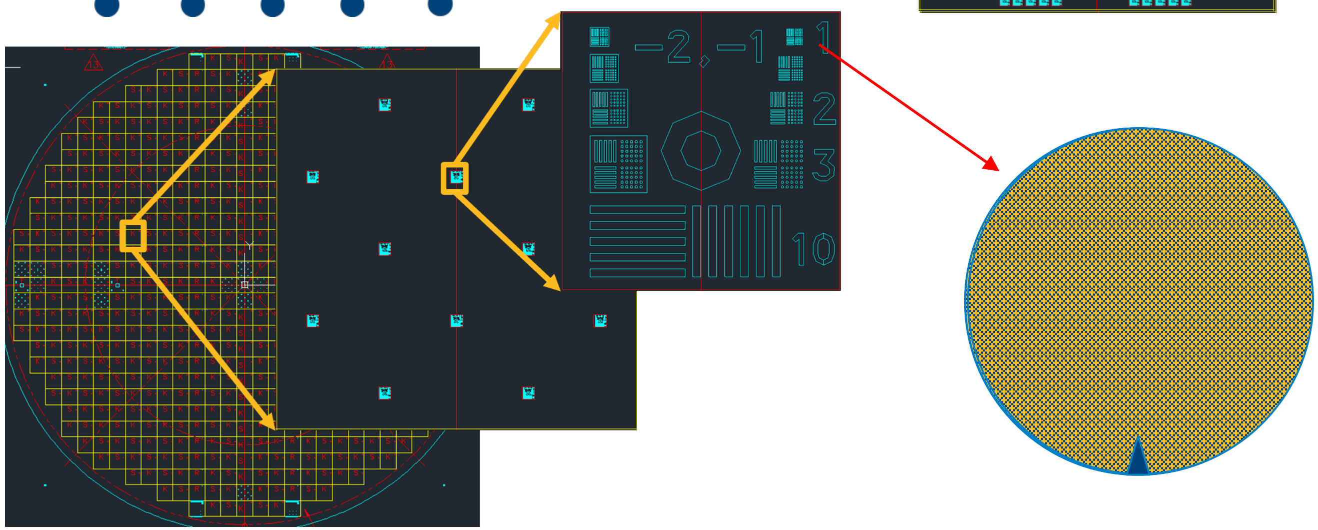
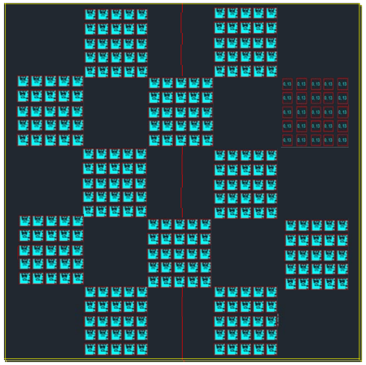
Micropos Position travel range up to ±2.5mm in x and y







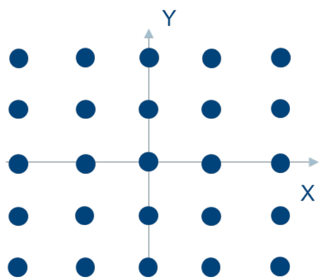
UV PROJECTION SCANNER CAPABILITIES

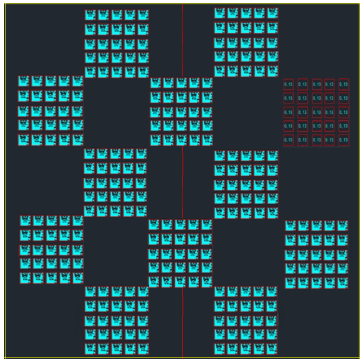
Multiple matrices across the wafer

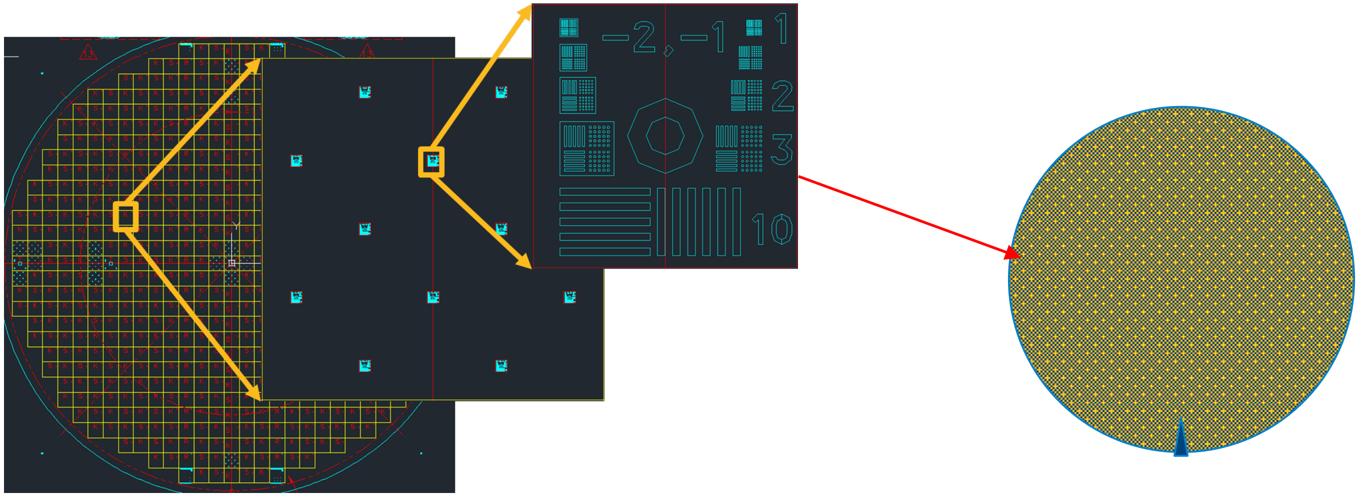
Depending on feature size up to 50 x 50 matrix are possible (for 2/2µm L/S) -> THESE ARE **2500 conditions** in one matrix

