Enhancing HBLED EPI Wafer Yield using Accurate Electroluminescence Metrology
December 12th, 2013

Atomic Force Microscopy
3D Optical Microscopy
Tribology
Automated AFM
Stylus Profilometry
Mechanical Testing, Nanoindentation
Agenda

- Bruker Introduction
- Industry Problem - Current MOCVD Epi Wafer Metrology Methods are Limited
- Industry Solution – Reliable, Fast Electro-Luminescence
- LumiMap – Bruker’s New Electro-Luminescence Technology
- How it Works
- LumiMap’s Unique Features
- Customer Data
- Production Solution
- Validation and Summary
About the Presenter

Hugh Palmer is the Senior Product Line Marketing Manager at Bruker Nano Surfaces in Tucson, Arizona. He has an undergraduate degree in Chemical Engineering from BYU and a Master’s degree from Thunderbird in International Business. Hugh has worked in product management for 15 years, 6 of which were in China as a regional product manager for ASM International.

Hugh can be contacted at:
Hugh.Palmer@Bruker-nano.com
**Bruker**: the leading provider of high-performance scientific instruments and solutions for life science, diagnostic and applied markets.

**KEY FIGURES**

- Founded in 1960
- $1.79B revenue
- ~6,700 employees
- ~82% of revenues outside of the US
- ~Direct sales organizations in 33 countries
- ~1,000 R&D professionals with strong track record of innovation
Bruker Stylus and Optical Metrology
SOM - World Leading Surface Metrology

- History of QA/QC solutions for industry
  - **Semiconductor**
    - 100+ Installed base multi-chip module inspection at board level
  - **Data Storage**
    - 500+ Installed base slider metrology
  - **Electronics and Industrial**
    - 1000+ Installed base
  - **Worldwide**
    - 10,000+ Installed base
- **Manufacturing Excellence**
  - Lean, six sigma-based process
  - 100+ systems/quarter capacity
  - Rapid production ramp capability

New Facility - Tucson, Arizona, USA
Opened December 2011

12/12/2013
Bruker Confidential
Industry Problem
Current Epi Wafer Metrology Methods are Limited

Problem: MOCVD is a Critical Process for Device Performance and NEEDS Better Metrology that can Correlate to final device

• The critical stage is the growth of the (InGaN)/GaN MQW active region
• LED color, brightness and electrical parameters are determined at this MOCVD Epi stage
• These parameters are sensitive to temperature and complex chemistry interdependencies
• Variation in these parameters result in yield loss and end of line binning
• A yield of 85% will contribute greatly to the cost of back end processing → the highest cost associated with the packaged LED

Bin Spread Example
• 3 available flux bins
• 8 available color bins
• 4 available Vf bins

Yield is the single highest contributor to Epi Cost!

Minimizing variation in each parameter minimizes end of line binning and improves yield
Industry Problem
Current Epi Wafer Metrology Methods are Limited

Undetected process shifts result in COSTLY scrap events!

- **Substrate Processing** - 6% of total wafer cost
- **MOCVD (Epitaxy)** - 6% of total wafer cost
- **Post MOCVD to Device** - 88% of total costs

- If an MOCVD quality excursion is not caught at the Epi stage, it will likely not be realized until after significant process expenses
- An MOCVD tool can produce 42 (4 inch) wafers/day in full production
- A scrap event left undetected for 7 days could result in ~ 300 wafers affected
- @ $800/wafer a single undetected scrap event could cost ~$250,000
- Multiply this by the number of tools affected
Industry Problem
Current Epi Wafer Metrology Methods are Limited

Photoluminescence (PL) Mapping
- Laser Excitation vs Electrical Excitation
- Relative Spectral Data Only
- Provides No Electrical Feedback

Indium Dot Metrology “n-Dot” is embedded in contact location
- Limited Accuracy
- Labor Intensive
- Operator Dependent
- Time consuming
- Destructive in test region
- Limited wafer coverage
- Does not correlate to device level
Industry Problem
Current Epi Wafer Metrology Methods are Limited

- The SSL Manufacturing Roadmap stated that there remains a strong need to develop in-line characterization of the epitaxial wafers for rapid feedback to the manufacturing process.

- Development of high-speed, high-capability, non-destructive test equipment at the Epi wafer stage was called out as an R&D priority task.

- Rapid, accurate and reliable Metrology at the Epi Wafer Stage can guide MOCVD reactor process tuning, which in turn will improve yields and reduce scrap.
Industry Solution
Reliable Electro-Luminescence Mapping

LumiMap
Bruker’s New EL Metrology!
Integrates all Epi-Wafer Electrical and Spectral Testing in ONE System

- Wavelength
- Spectral Intensity
- Forward and Reverse IV Characteristics
- Spectral Width

First System with Vf Accuracy Good Enough to Correlate with Chip Level Test!

