Advanced Stepper Lithography Technology to Enable Flexible AMOLED Displays

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RUDOLPH TECHNOLOGIES

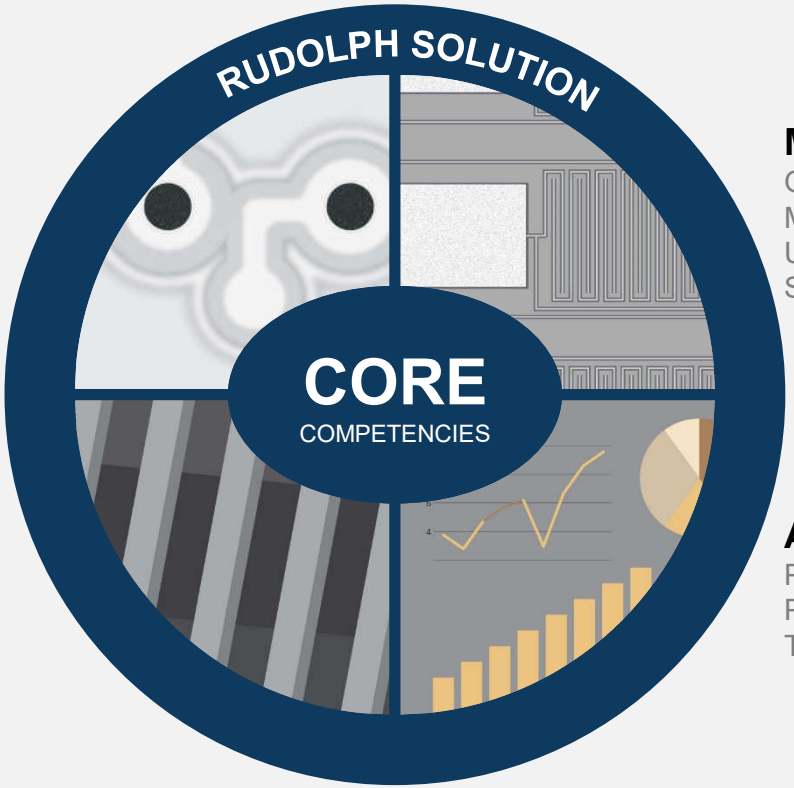
Agenda

- About Rudolph
- JetStep® G System overview and performance
- Display Market Trends - Migration to Flex
- Flexible Display Lithography Challenges
- Results
- Conclusion

Process Solutions Across the Semiconductor Industry

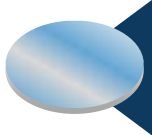
INSPECT
Macro Defects Silicon to Die
Dicing and Chipping Detection
Interconnect Metrology
3D/2D Inspection
Residue Detection

IMAGE
Lithography resolution ≤1.5µm
Active Matrix Display Backplanes
Fan-out and Cu Pillar
Wafer and Panel

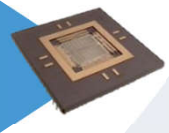


MEASURE
On Product and In-die
Multi-layer Film Stacks
UBM, RDL, PR, PI, Dielectrics
Structure CD

