How can MOCVD enable production of cost efficient HB LED's

Dr. Frank Schulte

AIXTRON SE
Company and Market

Market requests and challenges

Answer from the technology

Conclusion
AIXTRON Global Presence

Key figures:
Est. 1983 as spin-off from RWTH Aachen, Germany
Legal form: Public Company
Employees: ~ 800
Product: Gas Deposition Equipment
24 - Month Business Development

(€ million)

Equipment (only)
Order Intake

Order Intake and Order Backlog are recorded at the prevailing budget rate (2011: $1.35/€)

Equipment (only)
Order Backlog

Total Revenues
(incl. equipment, service, spare parts)

*1 revalued on January 1, 2011 to €302.3m at $1.35/€
LED Growth Opportunities: Lighting and BLU

LCD BACKLIGHT AND ILLUMINATION FORECAST VERSUS OTHER APPLICATIONS FORECAST (REVENUE) 2010–2014

- Illumination: 45%
- Signs/Displays: 60%
- CAGR 2010 – 2014: 30%

Illumination currently 12% of total market

→ MOCVD is one of the key/enabling technology
Advances in LED Performance and Application

The LED Industry has changed
Advances in MOCVD

MOCVD 1983

MOCVD Technology has Advanced...

MOCVD 2010
Gas Phase Deposition Technology Evolution for Compound Semiconductor

- Research -led, driven by Science (Compound 1960-1980)
- Technology -led, driven by Research (Compound 1980-1990)
- Application -led, driven by Technology (Compound 1990-2000)
- Market -led, driven by Applications (Compound 2000-2008)
- Cost of Ownership -driven, led by the Market (2008 - Now)
- Semiconductor Market – CoO-driven, led by the Market (10 Yrs +)
- Display Market – CoO-driven, led by the Market (10 Yrs +)

→ More and more Si-like technology directions mainly driving by LED production
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Fig 1: LED Device Manufacturing Process Flow-Chart
Cost reduction Roadmap

Figure 2. Projected LED Package Cost Track. Source: Preliminary data provided by the Cost Modeling Working Group

Cost Reduction 20% per year
Table 4. Epitaxy Metrics

Source: DOE Workshop Consensus

<table>
<thead>
<tr>
<th>Metric</th>
<th>Unit</th>
<th>2009</th>
<th>2010</th>
<th>2012</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wafer Uniformity (standard deviation of wavelength for each wafer)</td>
<td>nm</td>
<td>1.7</td>
<td>1.5</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Wafer-to-wafer Reproducibility (maximum spread of mean wavelength for all wafers in a run)</td>
<td>nm</td>
<td>1.5</td>
<td>1.1</td>
<td>0.9</td>
<td>0.6</td>
</tr>
<tr>
<td>Run-to-run Reproducibility (maximum variation from run-to-run of the mean wavelength for all wafers in a run)</td>
<td>nm</td>
<td>2.0</td>
<td>1.5</td>
<td>1.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Cost of Ownership</td>
<td>-</td>
<td>Factor of 2 reduction every 5 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epitaxy Cost</td>
<td>$/\mu m \cdot cm^2</td>
<td>0.3</td>
<td>0.25</td>
<td>0.17</td>
<td>0.1</td>
</tr>
</tbody>
</table>

....but wavelength is only one LED parameter
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LED Industry’s Requirements

**LEDs**
- Chip volumes ↑↑
- Cost per chip ↓↓
- Brightness & efficacy ↑
- New device Layouts
- “Silicon style” fabs

**MOCVD**
Typical LED

- \( p_{\text{tot}} = 50\,\text{–}\,600\,\text{mbar} \)
- \( T_D = 500\,\text{–}\,1100^\circ\text{C} \)
- TMGa, TEGa, TMIn, NH\(_3\)
- Carrier gas N\(_2\) during MQW
- Carrier gas H\(_2\) during GaN

**InGaN/GaN MQW + cap**

3.5 µm GaN Buffer with thin nucleation onto sapphire

**150 mm sapphire**
## Cost reducing factors

<table>
<thead>
<tr>
<th>Advances in MOCVD</th>
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</thead>
<tbody>
<tr>
<td><strong>Throughput</strong></td>
</tr>
<tr>
<td>- Wafer size and Capacity ↑</td>
</tr>
<tr>
<td>- Cycle time ↓</td>
</tr>
<tr>
<td>- Uptime ↑</td>
</tr>
<tr>
<td>- Time to Production: True Scaling ↓</td>
</tr>
<tr>
<td><strong>Yield</strong></td>
</tr>
<tr>
<td>- Design to Uniformity ↑</td>
</tr>
<tr>
<td>- Repeatability r2r, s2s ↑</td>
</tr>
<tr>
<td>- Reliability, Stability ↑</td>
</tr>
</tbody>
</table>

**MOCVD Solutions**

for Best Performance and Highest Productivity

AIX G5 HT and CRIUS II
Compound ‘Common Platform’ Systems

- One common platform for CCS and Planetary Reactors®
- One common platform for different application

Planetary Reactor®
AIX G5 HT, 56x2”
(14x4”, 8x6”, 5x8”)

Close Coupled Showerhead®
CRIUS® II, 55x2”
(13x4”, 7x6”, 3x8”)

Confidential • Proprietary
“Compound Technology is moving to Silicon rules”

Up to now Sapphire is dominating the market going from 2” to 4” … to 6”

Larger wafers allow to increase the number of devices per wafer whilst keeping processing costs low.

If the same edge exclusion can be maintained then the yield is improved.

High degree of automation is available for large wafers → convergence with Si-industry

Si-substrates are widely available → possible road for further cost reduction
Improved Yield and Reproducibility by In Situ Control for all wafer

- Monitoring and control of surface temperature, film thickness, bowing and uniformity during growth
Manufacturing Execution System

Control System / Database

Centralized  Remote  Fab-wide Linked

Analyze ➔ Manage ➔ Control
in real-time for the whole factory

➔➔ Efficiency ➔ ➔ Productivity
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Conclusion

- LED Industry is changing
- Proven technology reducing CoO implemented for LED production
- Fab integration: AIXTRON MES interface installed & running on already > 200 tools
SSL will turn into reality

MOCVD is one of the key/enabling technology for SSL
Thank you for your attention

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