Manufacturing of Integrated, Low Cost, High Performance SSL Luminaires

Contract #DE-EE0006260

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SSL Market Drivers

- Cost Reduction (Lm/$)
- Manufacturability (DFM, Throughput)
- Reliability/Quality (L70, B10)
- Performance (Lm, Lm/W)
- Energy Savings
Luminaire Relative Cost Projections

2008

- LED 42%
- LED Driver 27%
- Other 31%

2010

- LED 31%
- LED Driver 35%
- Other 34%

2015

- LED 25%
- LED Driver 19%
- Other 56%

“Other” costs become dominant in the future

LED PKG PROJECTIONS

<table>
<thead>
<tr>
<th>Metric</th>
<th>2010</th>
<th>2012</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool Efficacy (Lm/W)</td>
<td>134</td>
<td>176</td>
<td>224</td>
<td>258</td>
</tr>
<tr>
<td>White Cost ($/kLm)</td>
<td>13</td>
<td>6</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Warm Efficacy (Lm/W)</td>
<td>96</td>
<td>141</td>
<td>202</td>
<td>253</td>
</tr>
<tr>
<td>White Cost ($/kLm)</td>
<td>18</td>
<td>7.5</td>
<td>2.2</td>
<td>1</td>
</tr>
</tbody>
</table>

DOE SSL MYPP: April 2013
LED System Roll-up

• ~ 80% direct pc cost-out
• Ass’y cost secondary benefits
• Thermal performance improvement aids LED count reduction

L1: Traditional PC approach
L2: LED Pkg on Heatsink
L3: LED Chip Scale Package on Fixture
L4: L3 + Integrated Electronics
Screen Printing Process Flow

Screen Printing Technique Adapted with New Material Sets for Electronic Circuitry

Cycle is repeated multiple times for each circuit layer (dielectric and conductor)
Conventional Fixture Components
(L1 vs Integrated Fixture)

Eliminated
- Wires/Gaskets
- PCB
- Supply Chain Complexity

Integrated/Optimized
- Driver
- Heatsink
- Optics
- Housing
- LEDs
L2 Structure/Thermal Improvement

Temperature Comparison

- MCPCB
- LED Pkg on Al Substrate
- LED Pkg on Al Heatsink

Thermal Improvement Options:
- 1.8 – 2X Lifetime increase
- Up to 5% LED count reduction
Substrate Mfg. Throughput Reduction

Manufacturing Throughput Reduction

5X Reduction in Process Time
2.5X Reduction in Process Steps

- Sept-2013
- Dec-2014
- Sept-2015
## DOE Areas of Interest (AOI) Projections

<table>
<thead>
<tr>
<th>AOI 1 Metric(s)</th>
<th>Current Status</th>
<th>2015 Target(s)</th>
<th>Program Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing Throughput</td>
<td>n/a</td>
<td>x2 increase</td>
<td>3.07x</td>
</tr>
<tr>
<td>OEM Lamp Price</td>
<td>$50/klm</td>
<td>$10/klm</td>
<td>$0.94/klm - $3.13/klm*</td>
</tr>
<tr>
<td>Assembly Cost ($)</td>
<td>n/a</td>
<td>50% reduction every 2-3 years</td>
<td>-75.69%</td>
</tr>
<tr>
<td>Color Control (SDCM)</td>
<td>7</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
Summary

- LED Board costs inflating on a relative basis
- Costs can be eliminated by integrating a Thick Film Mfg Process
- AOI Metrics can be exceeded
- Early Results very promising