LED Chip Manufacturing Outlook
and Standards Update

Tom Morrow, SEMI
Agenda

• LED Manufacturing Outlook
  – Capacity by region
  – Equipment spending by region
  – China Manufacturing Update

• SEMI LED Standards Update
  – Wafer Geometries
  – Automation
  – Other

• How LED Industrial Development Compares with other Industries
  – Options and Policies
SEMI & LEDs

- **SEMI**
  - Global Association for the Microelectronics Manufacturing Supply Chain
  - Established in 1971
  - ~2000 global members, primarily equipment and materials suppliers to the semiconductor, display, PV, LED, MEMS and related industries

- Exhibitions, Conferences, Forums in All Regions of World
- Industry Research-Opto/LED Fab Watch and Forecast
- Manufacturing Standards Development in LEDs
- Public Policy
Manufacturing Outlook
LED Dedicated Fabs
Changing LED Landscape

<table>
<thead>
<tr>
<th>Year (Begin Operation)</th>
<th>2001</th>
<th>2006</th>
<th>2013 (est)</th>
</tr>
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<tbody>
<tr>
<td>Total Count of LED Fabs*</td>
<td>36</td>
<td>64</td>
<td>170</td>
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<tr>
<td>Capacity in 4-inch EQs/w/m</td>
<td>127,124</td>
<td>376,400</td>
<td>~2,400,000</td>
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</table>

*Fab number includes both LED epitaxy and chip facilities.

Source: SEMI Opto/LED Fab Forecast, Feb. 2013
World LED Capacity Trend

Source: SEMI Opto/LED Fab Forecast, Feb. 2013
LED Fab Capacity by Region

Worldwide LED Epitaxy capacity to reach 2.4 M in 2013 (4” equivalent per month)

Source: SEMI Opto/LED Fab Forecast, Feb. 2013
LED Fab Equipment Spending

In $US Million

Source: SEMI Opto/LED Fab Forecast, April 2013 (prelim.)
China LED Fab Utilization Rate

- China LED Fabs utilization (based on MOCVD tool) was down to 40% Q4 2011–Q1 2012.
China LED Fabs Status

In 2013:
4 New LED Fabs are still under construction;
10+ existed LED Fabs to be shut down

- China LED Fabs came to merging stage since 2012.
- ~40% LED Fabs will quit or be acquired by 2015.

Source: SEMI China, 2013
Sapphire Pricing Trend
(Price refers to epi-ready polished wafer, not Pattern Sapphire Substrate)

Source: Company data, Digitimes, SEMI IRS

6” Price Trend
- $450 in 3Q11
- $300 in 4Q12
- 25% decline in 2012
Manufacturing Outlook

• Overcapacity and margin pressure dampening investment incentives
• Industry awaits GaN-on-Si results; Skepticism Abounds
  – Toshiba/Bridgelux begins production of white LEDs using GaN on 200mm silicon in 2012
  – Toshiba acquires Bridgelux GaN on Si technology (April 2013)
  – Azzurro announced that Epistar has successfully migrated their LED structures to its 150mm GaN-on-Si templates and is working on 200mm
  – TSMC reportedly beginning GaN on 8 inch Silicon
• Industry consolidation, vertical integration continues
• Capex focus on yield, not scale
SEMI Standards Update
SEMI Standards

• Manufacturing Standards
  Development for over 35 years
  • Serving the semiconductor, LED, flat panel display, PV and MEMS industries
  • ~1800 standards
  • 3000 volunteers
  • Over 20 Technical Committees and 200 Task Forces
  • November 2010--HB-LED Standards Committee formed with strong industry support (VP-level device makers, key equipment manufacturers, material suppliers)
## Participating LED Companies*

Over 120 registered Task Force members

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<thead>
<tr>
<th>AIS Automation</th>
<th>Hitachi High-Tech</th>
<th>Op-Test</th>
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<tr>
<td>Aixtron</td>
<td>ILJIN Display</td>
<td>OSRAM</td>
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<td>Applied Materials</td>
<td>KLA-Tencor</td>
<td>Oxford Instruments</td>
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<td>ARC Energy</td>
<td>Kulicke &amp; Soffa</td>
<td>Pall</td>
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<td>Brooks Automation</td>
<td>Lam Research</td>
<td>PEER Group</td>
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<td>Cimetrix</td>
<td>LayTec</td>
<td>Philips Lumileds</td>
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<td>Daifuku</td>
<td>Meyer Burger AG</td>
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<td>GT Advanced Tech</td>
<td>NIST</td>
<td>Sapphire Tech</td>
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* Partial List
Published Standards