For 10/10µm L/S still 900 conditions possible

Over 10000 of the matrices can be distributed across **ONE** wafer







UV PROJECTION SCANNER CAPABILITIES

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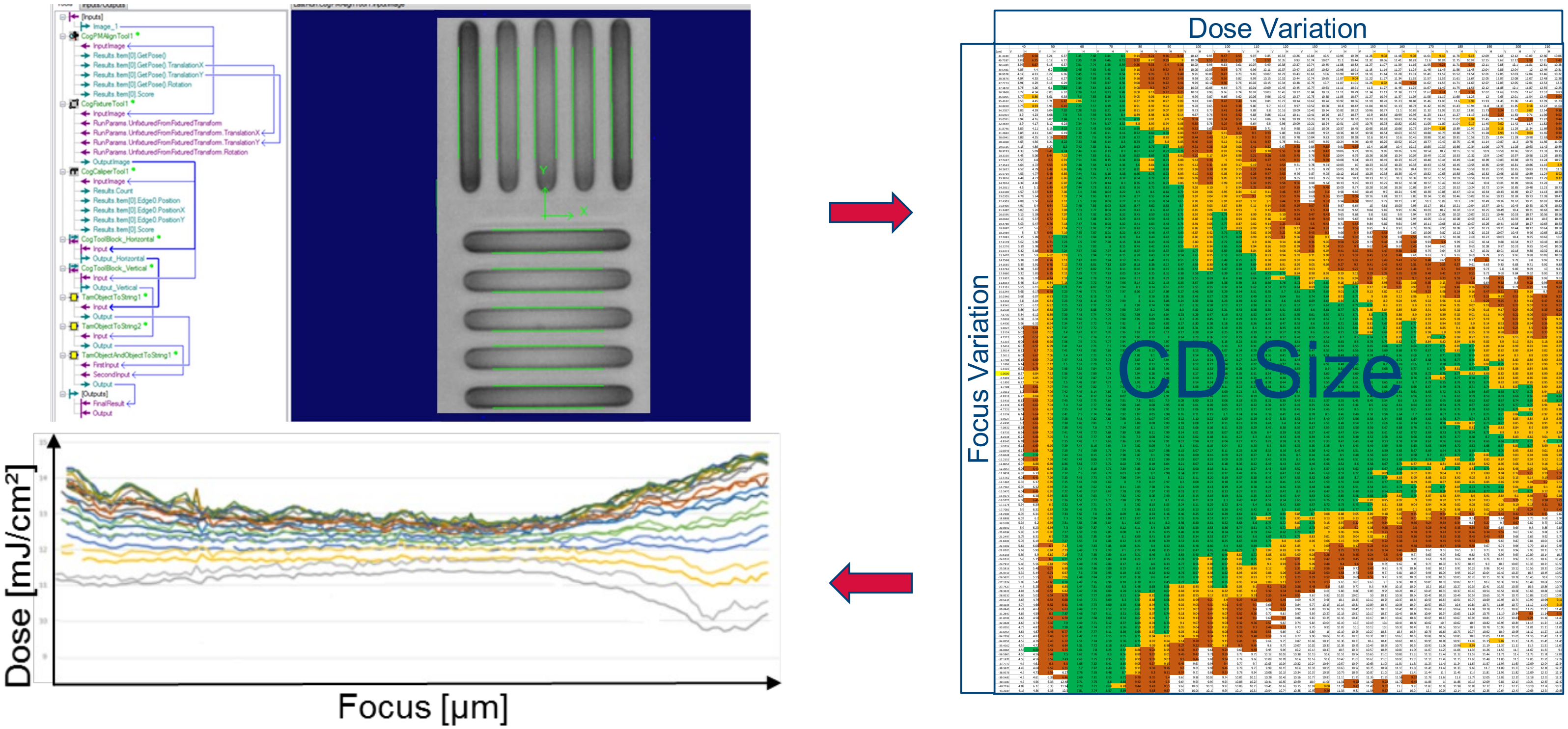
- Combination of smart mask design, multi-scan capabilities and Vision System of Scanner for process evaluation
- Generating over **7000 different conditions on ONE Wafer** to determine full process window



