450mm patterning out of darkness

Backend Process Exposure Tool

SOKUDO Lithography Breakfast Forum 2013

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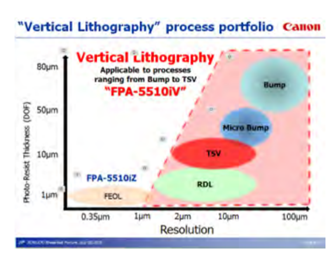
Introduction

		2013	2014	2015	2016	2017	2018	2019	2020	2021
Half Pitch [nm]	Flash	18	17	15	14	13	12	11	10	9
	MPU	27	24	21	19	17	15	13	12	11
Advanced packaging		2.5D Si-interposer	2.5D Si-interposer	Wide-I/O 2	Wide-I/O 2 / 3D High-end MPU Heterogeneous Chip Stacking	Wide-I/O 2 / 3D High-end MPU Heterogeneous Chip Stacking	Wide-I/O 2 / 3D High-end MPU Heterogeneous Chip Stacking	3D High-end MPU Heterogeneous Chip Stacking		
450 mm Production				Pilot	Pilot	Pilot	HVM	HVM	HVM	HVM

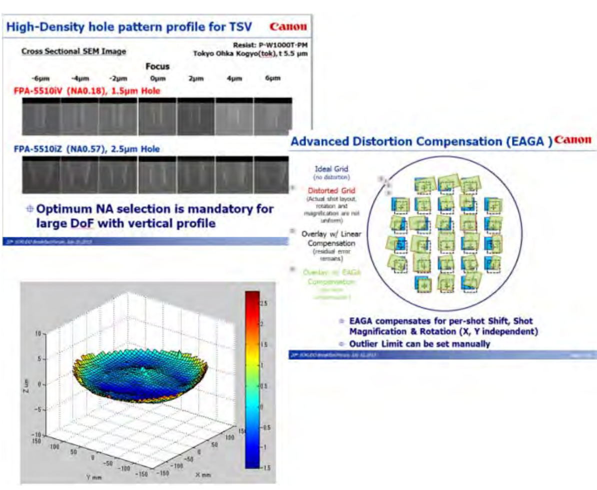
450 mm HVM production ramps in 2018
Advanced packaging processes required at the same time

Canon 450 mm backend exposure tool

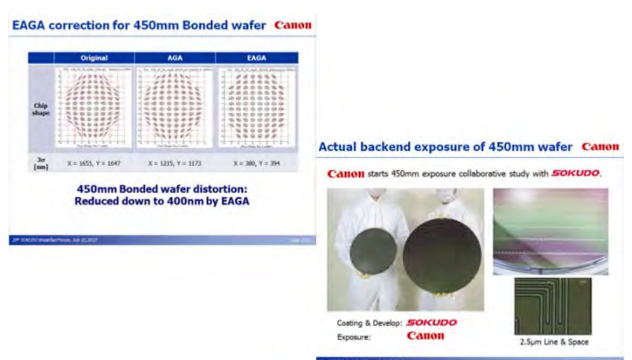
- Canon Advanced Packaging Solutions



- 300mm functions and performance
  - Vertical thick resist patterning
  - 3D alignment capability
  - Warped wafer



- Lithography issues for 450mm
- 450mm wafer exposure results
- Summary



"Vertical Lithography" process portfolio

Vertical Lithography

Applicable to processes ranging from Bump to TSV

"FPA-5510iV"

3D & 2.5D Lithography Requirements

Micro-Bump (20~40 µm)
- Profile stability
- Overlay Accuracy

TSV (1-4 µm)
- High Resolution
- Profile Stability
- Overlay Accuracy

Thinned Semiconductor Chip

Memory

Memory

Processor

Silicon Interposer

Interposer RDL (0.40~1.0 µm)
- High Resolution
- Profile Stability
- Overlay Accuracy

TSV (2.0~5.0 µm)
- Thick Resist
- Focus Margin Management
- Overlay Accuracy
- Warped Wafer