ANALYZE
Process Analysis
Process Control
Tool-centric and Fabwide



FRONT-END **BACK-END**

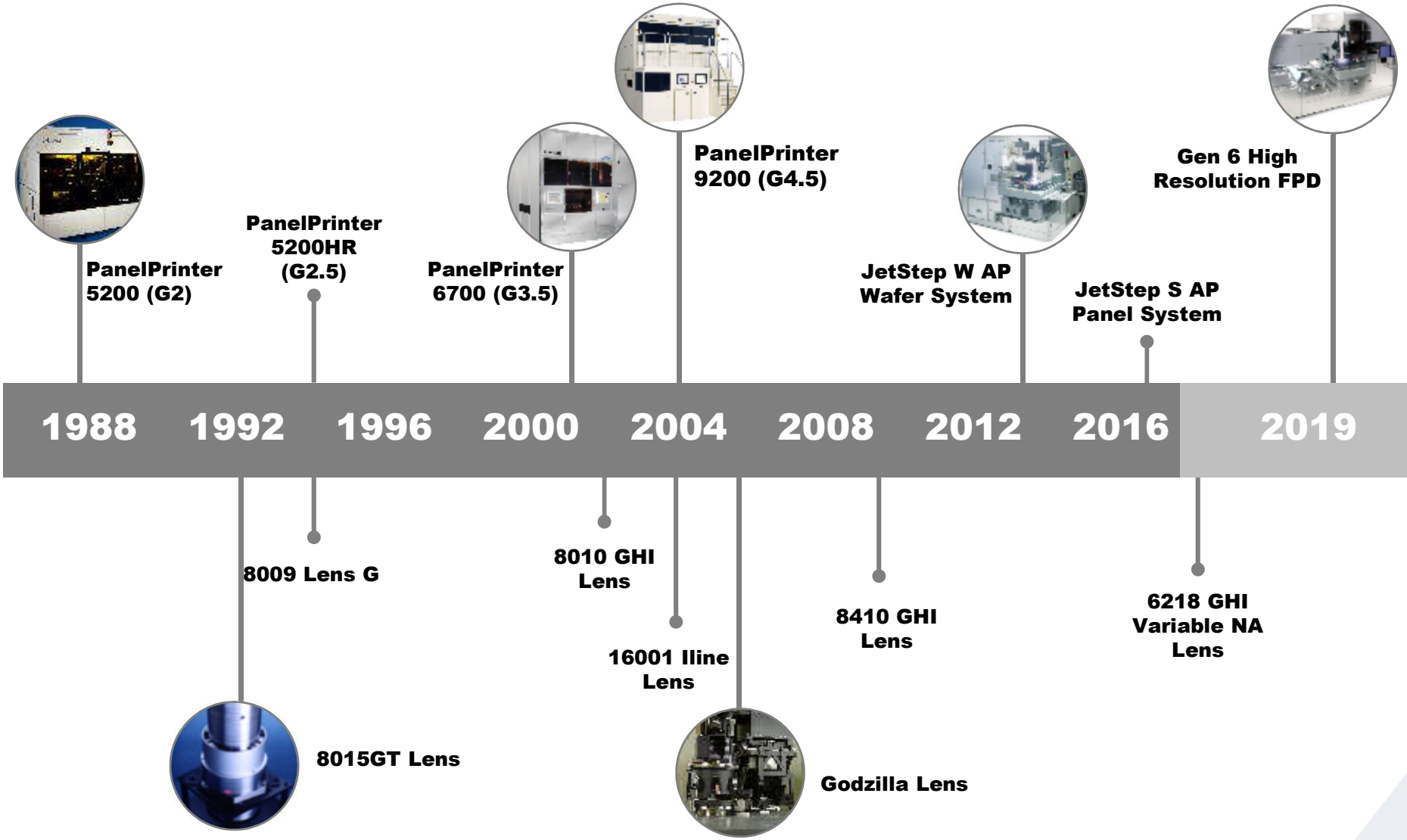


SILICON

RUDOLPH SOLUTIONS APPLY ACROSS THE SEMICONDUCTOR VALUE CHAIN

TEST

Lithography Experience Spanning >25 Years



Rudolph Lithography Family

Advanced Packaging Lithography Systems

JetStep W2300
(wafers)

JetStep S3500
(panels)

Display Lithography Systems JetStep G Series

JetStep G35

JetStep G45

	JetStep G35	JetStep G45
Resolution in µm	2.5	1.5
Field Size Ø in mm	80	200
Substrate size	Gen 2 to 3.5	Gen 4.5