UV PROJECTION SCANNER CAPABILITIES

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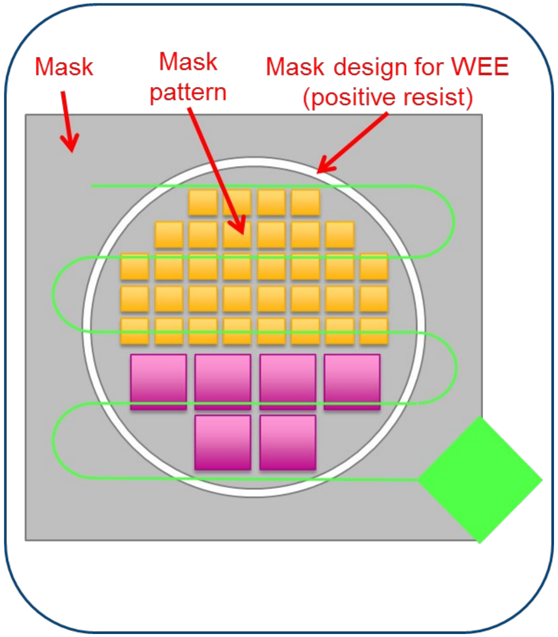
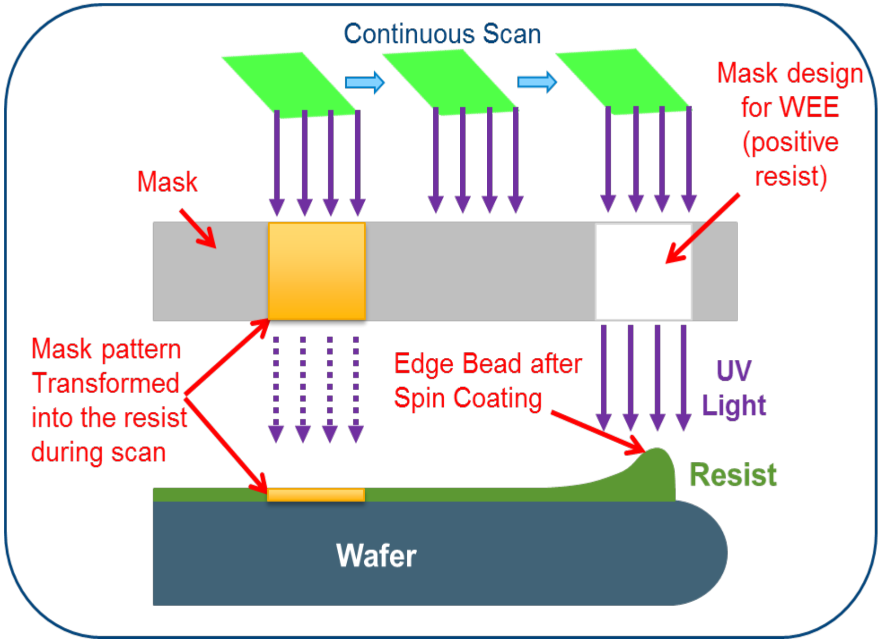
WEE – Wafer Edge Exposure

- Over-scan and intelligent mask design results in WEE during processing
- Case 1: Exposure energy is high enough to expose and eliminate edge beat fully
- Case 2: Pre-exposure of edge reduces process time of Wafer Edge Exposure Unit (WEEU)





RESOLUTION FOR HETEROGENEOUS INTEGRATION

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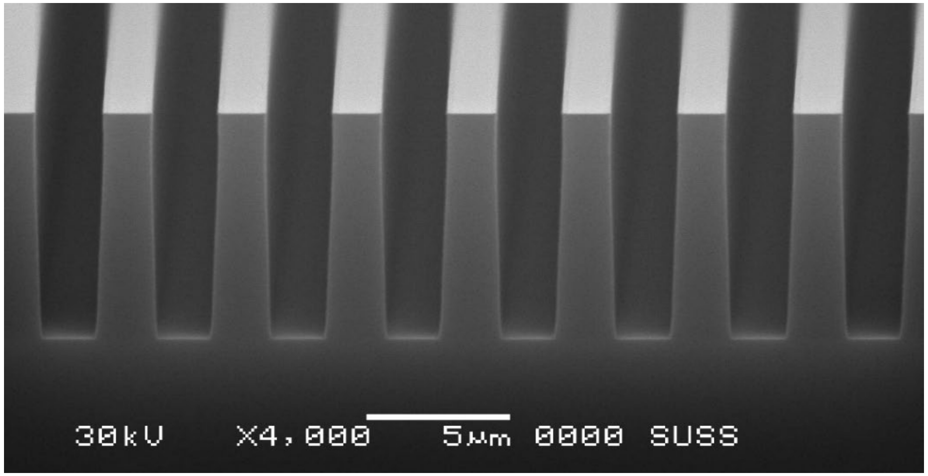
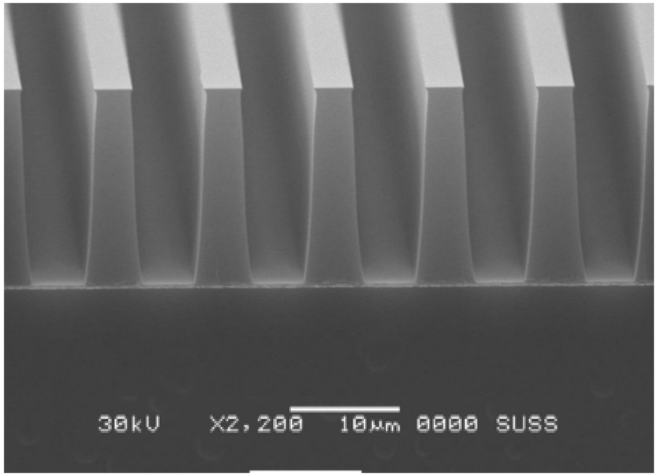
TOK PW-1000T