Printed substrate

Bump (60~100 µm)
- Profile Stability

- **Photo-lithography is required for TSV, RDL, Micro-Bump processes to form resist mask for deep etching or plating**

Solutions for Vertical Litho challenges

- Thick-Resist Patterning
  - Large DOF imaging

    Thick resist patterning with good profile

- 3D Alignment Capability
  - Through Silicon Alignment Scope(TSA-Scope)
  - Bonded wafer distortion

    Excellent overlay performance

- Warped Wafer Handling
  - Good flatness achieved by new wafer chucking

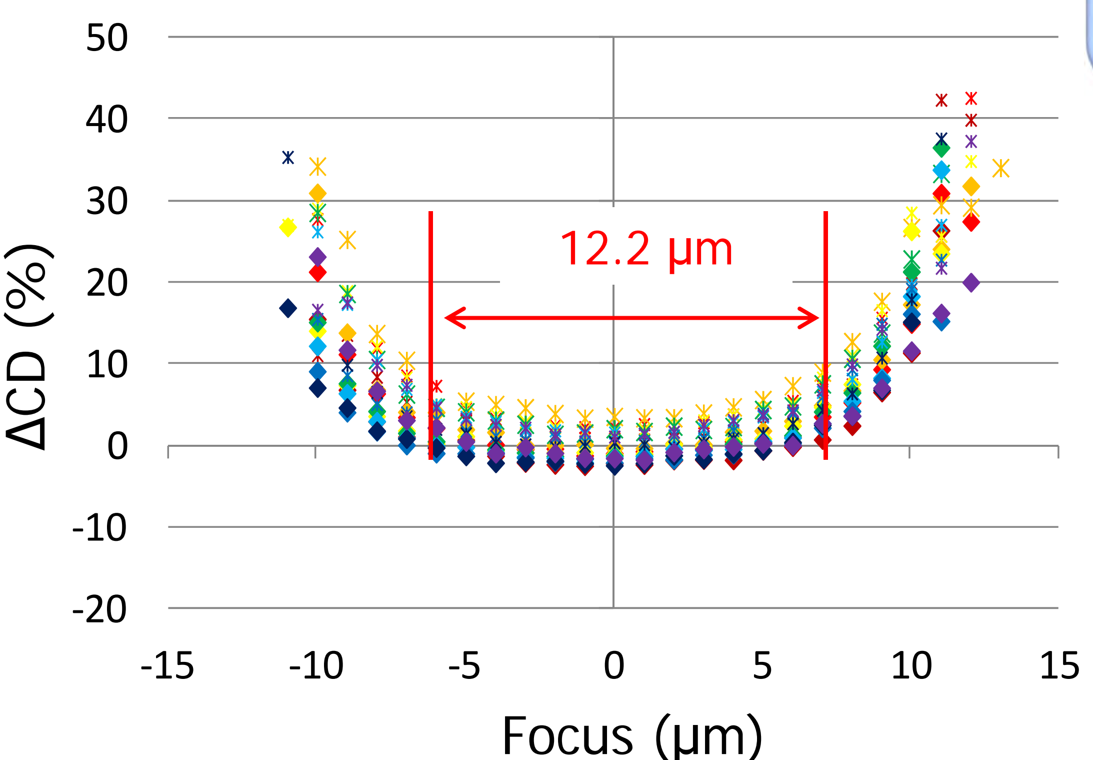
    Wide Focus margin achieved

300 mm Performance

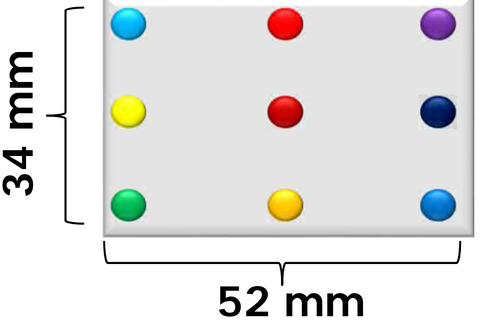
Depth of Focus for 1 μm pattern

- FPA-5510iV achieves large common DOF
  - Reduction optics
  - New chuck system
  - Die-by-die tilt & focus