Specifically designed for mobile display and pilot production

Display Market Trends

Changes Driven by Electronics Everywhere

AMOLED displays are key differentiation and wearable enabler

Panel makers are aggressively investing in flexible AMOLED to meet demand

Bendable

Foldable

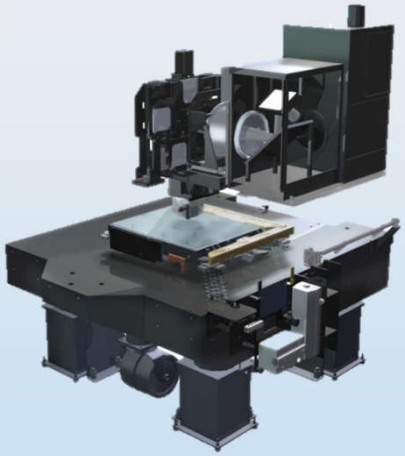
Rollable

Trends Driving Changes in Lithography

AUTOMATION		Lithography systems need to process G5 & 6 highly compliant substrate with warp			
PIXEL CREATION	AMLCD Color Filter	OLED Front Plane			
SUBSTRATE	Glass		PI on Glass up to Gen 5 & 6		
DISPLAY PRODUCTS	**Rigid** 	**Curved** 	**Bendable** 	**Foldable** 	**Rollable**
	NOW	2018	2019	2020	2021
END MARKET	**Mobile/ Tablets**  **Automotive**	 **Wearables**	 **VR**	 **AR**	
PPI	440	>500	800	1000	2000
TRANSISTOR TECH	TFT LTPS	LTPS with OLED			
LITHO PERFORMANCE	0.5µm Overlay-1.5µm Resolution	0.35µm Overlay - 1.35µm Resolution		0.25µm Overlay – 1.0µm Resolution	

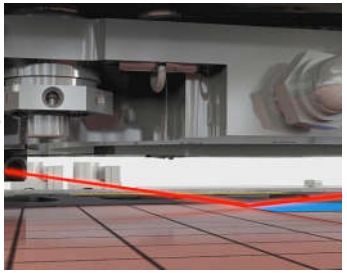
Compiled by Simax Asia Pacific Limited May 2017

A Path to Flex Substrate Lithography



JetStep G35

Addressing dimensional Instability



Addressing handling and topography Variations

Scaling to R2R

Stage to accommodate an 8” Web

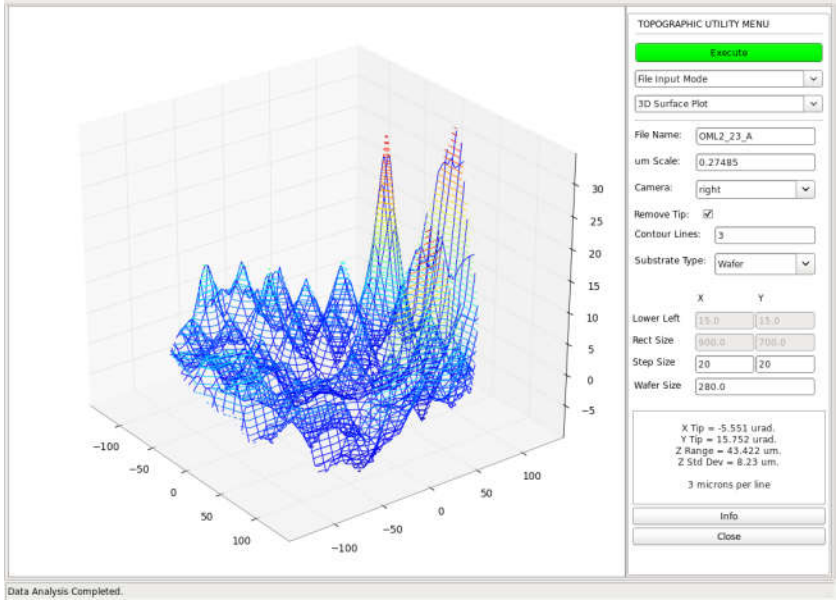
R2R to support an 8” web

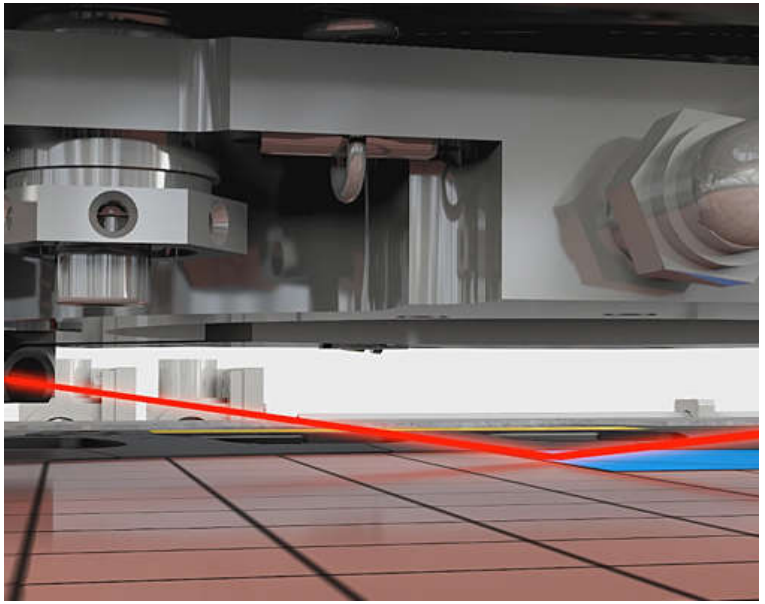
Overcoming Flex Manufacturing Challenges