- Film Thickness 7.0µm
- 2/2µm line and space
- Side Wall angle (SWA) > 87°

AZ4620

- Film Thickness 15.0µm
- 5/5µm line and space
- Side Wall angle (SWA) > 87°





RESOLUTION FOR HETEROGENEOUS INTEGRATION

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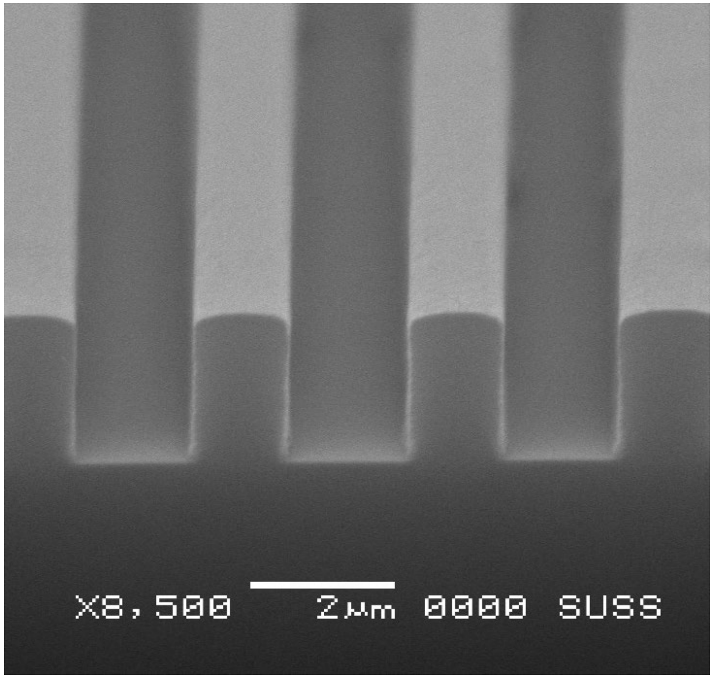
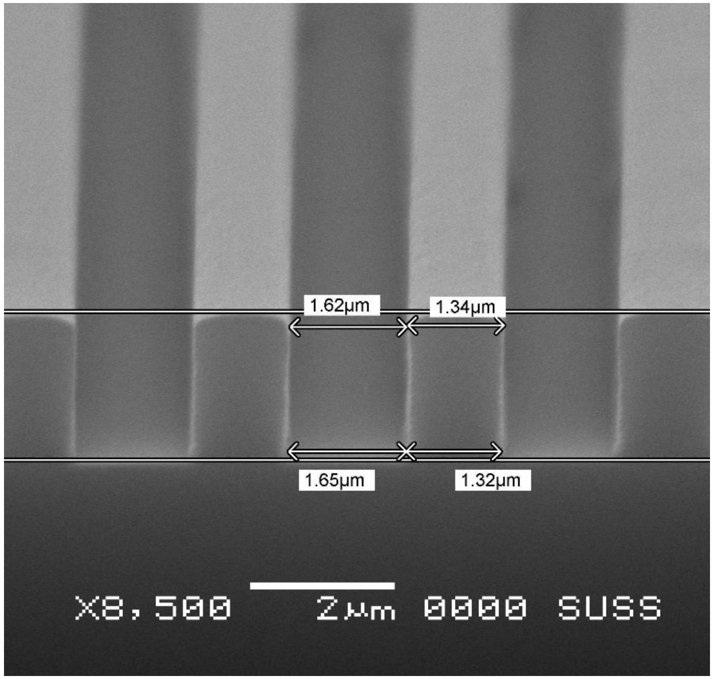
Sumitomo's PXi-105J12US

- Film Thickness: 2µm
- CD Size: 1.5/1.5µm L/S
- Side Wall Angle: >89°





PROCESS WINDOW FOR HETEROGENEOUS INTEGRATION

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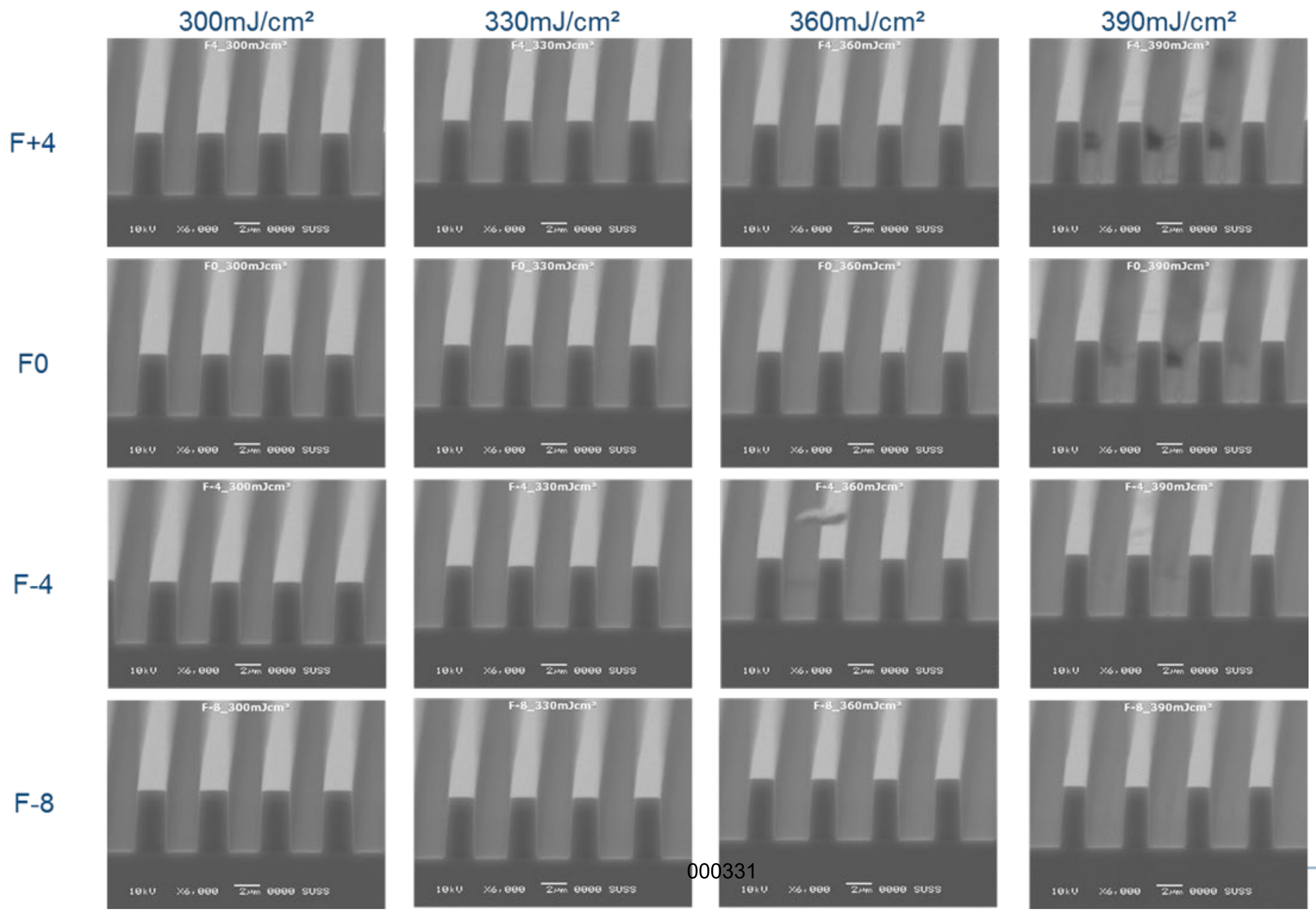
Sumitomo's PXi-105J12US