FPA-5510iV
Target: 1.0 μm L/S
Image Field: 52 ×34
Measurement points:
9points / Field



Measurement Points



High-Density hole pattern profile for TSV

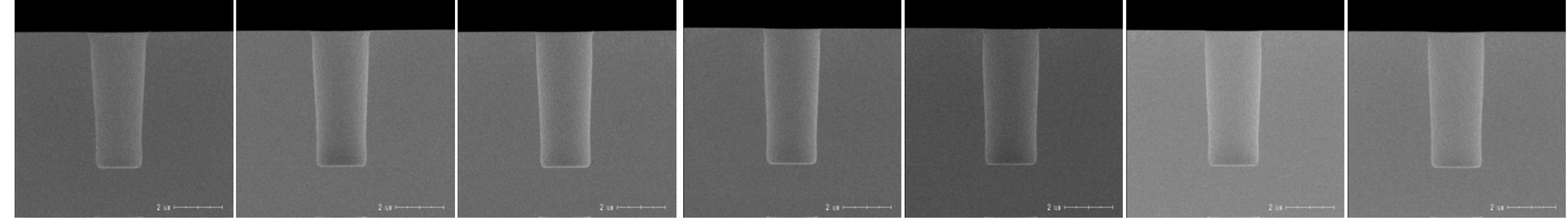
Cross Sectional SEM Image

Resist: P-W1000T-PM
Tokyo Ohka Kogyo(tok), t 5.5 μm

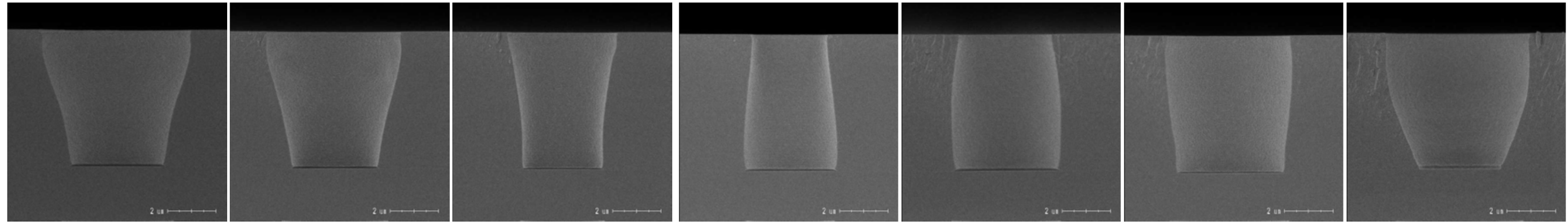
Focus

-6μm	-4μm	-2μm	0μm	2μm	4μm	6μm

FPA-5510iV (NA0.18), 1.5μm Hole



FPA-5510iZ (NA0.57), 2.5μm Hole



- **Optimum NA selection is mandatory for large DoF with vertical profile**

Through-Silicon Alignment [TSA]

- Through-Si Alignment Scope "TSA-Scope" with IR
  - Both front and back-side alignment possible
  - Suitable for back via processes

Overlay accuracy of Through-Si Alignment

Overlay accuracy with FEOL machine

Si Wafer thickness: 775 µm
Backside 1st patterning: FPA-5510iZ
Frontside 2nd patterning: FPA-5510iV

- TSA-Scope overlay accuracy ≤ 120 nm is achieved
- TSA Accuracy is suitable for TSV processes

Bonded Wafer Distortion

300nm

150
100
50
0
-50
-100
-150
-150 -100 -50 0 50 100 150 (mm)

TSA-Scope
Alignment Mark
Thinned Si Wafer
Glue
30µm
Support Substrate

- Wafer Bonding and Thinning cause wafer distortion
- 300 mm Bonded wafer distortion measurement using TSA-Scope