Addressing Topography Challenges

On-the-fly auto focus

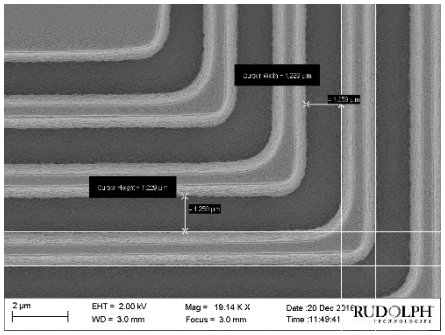
- Allows lens to follow wafer contours
- Addresses the challenges of imaging on warped substrates
- Capability to measure and monitor wafer topography



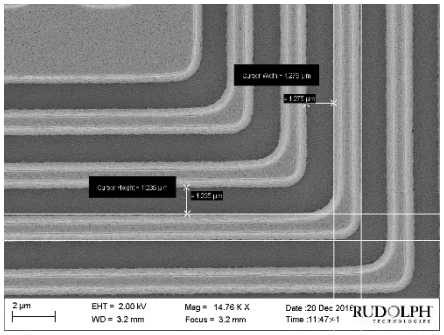


Imaging on Thin Substrates

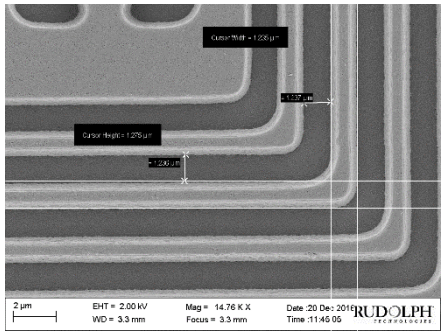
Photoresist: DOW SPR955CM, 1.4µm FT on Si. Dose: 300 mJ



