Technology and Economic Considerations for High Volume HBLED Lithography Manufacturing

Manish Ranjan
Vice President, Marketing
Advanced Packaging/Nanotechnology
Topics for Discussion

• Market Momentum
• Key Lithography Considerations
• Technology and Economic Considerations
• Summary
HBLED Market Momentum
(LED Lighting Only Accounts for Small Portion of Worlds Lighting)

China: Active LED Streetlight Replacement Programs. Incentive Policy for 125 Plan

Taiwan: 250,000 HID Streetlights Will Be Replaced by LED in 2012

Korea: 20/60 Plan Targets 60% LED Penetration by 2020

Japan: Aggressive Goals for Energy Efficient Lighting
HBLED Market Momentum
(Semi Market Perspective)

Highlights
• HBLED industry will follow similar manufacturing path as established semiconductor market segment
• Intense focus on technology and productivity enhancement will reduce cost thereby driving demand
LED Device Fabrication Requires Multiple Lithography Process Steps

**Highlights**

- Challenges during photolithography process include fine resolution exposure for PSS and metal pad layers, alignment for rough epi layers and warped wafer processing.

- Use of 1X technology offers significantly superior technical and economic solutions for HBLED manufacturing.

Source: Epistar
**Key Lithography Challenges**

- **PSS Layer Considerations**
  - Use of PSS layer increases light extraction efficiency

- **Pad Layer Considerations**
  - Smaller metal pad geometries provide superior brightness

- **Process Considerations**
  - Use of unique process requires new feature development
Key Lithography Challenges
(Photolithography Process: PSS Layer)

Transition to PSS Substrates Requires Use of Projection Lithography Technology

Highlights
- Patterned Sapphire Substrate (PSS) technology is used to enhance the light extraction efficiency
- Transition to fine resolution PSS necessitates use of projection lithography technology
Key Lithography Challenges
(Photolithography Process: Metal Pad Layer)

Mask Aligner Performance

Projection Lithography Performance
Key Lithography Challenges
(Photolithography Process: Metal Pad Layer)

**Highlights**
- Advanced current spreading finger layout with reduced width will significantly improve the light output
- Use of projection lithography meets the imaging requirements without any impact to product yield

Classic Current Finger Design

Advanced Current Finger Design for Maximum Light Extraction
Highlights

- Most HBLED companies are developing a vertical LED structure for solid state lighting applications

- VLED structure provides more uniform current flow, effective heat dissipation and maximum use of active sapphire substrates

VLED Illustration
Key Lithography Challenges

(Imaging Performance)

1x Lens Highlights

- Robust 1X lens design with low numerical aperture for large depth of focus for maximum process flexibility

Risks with Reduction Lens

- Narrow depth of focus from a high numerical aperture system is not suited for warped LED substrate
Key Lithography Challenges
(Alignment Performance)

**Highlights of Off-Axis Alignment System**
- Production-proven alignment for thick resist applications. Both top-side and off axis alignment systems use pattern recognition for operational flexibility.

**Secondary Alignment Solution**
- Target recognition is a concern for certain process layers. Production proven unique off axis alignment solution for certain process levels.
The focus grids are equally spaced on the wafer. X-pitch may be different from y-pitch. Users may assign the pitches and the grid offset.

If the point is outside the wafer safe radius area, it is set to the intersection of the safe radius and the line connecting the point and the center of the wafer.

The user may add, delete or move the grids from GUI.

The user may save the x and y coordinates of focus grids to process program.

The figure shows the grids of which pitches are exactly the same as the wafer step size.

Highlights

- Generates focus map of entire wafer before exposure
- Determines local tilt and applies corrections during exposure
- User can add, delete or move mapping points from the GUI
Technology and Economic Considerations (PSS Production)

Highlights
- Tools with Warped Wafer Handling Capabilities have demonstrated robust production performance for leading edge PSS geometry.
Technology and Economic Considerations
(Chip Production)

Brightness Curve for Current Spreading Layer Width

Performance Comparison
Technology and Economic Considerations
(Yield Comparison for Display Chips)

<table>
<thead>
<tr>
<th>Lot Number</th>
<th>Final Yield</th>
</tr>
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<tbody>
<tr>
<td>1-6</td>
<td>83%</td>
</tr>
<tr>
<td>7-12</td>
<td>87%</td>
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</tbody>
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Actual Customer Data (Based on 4-inch wafers)

- **Aligner**: 83%
- **1x-Projection Tools**: 87%
Technology and Economic Considerations
(Yield Comparison for Power Chips)

Actual Customer Data
(Based on 2-inch wafers)

Lot Number

Final Yield

89%

96%

Aligner

1x Projection Tools

96%
Technology and Economic Considerations
(Pay Back Period and Return on Investment)

**Highlights**
- 1x Projection tools enable cost effective LED production and significant operational cost savings (>10M) over the useful life of equipment

**EVC Comparison**

Significant yield savings result in a past pay back period (~20 weeks)*
Economic Value Considerations
(New Product Introduction Drives Superior COO)

Highlights

• Ultratech offers a cost-effective, production proven, 1x projection tool with better alignment, better yields and better ROI
  • Recent LED adoption for backlighting has pushed customers towards stepper adoption
  • Significant momentum in Asia market after introduction of Sapphire product
    • Sapphire provides smallest footprint stepper with a cost effective technology upgrade solution

Repositioning Legacy Product for HBLED Market Has Gained Considerable Momentum
Summary

- **Technology Introduction**
  - Limited early adoption by HB LED leaders (Nichia)

- **Initial Adoption**
  - Driven by requirements for improved process technology for new HB LEDs

- **Rapid Growth**
  - Growth drivers will be SSL and flat panel display backlighting

**Ultratech offers**
- Market specific lens design for thick resist applications
- Technology readiness and volume production capability for current & future HBLED product offering

**HBLED Adoption Timeline**
- 1990’s
- Late 2000’s
- 2010+