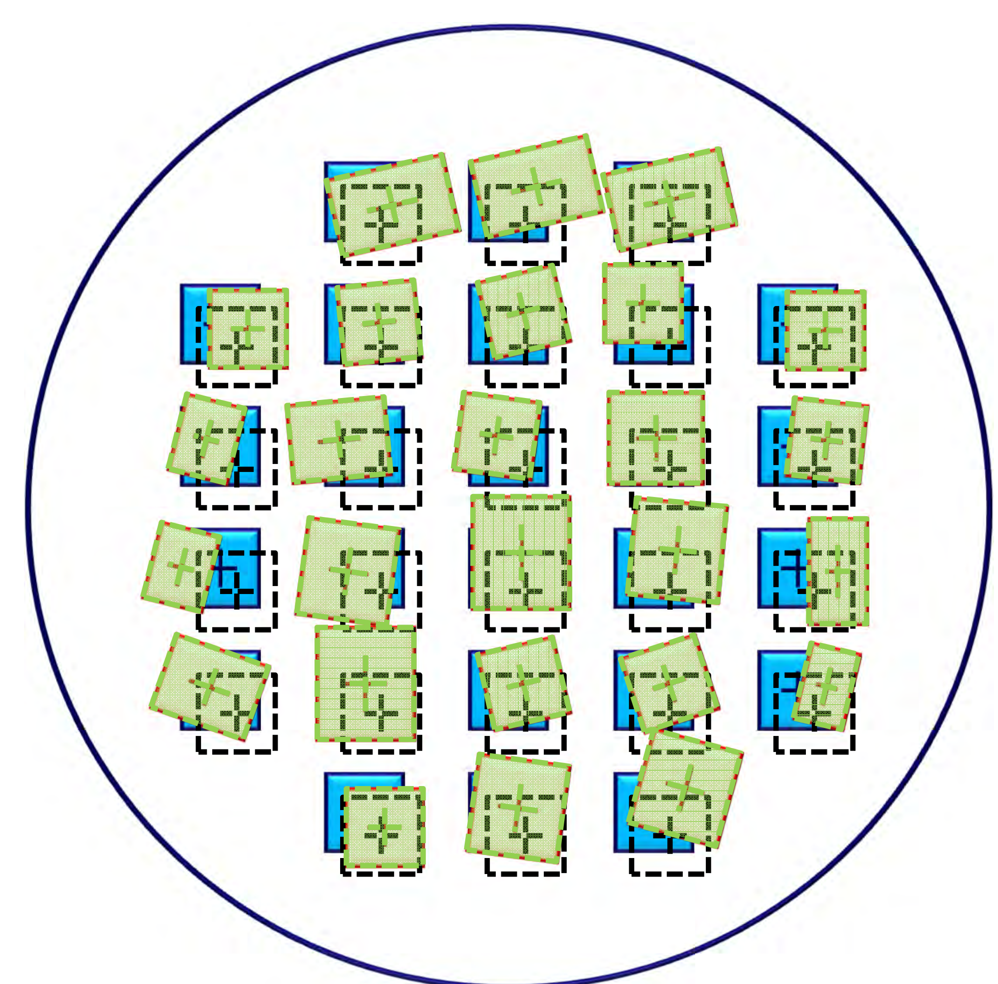
Advanced Distortion Compensation (EAGA) Canon

Ideal Grid
(no distortion)

Distorted Grid
(Actual shot layout, rotation and magnification are not uniform)

Overlay w/ Linear Compensation
(residual error remains)

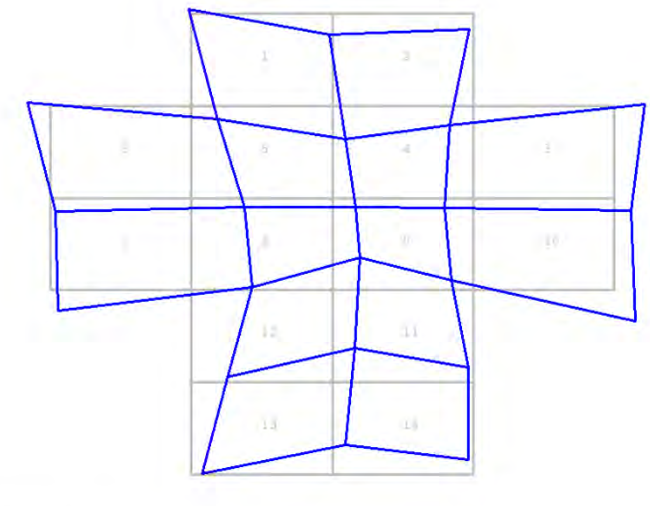
Overlay w/ EAGA Compensation
(per-shot compensation)