+ Film Thickness: 5µm
+ CD Size: 2/2µm L/S

Process Window:

+ DOF >12µm
+ Dose Latitude > 90mJ/cm²
+ Side Wall Angle > 88°



HIGH ASPECT RATIO FOR HETEROGENEOUS INTEGRATION

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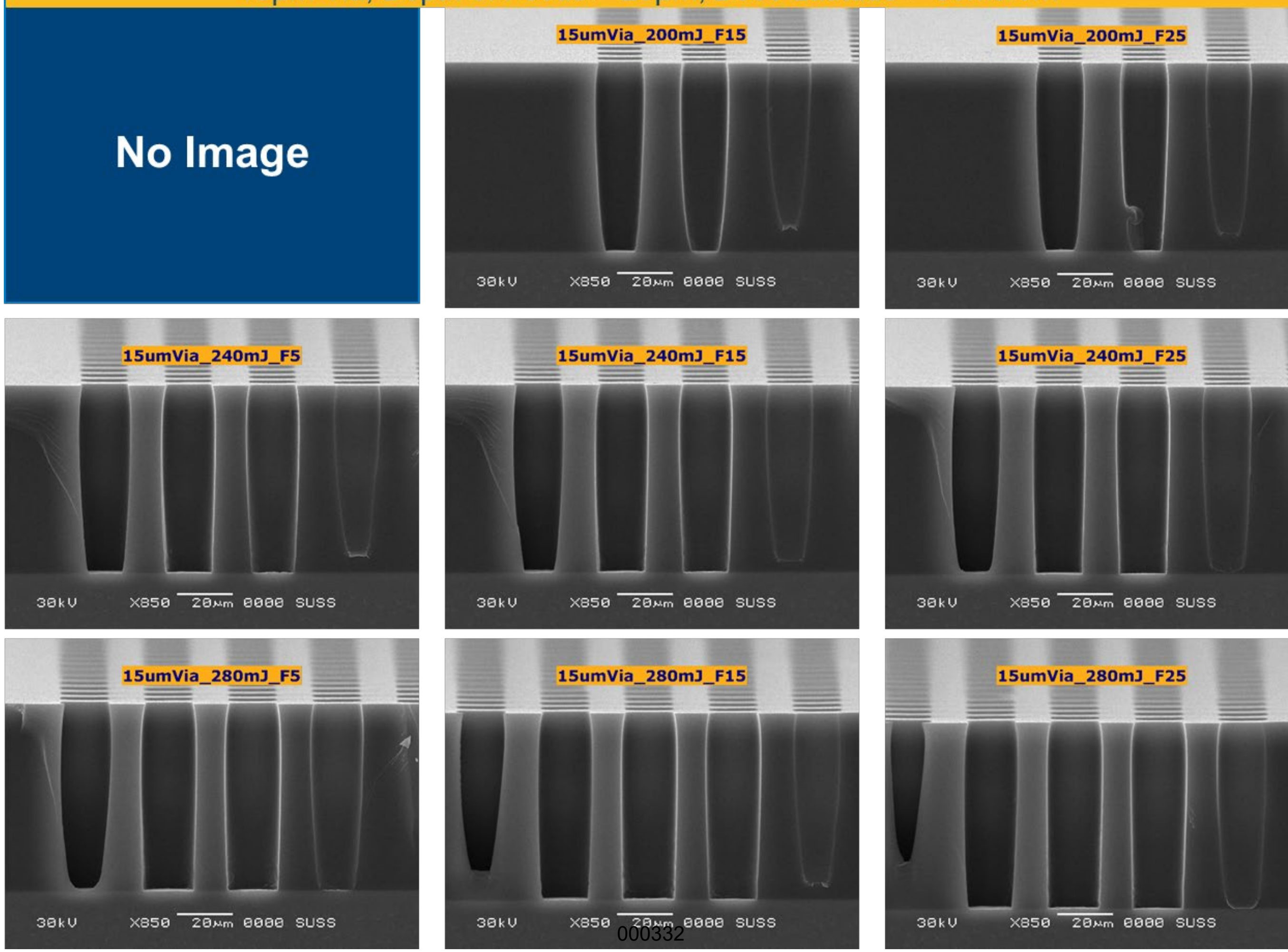
TOK's CR- 4000