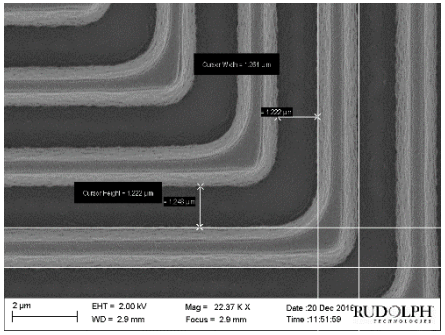
Focus = 0 um



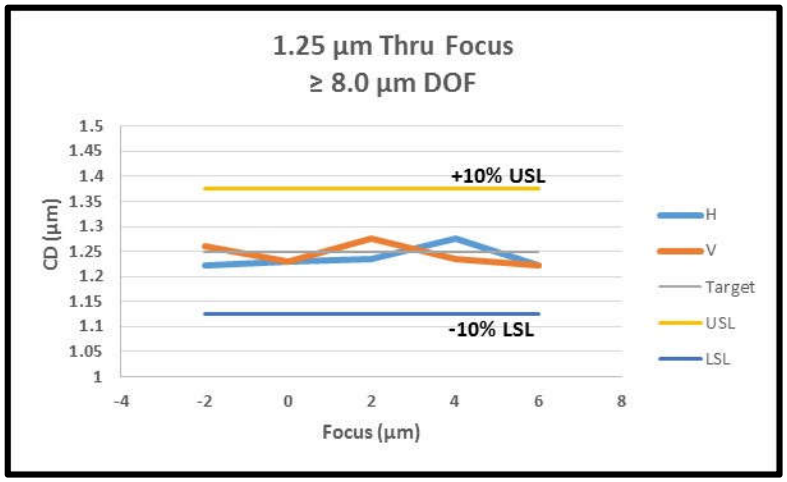
Focus = +2 um

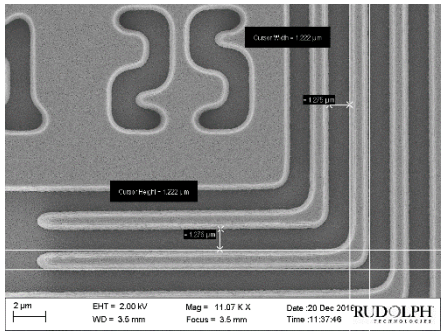


Focus = +4 um



Focus = -2 um





Focus = +6 um

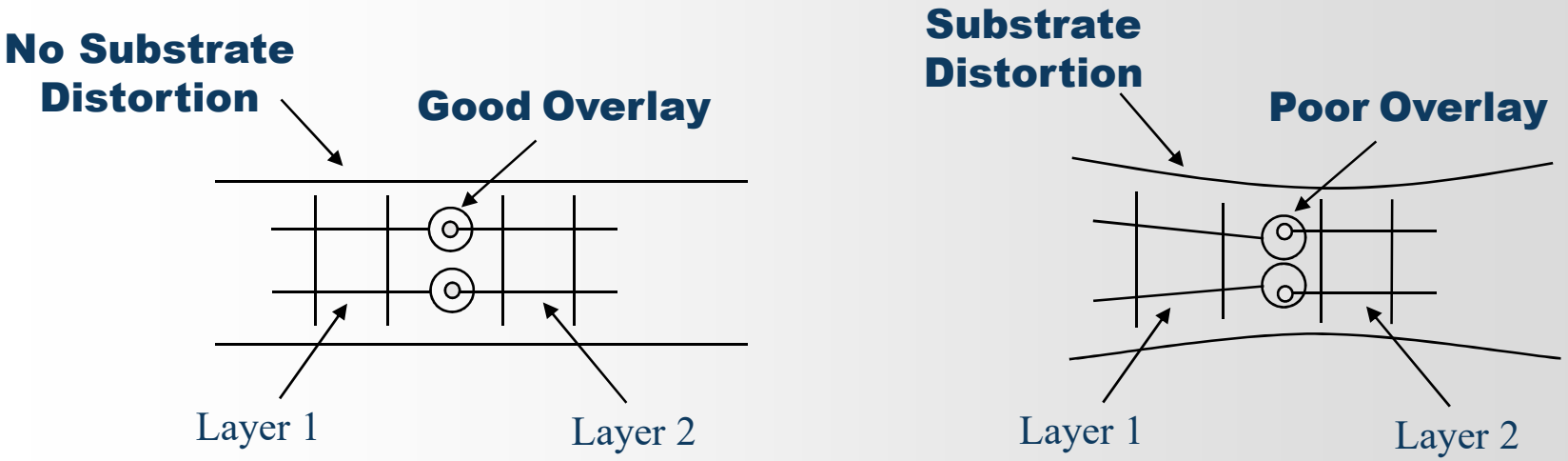
1.25 µm thru Focus, ≥ 8.0 µm DOF

Flexible Substrates Distortion Characteristics

Compaction and Expansion

- Environment Induced
  - Temperature Effects: ~2um over 100mm field per degree C
  - Relative Humidity Effects: ~ 1um over 100mm field per % change in RH