- **EAGA compensates for per-shot Shift, Shot Magnification & Rotation (X, Y independent)**
- **Bonded Wafer distortion will become more challenging for 450mm wafers**

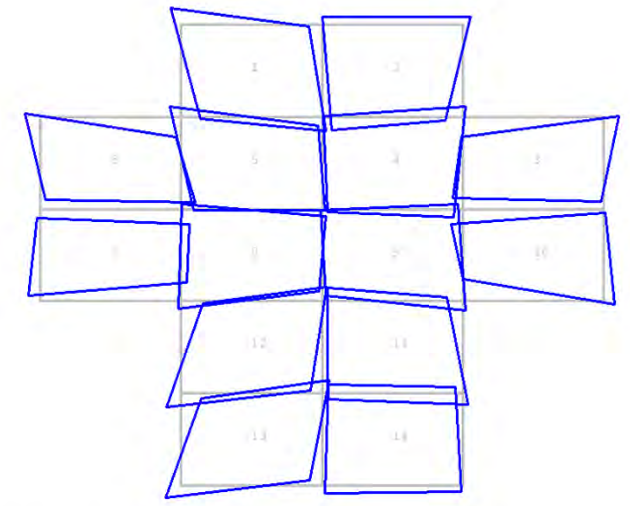
Overlay improvement for distorted wafer

Linear Compensation Simulation



|M|+3σ X: 278 nm
Y: 213 nm

Shot by Shot
Compensation Simulation
(Rotation and magnification)

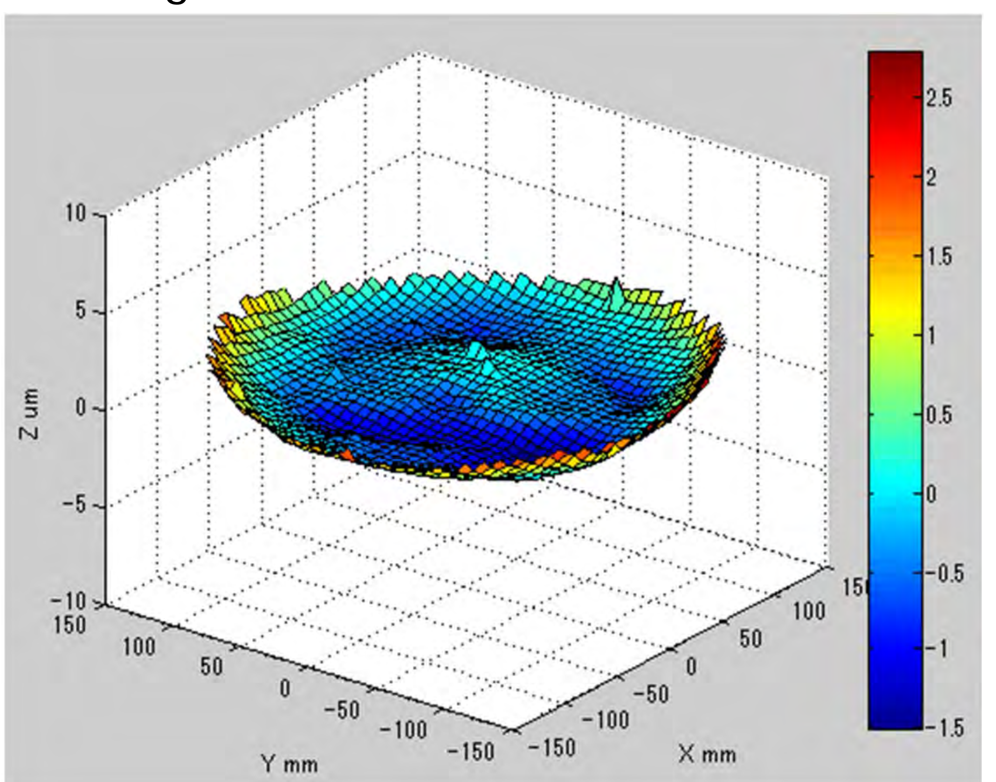


|M|+3σ X: 106 nm
Y: 107 nm

- Shot by shot compensation can improve the overlay accuracy
- FPA-5510iV can cope with 1.0 μm generation high-density TSV processes in the future

