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
Heterogeneous Integration

1970
Multi-Chip Module (MCM)

1998
System In Package (SIP)

2008
Silicon Interposer
2.5D-IC

2012
FOWLP
3D-IC

Now and Future
Heterogenous Integration

Next-generation Device Performance
Combining multiple silicon nodes and designs inside one package.

Packaging Size Expected Increasing
The package size is expected that increasing to 75 x 75 mm, 150 x 150 mm and even larger within the next few years.
Advanced IC Substrate Product Yield Challenge

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
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Substrate Deformation Induces Pattern Distortion

Key Processes
- Temperature
- Stress

Panel Substrate
- Glass Panel
- ABF+CCL Panel

Panel Deformation Induces Pattern Distortion
- Panel Topography 3D Map

Large Overlay Error Due To Pattern Distortion
- Die Error Heat Map
Pattern Distortion Analysis Method

**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
Analyze Results: Distortion Components and Error Terms

Quadrant Scale Distortion Coefficients

<table>
<thead>
<tr>
<th>Term</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>X Tran</td>
<td>-1.76E-03</td>
</tr>
<tr>
<td>Y Tran</td>
<td>5.97E-04</td>
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<tr>
<td>Mag</td>
<td>-3.06E-06</td>
</tr>
<tr>
<td>Ana Mag</td>
<td>-3.06E-06</td>
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<tr>
<td>Rotation</td>
<td>1.20E-05</td>
</tr>
<tr>
<td>Skew</td>
<td>1.20E-05</td>
</tr>
<tr>
<td>X Trap</td>
<td>1.67E-07</td>
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<tr>
<td>Y Trap</td>
<td>-6.28E-08</td>
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Panel Scale Distortion Coefficients

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<tr>
<td>3rd Rad</td>
<td>2.75E-10</td>
</tr>
<tr>
<td>Ana</td>
<td>-2.81E-10</td>
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</table>

Quadrant Scale Distortion Component

- Translation
- Magnification
- Ana. Mag.
- Rotation
- Skew
- Trapezoid

Panel Scale Distortion Component

3rd Rad
Ana Pin

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

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
Correction Method Discussion

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
Correction Method Discussion

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
Correction Method Discussion

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
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<td>3µm</td>
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<tr>
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Lithography Tool Standard Resolution Results

**3µm Resolution Resolved**

- 3µm L/S with 10µm DFT

**60µm Depth Of Focus**

60µm DOF (3µm LS with 10µm DFT)

**4.32% CD Uniformity in Panel**

- CD Values in a 250 mm x 250 mm Field

**3µm Cross Section**

- 3µm L/S with 10µm DFT

**Focus Matrix of 3µm Line/Space**

- 3µm with 10µm DFT CD deviation Chart
Lithography Tool Standard Overlay Results

9 Pts a Zone, 36 Pts Measurement a Panel

Lithography Tool Overlay Results < 1.5µm

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<tr>
<th>OVL</th>
<th>Dx</th>
<th>Dy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>0.52</td>
<td>0.39</td>
</tr>
<tr>
<td>Min</td>
<td>-0.32</td>
<td>-0.39</td>
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<tr>
<td>Mean</td>
<td>0.2</td>
<td>0.2</td>
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<tr>
<td>Std</td>
<td>0.24</td>
<td>0.24</td>
</tr>
<tr>
<td>Mean+3σ</td>
<td>0.91</td>
<td>0.91</td>
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Overlay Error Table
Overlay Error Histogram
Overlay Error Chart
Lithography Tool Overlay Correction Capability

**Reticle Chuck**
- Translation (Reticle-x,y)
- Rotation (Reticle-theta)
- Magnification (Reticle and lens - Mag)
- Radial distortion (Reticle and lens - 3rd order)
- Trapezoidal (Reticle-tip, tilt)

**Projection Lens**
- Intra-Field Correction

**Grid Stage**
- Global Correction
- Translation (Stage - x,y)
- Rotation (Stage - theta)
- Scale (Stage - x, y)
- Orthogonality (Stage – parallelogram)