- FT 70µm, 15µm Via

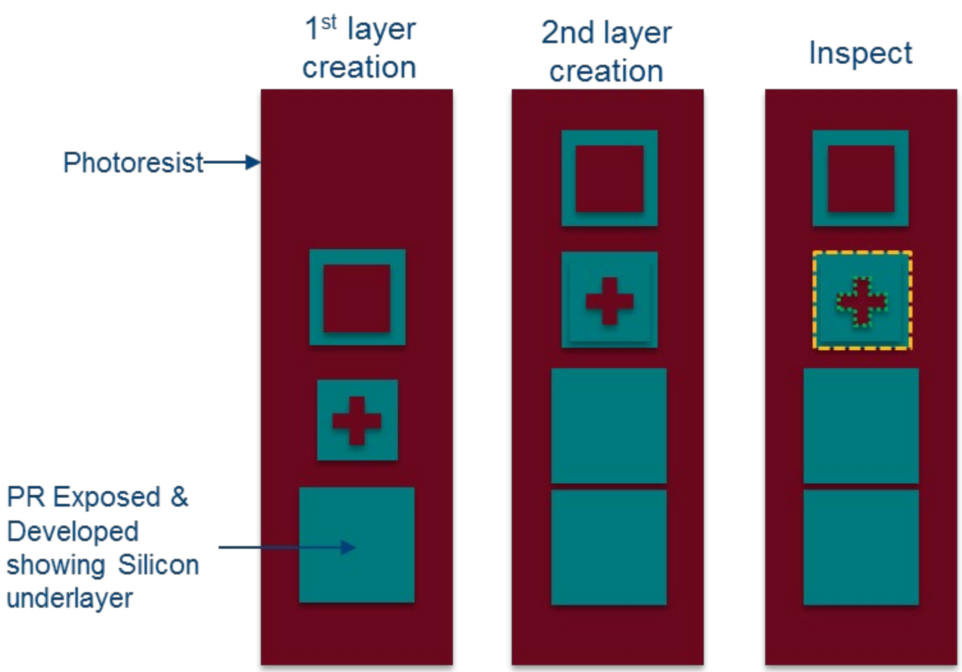
15µm Via, Depth of Focus > 20µm, Dose Latitude > 80mJ/cm²

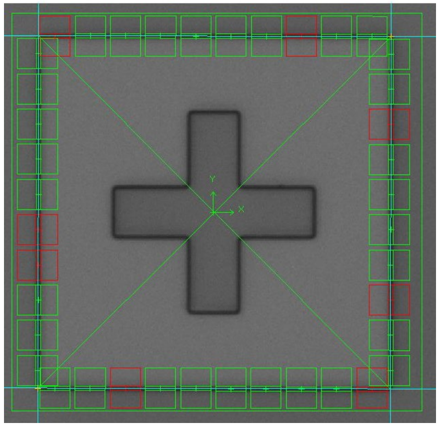


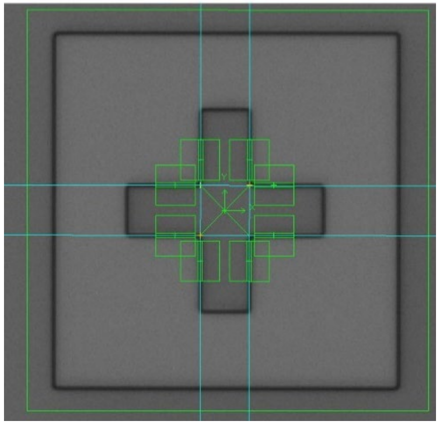
HIGH ACCURACY OVERLAY

Exposed at best condition, then stepped in Y, aligned and exposed again on top of existing patterns

- The feature is at every 20mm interval in X or Y.
- Separate testing is done by stepping in X







HIGH ACCURACY OVERLAY FOR HETEROGENEOUS INTEGRATION

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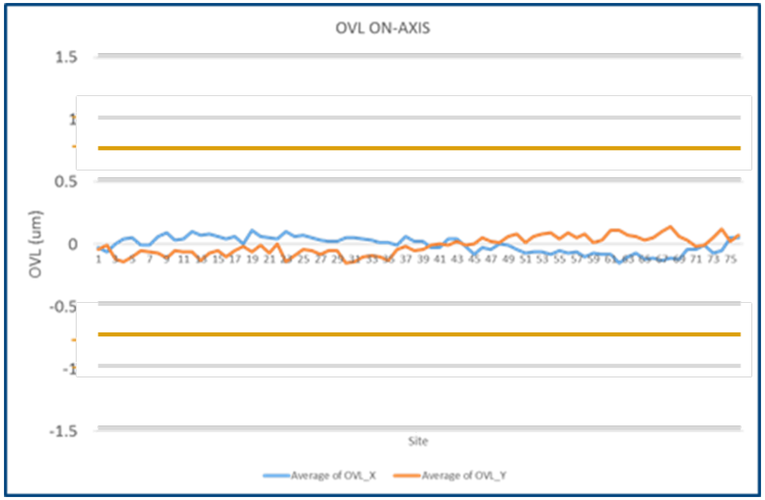
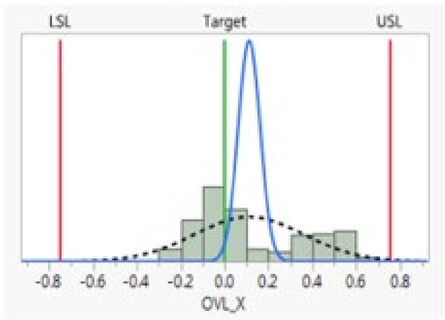
- Sample Size: 454 measurements on six different substrates
- Overall 3σ ≤ 0.75μm