Wafer Warpage Correction Result

Wafer warpage is common in backend processes
Wafer flatness data of 730μm warped wafer can be reduced to < 5 μm after chucking



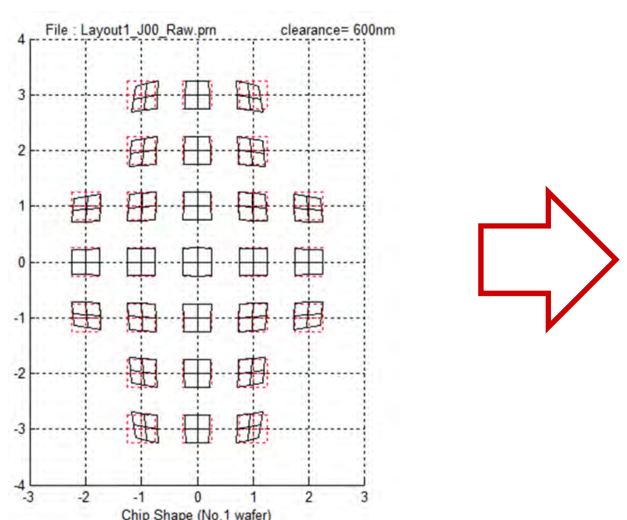
Tool: FPA-5510iV
Wafer warpage: 730 μm
Vacuum Region: 300 mm

Wafer Flatness after Chucking
Global Flatness: **4.3μm**
SFQR: **1.6μm**
(Site size: 52 mm × 34 mm)

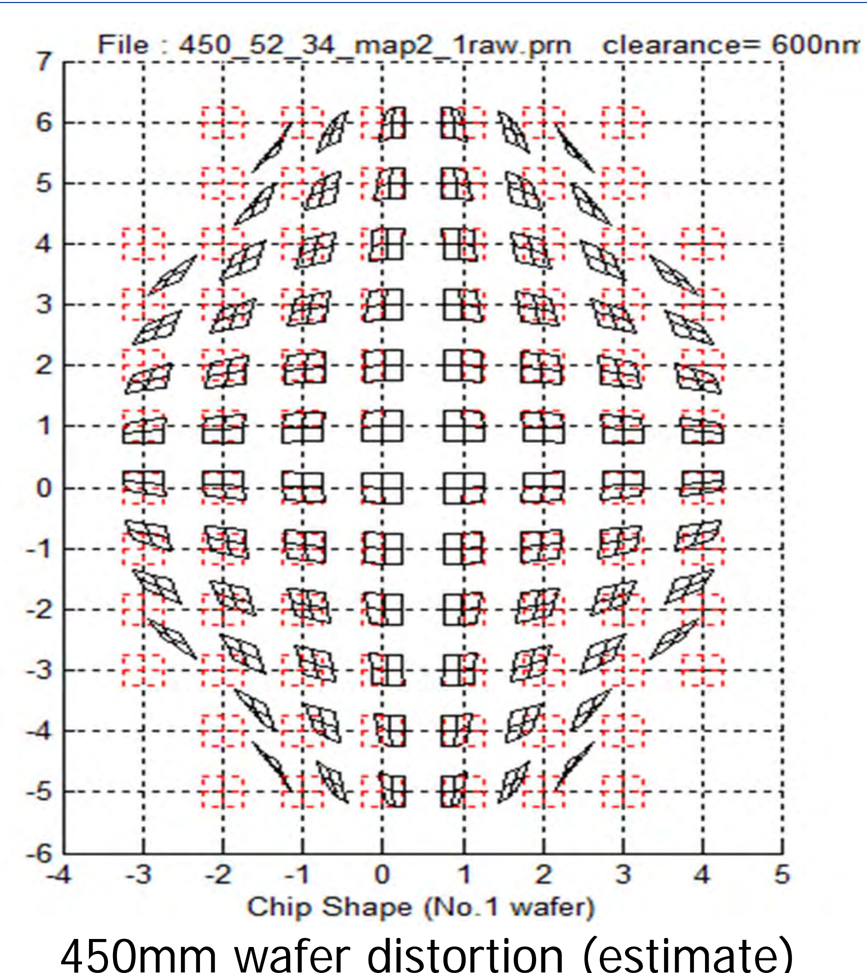
- **Canon's wafer chucking system vacuum locks the wafer across the entire wafer, improving wafer flatness at the edges**
  - **Yield of the peripheral region is not deteriorated**
- **Warpage correction will become more challenging for 450mm wafers**