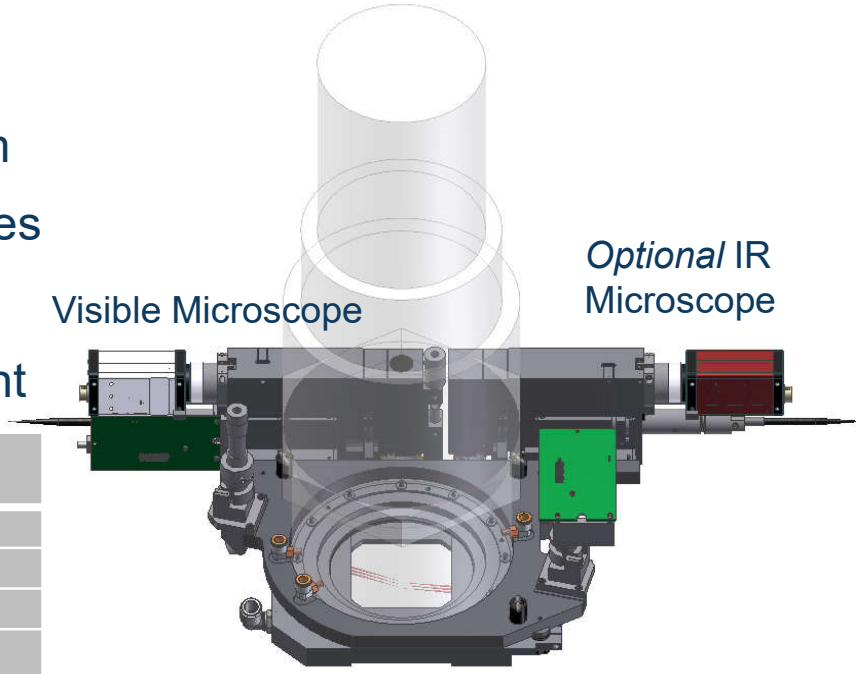
- Mechanical Induced Strain
  - Substrate Tension Variations in the Web line
  - Process Induced Distortion



Grid Measurement

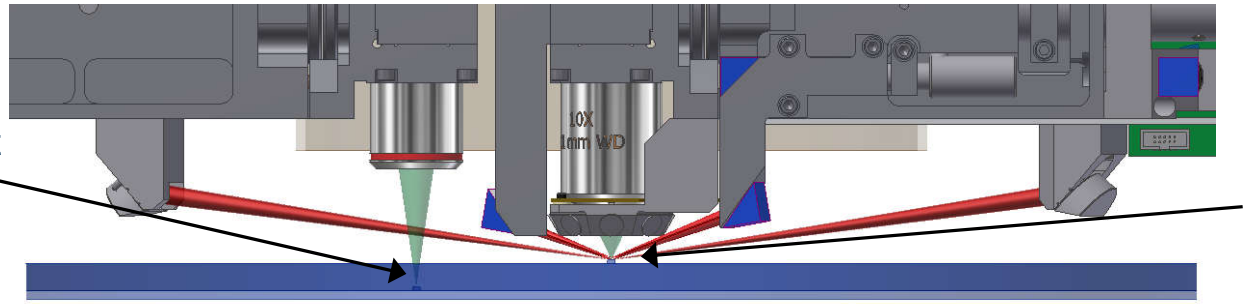
Front and backside alignment

- Integrated with JetStep alignment system
- Dual Head Off-axis alignment microscopes
- Real time auto-focus
- Entire wafer area accessible for alignment



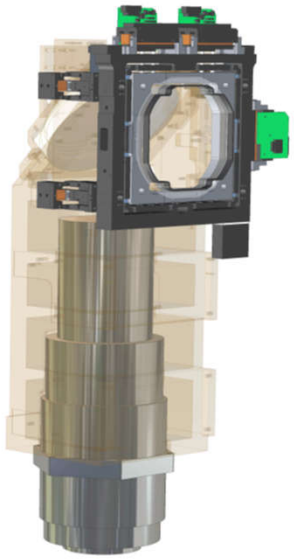
	Visible scope	IR scope
Objective	10X	5X
Wavelength	500-700nm	500-1050nm*
Field of View	1.35 x 1.35	2.7 x 2.7 mm
Resolved Feature Size	0.9 µm	5.3 µm
DOF	4.4 µm	200 µm
Align Precision (3σ)	0.15 µm	0.24 µm