- **SEMI HB1-0113, Specifications for Sapphire Wafers Intended for Use for Manufacturing High Brightness-Light Emitting Diode Devices**
  - These specifications cover dimensional, wafer preparation, and crystallographic orientation characteristics for five categories of single-crystal single-side polished sapphire wafers used in HB-LED manufacturing as follows:
    - Flatted 100 mm diameter, 650 μm thick, polished c-axis sapphire wafers
    - Flatted 150 mm diameter, 1,000 μm thick, polished c-axis sapphire wafers
    - Flatted 150 mm diameter, 1,300 μm thick, polished c-axis sapphire wafers
    - Notched 150 mm diameter, 1,000 μm thick, polished c-axis sapphire wafers
    - Notched 150 mm diameter, 1,300 μm thick, polished c-axis sapphire wafers
  - In addition, methods of measurements suitable for determining the characteristics in the specifications are indicated.
Recently Approved Document

- **SEMI Draft Document 5420A**, Specification for 150 mm Open Plastic and Metal Wafer Cassettes Intended for Use for Manufacturing HB-LED Devices

This specification provides the dimensional requirements for plastic and metal wafer cassettes used for the processing and handling of 150 mm diameter HB-LED sapphire wafers conforming to the SEMI HBI.
Current Activities

Equipment Automation TF

• Equipment Automation TF – Hardware WG
  – [Doc. 5468] New Standard: Mechanical Interface Specification for 150 mm HB-LED Load Port
    • This Document will define the basic interface dimensions of a load port and their arrangements on HB-LED manufacturing equipment, where HB-LED 150 mm cassettes can be loaded and unloaded. These interface specifications include:
      – Location of physical interface between an HB-LED cassette and HB-LED manufacturing equipment.
      – Definition of load port volume and horizontal spacing on the equipment.
      – Ergonomic clearances for manual cassette handling.
      – RFID reader/writer volumes.
    • Document development in progress, to be submitted for the Cycle 3, 2013 voting period.
Current Activities

Equipment Automation TF

• Equipment Automation TF – Software WG
    • Document development in progress, to be submitted for the Cycle 4, 2013 voting period.

  – New Activity:
Current Activities

HB-LED Wafer TF, Impurities & Defects TF

- HB-LED Wafer TF, Impurities & Defects TF
  - Working on next set of revisions to SEMI HB1, including:
    - laser marking and identification specification;
    - definitions and specifications of impurities and defects;
    - patterned sapphire substrate (PSS)-ready specification for 100mm and 150mm;
    - double sided polished wafers specifications;
    - updated surface roughness parameters & test methods; and
    - reclaimed wafer specifications
  
- **Ongoing**: Phase 2 of the wafer marking experiment to characterize mark survivability, mark width, and depth
LED Safety Task Force
Taiwan EHS Committee

- Formation Date: October 25, 2011
- Charter
  - The objective is to develop EHS (Environmental health and safety) technical standard specifications and guidelines related to LED manufacturing equipment.
- Scope
  - The activities of the task force will result in the development of an EHS industry standard which equipment suppliers, raw material suppliers, module makers and other involved parties can find conformity.
  - Initial work will focus on:
    - Determining if current LED equipment is covered by SEMI S2 or not
    - Developing EHS guidelines for manufacturing equipment for the LED industry
  - Future activities may include:
    - Establishing equipment safety event database
    - Collecting and analyzing the data of safety notice and SEMI reports which were certified by third party
    - Developing SEMI EHS guidelines for LED manufacturing
LED Manufacturing and Today’s Microelectronics Industry
### Comparisons with the Solar Industry

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<th><strong>PV</strong></th>
<th><strong>LED</strong></th>
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<td><strong>Demand Event</strong></td>
<td>German Feed-In Tariffs</td>
<td>LED TVs</td>
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<td><strong>Supply Chain Gaps</strong></td>
<td>Low scale mfg. Polysilicon Shortages</td>
<td>Low scale mfg. Sapphire Shortages</td>
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<td><strong>Global Race is On</strong></td>
<td>WW cap. increases 400% 2007-2011</td>
<td>WW cap. Increase 288% 2008-2012</td>
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<td><strong>China Investments</strong></td>
<td>~65% of world capex (2011)</td>
<td>~40% of world capex (2012)</td>
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<td><strong>Overcapacity</strong></td>
<td>Rapid price declines; widespread financial losses</td>
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<td><strong>Global Trade Impact</strong></td>
<td>Trade Wars Quality Gaps</td>
<td>???</td>
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US Share of Semiconductor Fab Equipment

- 2003 - Motorola Divests Semiconductor Operations
- 2005 - AMD Opens New 300mm Fab 36 in Dresden
- 2007 - Intel Begins Fab Construction in China
- 2007 - TI Stops 45nm Development

Source: SIA, SEMI
Solid State Lighting Policy

• SEMI supports increased funding for the DoE and EERE in particular
• SEMI supports SSL manufacturing and market support programs and prefers a clear, transparent SSL budget line, not just “Emerging Technologies”
• SEMI supports an accelerated solid state lighting adoption through a partnered manufacturing program between LED and lighting and equipment suppliers.
• SEMI supports DoE programs that retain and grow existing industries, not just try and create new ones.
Thank You
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Questions and Comments: tmorrow@semi.org