450mm Issues

Study of bonded wafer distortion compensation



300mm wafer distortion



450mm wafer distortion (estimate)

- **450 mm Bonded wafer distortion (estimate)**
  - **(3σ) X = 1655 nm, Y = 1647 nm**
- **450 mm is distortion is not acceptable for TSV processes**

EAGA correction for 450mm Bonded wafer

	Original	AGA	EAGA
Chip shape	File : 450_52_34_map2_1raw.prn clearance= 600nm Chip Shape (No.1 wafer)	File : 450_52_34_map2_2AGA.prn clearance= 600nm Chip Shape (No.2 wafer)	File : 450_52_34_map2_3EAGA.prn clearance= 600nm Chip Shape (No.3 wafer)
3σ [nm]	X = 1655, Y = 1647	X = 1215, Y = 1173	X = 380, Y = 394

- **450mm Bonded wafer distortion:**
  - **Reduced to 400 nm by EAGA**

EAGA correction for 450mm Bonded wafer

3σX (nm)

Overlay accuracy(nm): 0.0, 200.0, 400.0, 600.0, 800.0, 1000.0, 1200.0, 1400.0

Bonding Wafer Distortion(nm): 0.0, 500.0, 1000.0, 1500.0, 2000.0

AGA 52x34
AGA 26x33
EAGA 52x34
EAGA 26x33

3σY (nm)

Overlay accuracy(nm): 0.0, 200.0, 400.0, 600.0, 800.0, 1000.0, 1200.0, 1400.0

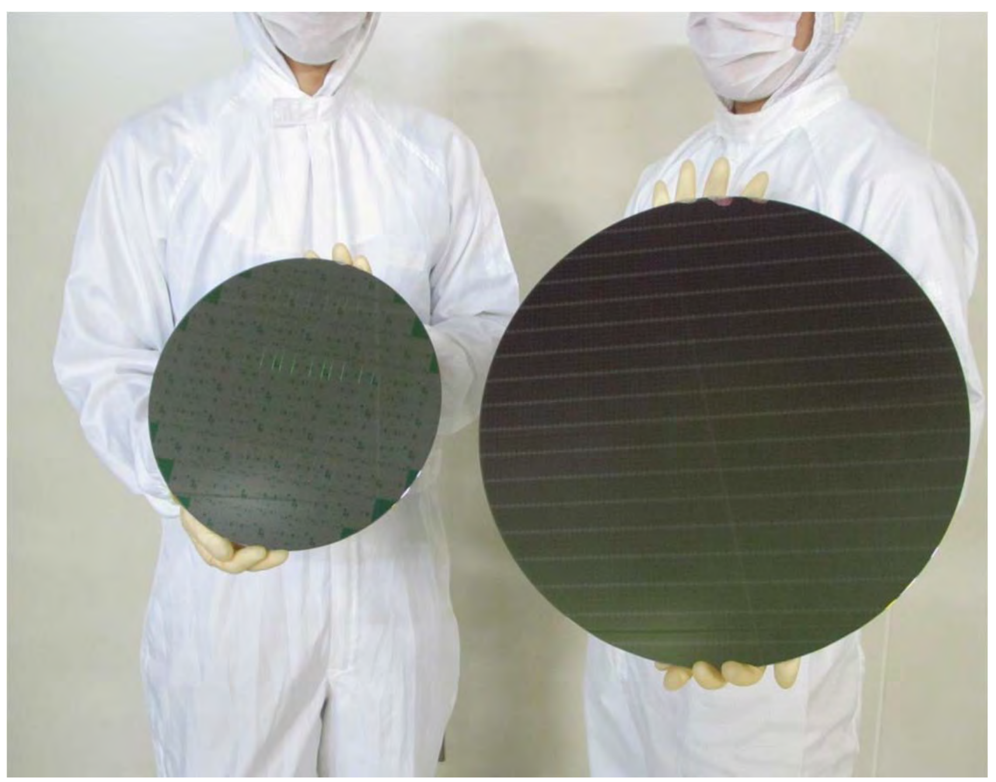
Bonding Wafer Distortion(nm): 0.0, 500.0, 1000.0, 1500.0, 2000.0