*Longer Wavelength Option Available

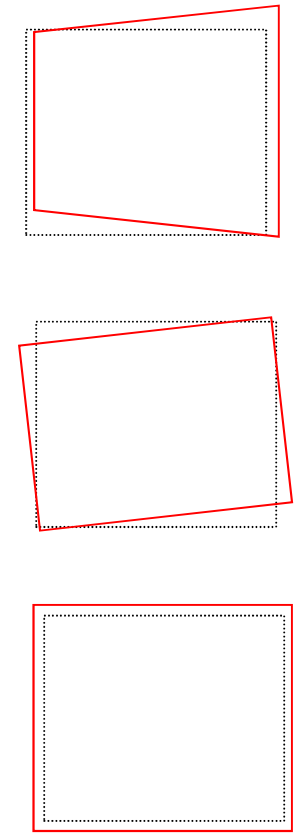


Compensation Method

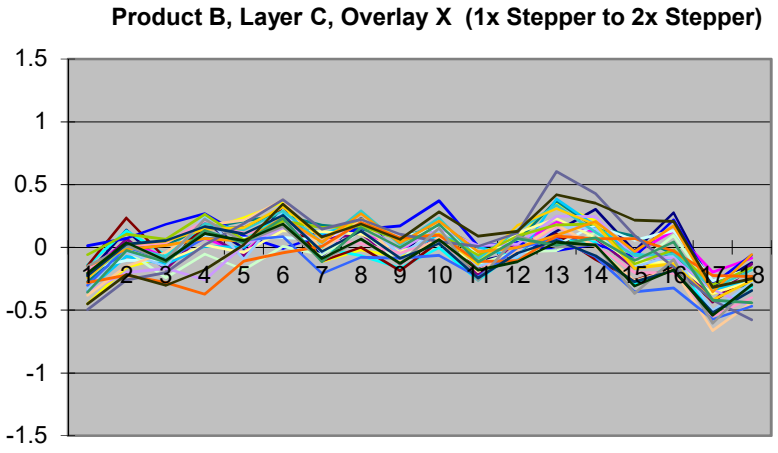
- 6 DOF Reticle chuck compensation
  - Up to 400PPM Compensation
- Minimize field distortion
  - Mag, Trap, and Local position displacements

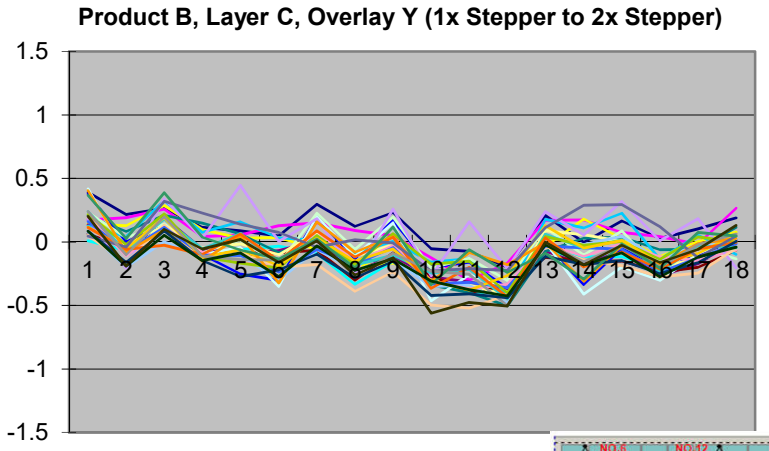


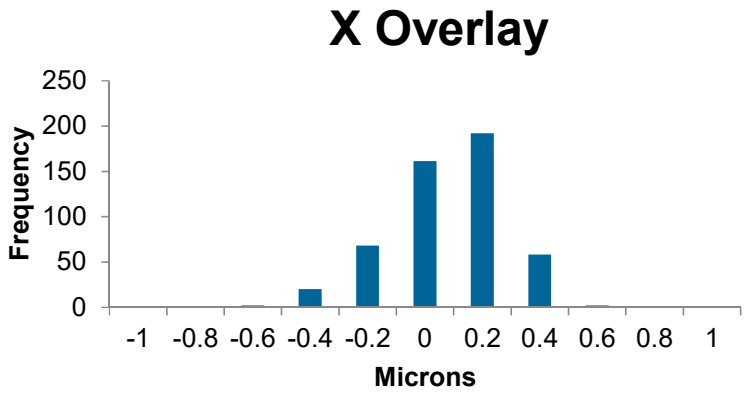
$$X_1, X_2, Y_1 \quad Z_1, Z_2, Z_3 \rightarrow X, Y, \theta \quad Z, \Psi_x, \Psi_y$$