Overlay_X



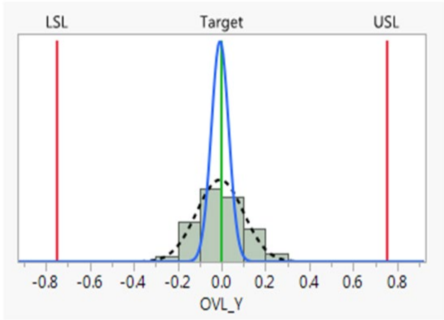
Within Sigma Capability

Index	Estimate	Lower 95%	Upper 95%
Cpk	4.257	3.904	4.611

Process Summary

LSL	-0.75
Target	0
USL	0.75
N	454
Sample Mean	0.111608
Within Sigma	0.049985

Overlay_Y



Within Sigma Capability

Index	Estimate	Lower 95%	Upper 95%
Cpk	6.274	5.754	6.794

Process Summary

LSL	-0.75
Target	0
USL	0.75
N	454
Sample Mean	-0.00692
Within Sigma	0.039479

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PROJECTION SCANNER THROUGHPUT FOR 300MM WAFERS

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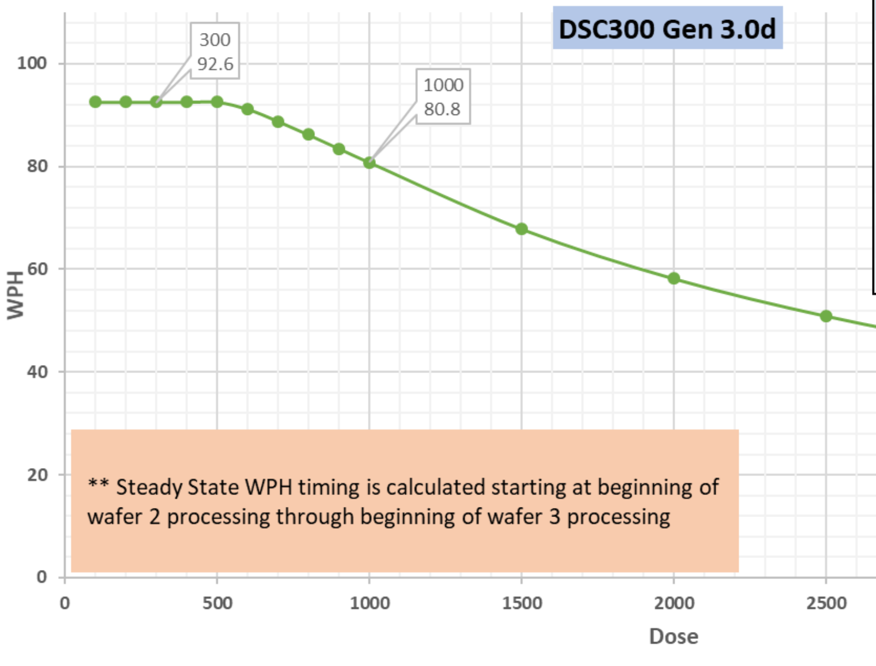

Conditions	
BeamShape	Diamond
Wafer Size (mm)	300
Wavelength	Broadband
Leveling	3gauge w/o Verify
Alignment	Dual_2pt w/ Verify
Intensity	6634
Wavelength	Broadband
Aperature	0.14

** Steady State WPH timing is calculated starting at beginning of wafer 2 processing through beginning of wafer 3 processing

DSC300 Gen 3.0d	
Dose	WPH
100	92.6
200	92.6
300	92.6
400	92.6
500	92.6
600	91.2
700	88.8
800	86.2
900	83.5
1000	80.8
1500	67.8
2000	58.2
2500	50.9
3000	45.2
3500	40.6
4000	36.9

THROUGHPUT SCANNER VS. 1X STEPPER

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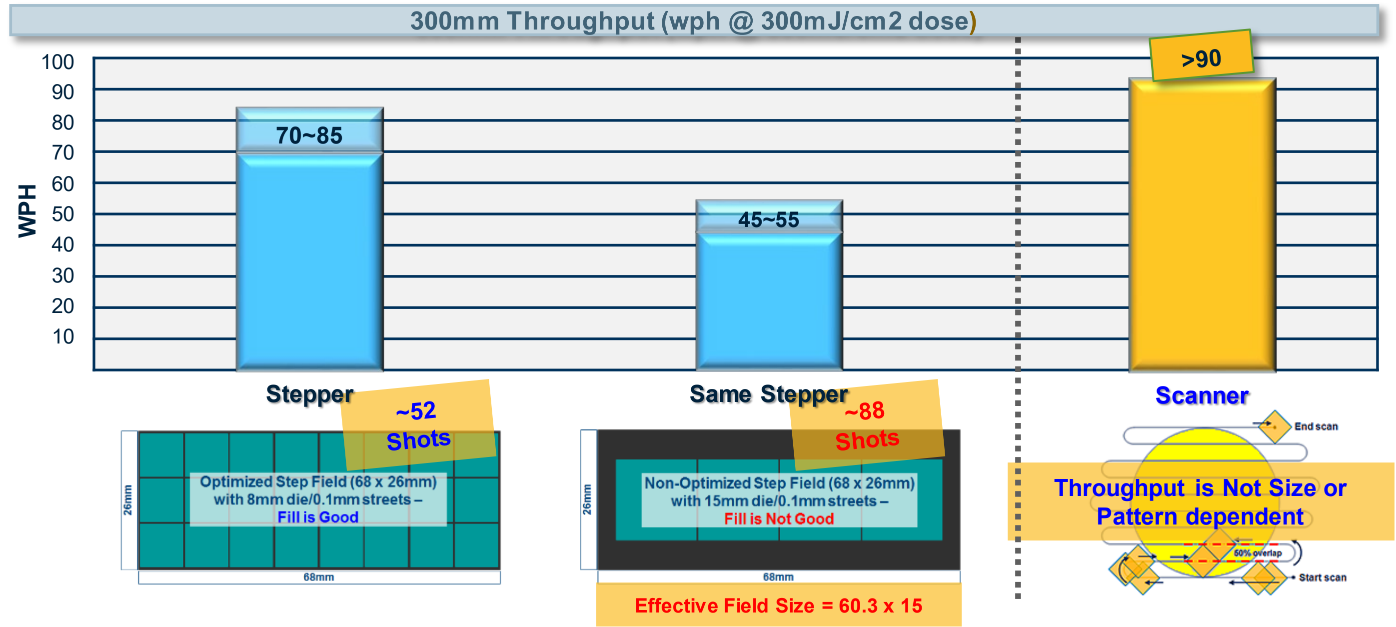
Throughput on stepper depends on additional parameters:

- Die size matching of step window ("fill factor")
- Additional time for edge exposure



SUMMARY 1X PROJECTION SCANNER

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CHALLENGES in Advanced Packaging

- **Advanced Packaging:**
  - Lower cost, increase performance and functionality through advanced packaging
  - Drive for multi die packages and systems thereof (SiP)
  - Advanced Flip Chip packages, WLP, 3D TSV, hybrid solutions

Yole Développement: Lithography technology and trends for « Semiconductor frontier » held by Amandine Pizzagalli on Semicon West 2016

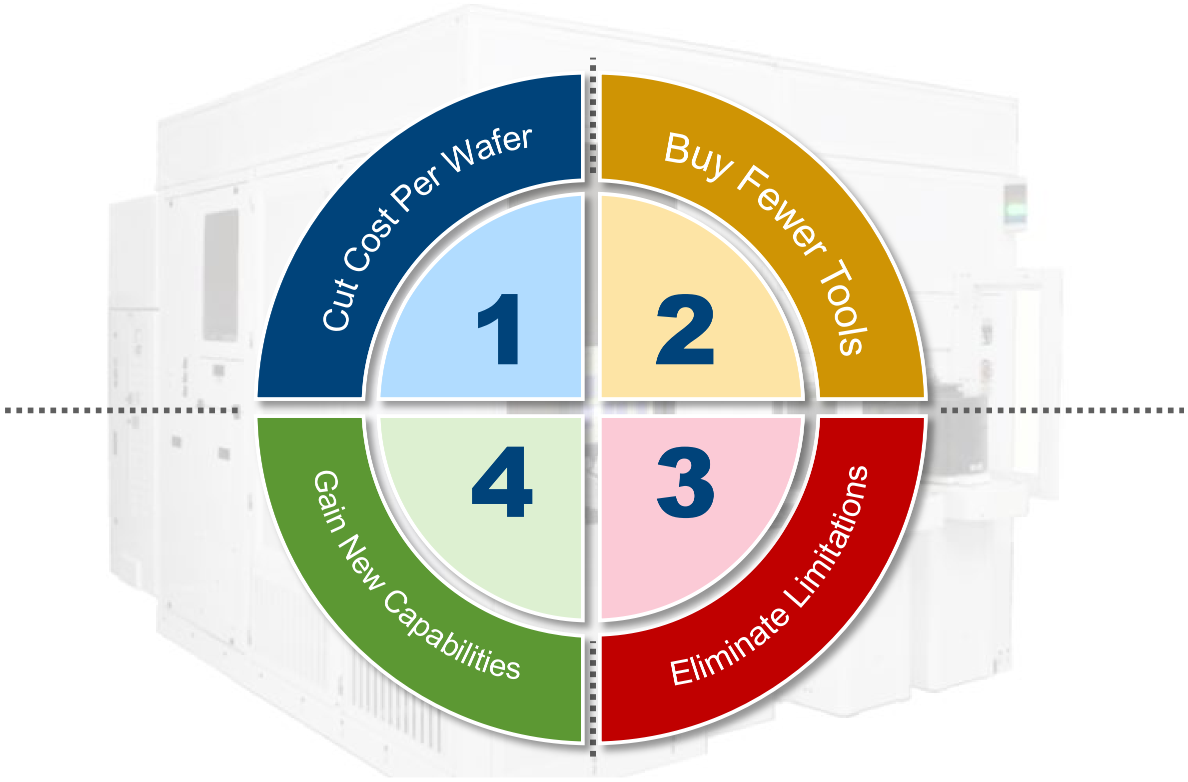
Advanced Packaging Requirements	Translate into AP Litho Tool Requirements	Satisfies New AP Litho Needs
Increased Performance	Higher Throughput	**Projection Scanner** ✔
Lower Cost	Lower CoO	**Projection Scanner** ✔
Increased Functionality	Heterogeneous Integration - Packages of any size	**Projection Scanner** ✔
	Scaling of FOWLP wafers	**Projection Scanner** ✔

ENABLING HI USING PROJECTION SCANNER SYSTEM

SÜSS MicroTec

confidential

+ The projection scanner system enables high resolution, depth of focus and overlay accuracy and opens new capabilities like limitless design with no stitching



SÜSS MicroTec Photonic Systems
220 Klug Circle
Corona, CA 92880

www.SUSS.com