AGA 52x34
AGA 26x33
EAGA 52x34
EAGA 26x33

- **450mm Bonded wafer distortion:**
  - **Reduced to ≦ 400 nm by EAGA**
- **To achieve excellent mix and match overlay, bonded wafer distortion must be reduced (upstream process) or compensated during litho process**

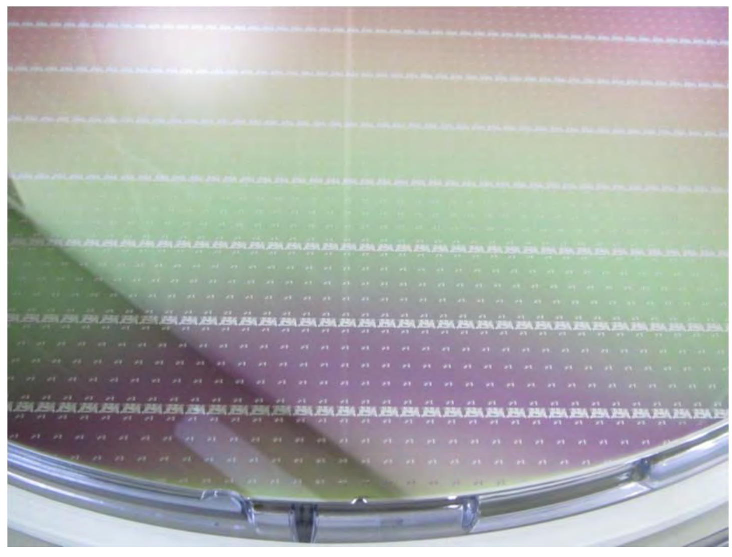
Actual backend exposure of 450mm wafer

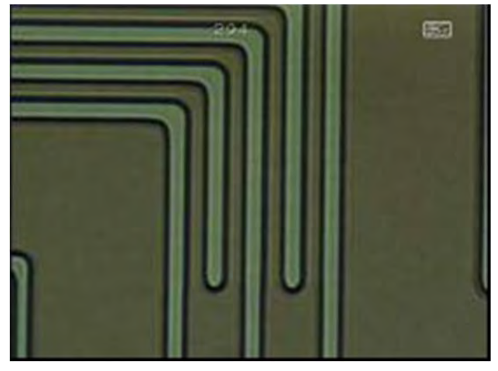
Canon starts 450mm exposure collaborative study with SOKUDO.



Coating & Develop: SOKUDO

Exposure: Canon





2.5µm Line & Space

Summary

- Advanced packaging litho-solution is ready .
  - Large DOF imaging for 3D application
    - Sufficient DOF with good vertical profile for 1.5 µm TSV
    - 2 µm line patterning with high aspect ratio for HD-RDL
  - Through-Silicon Alignment Scope for back via process
  - Warped Wafer handling
- 450mm backend litho issues still to be addressed.
  - Warped wafer handling, bonded wafer distortion, throughput…

Canon will continue to contribute towards successful 450mm transformation

THANK YOU FOR YOUR ATTENTION

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