Advanced Stepper Lithography Technology to Enable Flexible AMOLED Displays

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Elvino M da Silveira
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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

RUDOLPH SOLUTION

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

CORE COMPETENCIES

FRONT-END
BACK-END
SILICON
RUDOLPH SOLUTIONS APPLY ACROSS THE SEMICONDUCTOR VALUE CHAIN
TEST

RUDOLPH TECHNOLOGIES
## Rudolph Lithography Family

### Advanced Packaging Lithography Systems
- **JetStep W2300** (wafers)
- **JetStep S3500** (panels)

### Display Lithography Systems
- **JetStep G35**
- **JetStep G45**

<table>
<thead>
<tr>
<th></th>
<th>Resolution in µm</th>
<th>Field Size Ø in mm</th>
<th>Substrate size</th>
</tr>
</thead>
<tbody>
<tr>
<td>JetStep W2300</td>
<td>2.5</td>
<td>80</td>
<td>Gen 2 to 3.5</td>
</tr>
<tr>
<td>JetStep S3500</td>
<td>1.5</td>
<td>200</td>
<td>Gen 4.5</td>
</tr>
</tbody>
</table>

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
# Trends Driving Changes in Lithography

<table>
<thead>
<tr>
<th>AUTOMATION</th>
<th>Lithography systems need to process G5 &amp; 6 highly compliant substrate with warp</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIXEL CREATION</td>
<td>AMLCD Color Filter</td>
</tr>
<tr>
<td>SUBSTRATE</td>
<td>Glass</td>
</tr>
<tr>
<td>DISPLAY PRODUCTS</td>
<td>Rigid</td>
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</table>

<table>
<thead>
<tr>
<th>NOW</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>END MARKET</td>
<td>Mobile/ Tablets</td>
<td>Automotive</td>
<td>Wearables</td>
<td>VR</td>
</tr>
<tr>
<td>PPI</td>
<td>440</td>
<td>&gt;500</td>
<td>800</td>
<td>1000</td>
</tr>
<tr>
<td>TRANSISTOR TECH</td>
<td>TFT LTPS</td>
<td>LTPS with OLED</td>
<td></td>
<td></td>
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<tr>
<td>LITHO PERFORMANCE</td>
<td>0.5µm Overlay-1.5µm Resolution</td>
<td>0.35µm Overlay - 1.35µm Resolution</td>
<td>0.25µm Overlay – 1.0µm Resolution</td>
<td></td>
</tr>
</tbody>
</table>

Compiled by Simax Asia Pacific Limited May 2017
A Path to Flex Substrate Lithography

- JetStep G35
- Addressing dimensional instability
- Addressing handling and topography variations
- R2R to support an 8” web
- Stage to accommodate 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

Diagram:
- No Substrate Distortion
- Good Overlay
- Layer 1
- Layer 2

- Substrate Distortion
- Poor Overlay
- Layer 1
- Layer 2
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

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

*Longer Wavelength Option Available
Compensation Method

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

\[ X_1, X_2, Y_1 \rightarrow X, Y, \theta \]
\[ Z_1, Z_2, Z_3 \rightarrow Z, \Psi_x, \Psi_y \]
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
Rudolph R2R Lithography Systems

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

Conformal Display Concept
Conformal Display

Flex Map

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
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**
Thank You!

danke
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감사합니다
merci
obrigado