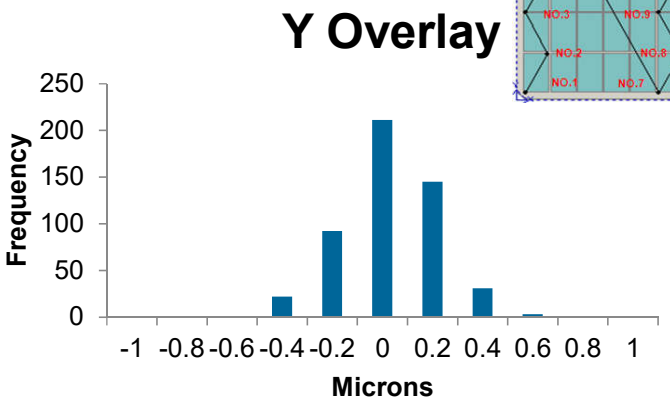


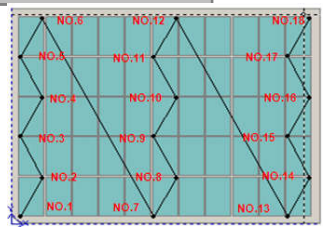
Overlay on Thin Substrates











Production Overlay Results – 28 Consecutive Substrates

Rudolph Flexible Lithography Systems

- Gen 2.5 Lithography System
  - Flexible Lithography Sheets
  - Custom Flexible Display Manufacturing and Research

Photo source: ASU monthly magazine

Delivering Enabling Capabilities

Rudolph R2R Lithography Systems

- 6600 Gen 3 R2R Lithography System
  - New highly improved R2R
  - Process development research

Solution Through Collaboration

Functioning Flexible Displays

Flex Map

Conformal Display Concept

Conformal Display

Working with World Leading Researches to Turn Concepts in Reality

Sources: Arizona State University (ASU) US Army Flexible Display Center & ASU Magazine, September 2013 volume 17 number 1

Beyond AMOLED

Development results in technology to open new possibilities

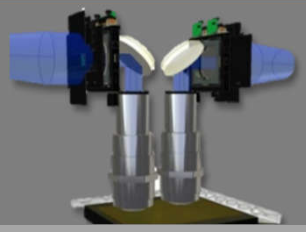
IP DEVELOPED

ADVANCED PACKAGING

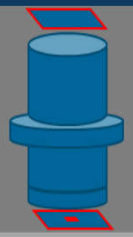
OLED MOBILE

Flexible DISPLAYS

TWO CAMERA

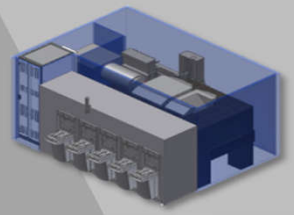


LARGE FIELD LENS

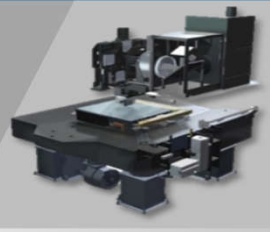


STITCHING

CU-PILLAR, C4, PCB

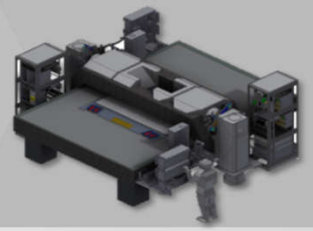


HR, AP, PANEL



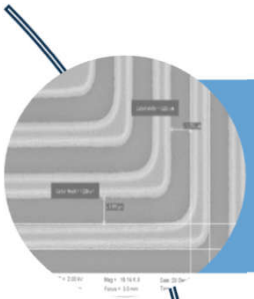
G6 FPD

HR, HIGH THROUGHPUT & LOW COO



NEXT GEN FPD

Photolithography for flexible displays



High Fidelity Imaging for Critical Layers
1.5um L/S resolution

Overlay Through Active Compensation
Real-time compensation while maintaining best focus

Addressing the Real World Challenges of Display Manufacturing on Flexible Substrates

谢谢 | 謝謝

danke

ありがとう

Thank You!

감사합니다

merci

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