Early warning of Chip/Device level performance

- MOCVD
- Epi Wafer
- LED Die Processing

3-7 days processing

Chip on Wafer

Correlation
LumiMap
Electro-Luminescence Metrology for HBLED Wafer Processing

Device Level Quality Control at the Epi-Wafer Stage!

- Immediate Epi Quality Feedback
  - No Pre Inspection Wafer Preparation
  - No Post Inspection Wafer Clean
  - Non Destructive
- Most Accurate Technology
  - Operator Independent
  - Repeatable / Reproducible
  - With-in wafer uniformity mapping
- High Throughput / Cycle Time
  - User defined multiple point inspection
  - Less than 1min/wafer (seconds per location)

Replaces Indium Dot Metrology!
LumiMap Improves Yields and Reduces Production Costs

- **Improves Yields** by providing rapid, accurate and reliable with-in wafer uniformity mapping that can guide MOCVD reactor process tuning
- **Minimizes End of Line Binning** by providing accurate, correlatable data at the wafer level
- **Reduces MOCVD Scrap** by providing early warning of process shifts
- **Improves MOCVD Reactor Uptime** by providing immediate re-qualification data when tools are down
- **Reduces Fab Ramp Time** by providing fast, reliable data during reactor tuning or process development
- **Reduces Expenses** for fabs that outsource device level testing
LumiMap
How it Works

- A wafer friendly **Conducting Probe** (P contact) touches the top surface of the wafer
- A unique **Wafer Edge Contact** (N contact) completes the circuit allowing a controlled current to flow through the Epi active layer causing it to emit light
- **Advanced Software** accurately displays and maps all electrical and optical data
- **Motorized Programmable Stage** for automated, user-defined, multiple point inspection
- **Advanced IV Curve Modeling** for accurate and repeatable electrical measurements
LumiMap
Bruker’s Electrical Probe – Heart of our Technology!

- Patent Pending Electrical Probe
  - Real Electrical Excitation vs Laser Excitation
  - Repeatable and Reproducible over time
  - Non-Contaminating
  - Long Life Time (> 10,000 touches)

Probe Technology is Critical for Production/QA/QC

Performance Spec on Sapphire

<table>
<thead>
<tr>
<th></th>
<th>STD%</th>
<th>Repeatability</th>
<th>Reproducibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Int</td>
<td></td>
<td>1.0%</td>
<td>1.5%</td>
</tr>
<tr>
<td>Centroid Wave</td>
<td></td>
<td>0.5nm</td>
<td>0.5nm</td>
</tr>
<tr>
<td>Spectral Width</td>
<td></td>
<td>0.5nm</td>
<td>0.5nm</td>
</tr>
<tr>
<td>VF</td>
<td></td>
<td>1.0%</td>
<td>3.0%</td>
</tr>
<tr>
<td>IR(-20V)</td>
<td></td>
<td>1.0%</td>
<td>3.0%</td>
</tr>
</tbody>
</table>

Repeatability: 25 measurements in same location;
Reproducibility: 9 locations; 1 wafer reloaded 25 times
Measurements taken at 100mA max current
LumiMap
Advanced IV Curve Correction Algorithm

- Advanced IV Curve modeling software removes probe and edge grip contact resistance (Rs) to more accurately model true device level measurements.

- Correction has proven to provide strong Vf Correlation to Chip Level.

Vf Correction Model correlates with R2 = 0.7
LumiMap Correlation to Chip Level Test

- “Vf-Chip” is customer chip level data
- “Mean A” and “Mean B” are LumiMap Wafer Level Measurements
- Data shows Correlation
LumiMap Correlation to Chip Level Test

IR(-20V)

Peak Int (127mA)

WLD(127mA)

HW(127mA)
LumiMap
Production Solution

Designed for the Production Environment

- Small Footprint
- Powerful analytical software provides device level SPC capability at the Epi Wafer Stage
- Intuitive Operator Friendly Interface
- Automated Stage for User Defined Multiple Point Inspection (up to 1000 locations)
- Robust Design is Easy to Maintain
- Low Cost of Ownership
- Automated Measurements for Repeatability over time

Replaces the Indium Dot Test
LumiMap
Production Software
Migration to more expensive substrates will increase the need for yield improvement.
Market Trends
Wafer Size Migration

Migration to larger wafer sizes will increase the need for yield improvement.
LumiMap
New Product Validated in Production!

- Tool Development Together with Three Industry Leading Manufacturers Over 6 months
- Solid Feedback from world’s leading production facilities
  - Good correlation of all parameters to flash test and chip level test
  - Hardware is robust
  - Easy to Maintain
  - Fast turn around time to data

“LumiMap provides more accurate and reliable electrical and optical epi wafer measurements than the traditional indium dot method.” Executive VP, CTO of NationStar

“A reliable electro-luminescence quality check immediately after MOCVD will help us further improve Epi wafer yield and reduce costs.”
Thank-You!

For More Information you can contact me directly at: 
Hugh.Palmer@Bruker-nano.com

Or speak with your local Bruker Sales Contact