**Overlay Correction**
- Translation (Stage - x,y)
- Rotation (Stage -theta)
- Magnification (Reticle and lens - Mag)
- Anamorphic Mag or scale with magnification (Stage - x, y and Lens)
- Skew or Orthogonality with rotation (Stage - Lens parallelogram)
Outline

• Introduction
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• Extremely Large Exposure Field Fine-Resolution Lithography
• Distortion Correction Demonstration, Results and Discussion
• Summary and Conclusion
Process Flow of Performance Demonstration

Test Vehicle

Control 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

Laminator
Laminating Dry Film

Lithography Process

Experiment Group

Developer
Immersion Type Conveyor

Results Inspection
Demonstration Review And Results

**Experiment Group : Overlay Results with Proper Corrections**

**Control Group : Overlay Results with Improper Corrections**

**Experiment Group Overlay Deviation Chart**

<table>
<thead>
<tr>
<th>OVL</th>
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<th>DY</th>
<th>Vector</th>
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<tr>
<td>Max.</td>
<td>3.94</td>
<td>5.72</td>
<td>6.94</td>
</tr>
<tr>
<td>Min.</td>
<td>-5.42</td>
<td>-3.94</td>
<td>0.58</td>
</tr>
<tr>
<td>Average</td>
<td>-0.24</td>
<td>0.57</td>
<td>3.37</td>
</tr>
<tr>
<td>STD</td>
<td>2.89</td>
<td>2.47</td>
<td>1.74</td>
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**Experiment Group Overlay Results Table**

**Control Group Overlay Deviation Chart**

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<td>19.35</td>
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<td>Min.</td>
<td>-16.77</td>
<td>-19.06</td>
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<td>Average</td>
<td>-5.47</td>
<td>-0.95</td>
<td>12.67</td>
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<tr>
<td>STD</td>
<td>6.46</td>
<td>11.26</td>
<td>5.76</td>
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**Control Group Overlay Results Table**
Demonstration Review And Results

**Experiment Group**: Overlay Results with Proper Corrections

- **Overlay Error with Proper Corrections**

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**Control Group**: Overlay Results with Improper Corrections

- **Overlay Error with Improper Corrections**

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Alignment Solution Error Induces Overlay Residual Error

- Poor Contrast of Alignment Mark
- Poor Shape of Alignment Mark
- Laser Driller Position Error

Core Pattern

Substrate with Core Pattern

Printing Pattern

Alignment Mark

Overlay Error
Additional Compensation Can Address Alignment Solution Error and Improve Overlay Significantly

Original Overlay Results

Panel 1
Max OVL Vector
9.3 µm
Max Overlay Error
40.86%

Panel 2
Max OVL Vector
3.9 µm
Max Overlay Error
62.14%

Overlay Correctables

With Additional Compensation

Max OVL Vector
5.5 µm
OVL error 3.8 µm

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

**Overlay Yield vs Product Yield**
- In 6 Layers Packaging
- Overlay Matters

**3µm / 60µm DOF**
- STD Overlay < 1.5µm
- Panel Uni. 4.32%
- Correction Capability
  - Correction Ability
  - Zone Correction
  - Add. Compensation

**Pattern Distortion Components**
- Non-linear Error
- Zone Level Error
- Huge Range Rotation Error

**Pattern Distortion and Correction Method**

**Correction Ability**

**Overlay With Proper Corrections**
- Max Overlay Error 6.94µm

**Overlay Without Proper Corrections**
- Max Overlay Error 23.26µm

**Conclusion**

**Overlay Demonstration Results**
- Extremely Large Exposure Field Fine Resolution Lithography
- Pattern Distortion Components
- Zone Correction Needed
- Overlay Matters

**Conclusion**
- Overlay Matters
- Extremely Large Exposure Field Fine Resolution Lithography

**Pattern Distortion Components**
- Non-linear Error
- Zone Level Error
- Huge Range Rotation Error

**Correction Ability**

**Overlay With Proper Corrections**
- Max Overlay Error 6.94µm

**Overlay Without Proper Corrections**
- Max Overlay Error 23.26µm

**Conclusion**

**Pattern Distortion and Correction Method**
Thank You

谢谢 | 謝謝 | ありがとう | Obrigado
Danke | 감사합니다 | Merci

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