Unlock Luminaire Design and Performance Possibilities

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Agenda

1. The market challenge
2. Leading by design
3. Material selection considerations
4. Production scale-up demonstration & best practices
The Lighting Market Challenge

- Technology Revolution
- Lighting Manufacturer
- New Competitors
- Costs & Prices Dropping
- Fickle Consumers
How Will You Lower Costs?

• “The price premium for LED lighting continues to pose a barrier to adoption in many applications.”

• LED lamp costs expected to drop 55% and luminaire costs to drop 30% by 2017

Materials & Manufacturing Represent 65-75% of Total Cost

Source: Internal PolyOne analysis
What if:

- You could understand what your customers really want and build that into your designs?

- You could design a luminaire with processing and performance in mind and get it right the first time?

- You could lower your cost per lumen while enhancing your brand and market share?
Polymers Have Unlocked Possibilities in Other Industries

1965 Mustang

2014 Mustang
Collaborate for Best Results

Successful polymer component
Design Philosophy

Have design involved early in your process

- Define
- Conceptualize
- Refine
- Prototype
- Implement

Speed & Reduced Risks

Material, Process, & Supply Chain Expertise
Design Process

Understand your manufacturing options
• EVERY application has more than one solution
Design for the “Future”

- Solve today’s problems but keep awareness on future needs
- Take advantage of emerging technologies
Part Finish

Options to fit every need **without** the post processing
Part Finish

Replicate natural materials with printed films for unique aesthetics

• Reduce manual labor costs and assembly times
Part Finish

Use *hydrographics* in unique applications that were never before possible
Collaborate for Best Results

- Property profile fit
- Availability
- Innovation

Successful polymer component

Material Selection

Design

Production

- Performance
- Regulatory
- Innovation

- Manufacturability
- Consistency
- Innovation
System thinking: Analyze the requirements for every subsystem and their interactions with hardware and software
LED Luminaire Component: Lens

Light Transmission:
- Clear
- Diffusion

Flammability:
- UL94-HB
- UL94-5VA

UV Performance:
- Indoor
- UL746C f1

Impact:
- > Glass
- Vandal proof
LED Luminaire Lenses
LED Luminaire Component: Reflector

- **Reflectivity:** Specular, Diffuse
- **Flammability:** UL94-HB, UL94-5VA
- **Coating:** Opaque white, Chrome/Metalized
- **Temperature:** RTI 75C, RTI 130C
Reflectors: Metalized or Opaque White
LED Luminaire Component: Housing

Temperature:
- RTI 75C
- RTI 130C

Flammability:
- UL94-HB
- UL94-5VA

Color:
- Opaque white
- Metallic

Weatherability:
- Indoor
- UL746C f1
Housing – Metal to Plastic Conversion
LED Luminaire Component: Heat Sink

**Flammability:**
- UL94-HB
- UL94-5VA

**Temperature:**
- RTI 75C
- RTI 130C

**Electrical:**
- Insulative
- Conductive

**Processing:**
- Extrusion
- Injection
Many Systems are Convection Limited

- **Metal**
  - Airflow
  - Material
  - Heat

- **Plastics**
  - Airflow
  - Material
  - Heat

- **Thermally-Conductive Polymers**
  - Airflow
  - Material
  - Heat
Thermally Conductive MR16 Case Study

The temperature across the thermal interface is uniform.

- The regime is called “Convection-Limited”.
- In this regime there is no thermal penalty when replacing the material.

120°C: Maximum Temperature in use (Junction Temperature)

Free Convection Coefficient (Air):
- 7 W/m²K
- 10 W/m²K

Conductivity of Therma-Tech®

Conductivity of cooling body
Redesign to optimize

<table>
<thead>
<tr>
<th></th>
<th>Aluminum</th>
<th>Thermal Polymer</th>
<th>Thermal Polymer</th>
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<tr>
<td></td>
<td></td>
<td>Same Design</td>
<td>Redesigned Part</td>
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<tr>
<td></td>
<td></td>
<td>10 W/mK</td>
<td>10 W/mK</td>
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<tr>
<td>Max Temperature</td>
<td>52</td>
<td>63</td>
<td>53 °C</td>
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<td>Min Temperature</td>
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<td>11.6 lb</td>
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α = 5 W/m²K
# Economic Impact

## LED Cost-Out Estimate: Replacing Metal with PolyOne Polymers

### Material

<table>
<thead>
<tr>
<th>Material</th>
<th>Current Material</th>
<th>Heat Sink</th>
<th>Housing</th>
<th>Reflector</th>
<th>Lens</th>
<th>Trim Ring</th>
<th>Fasteners</th>
<th>Cost Savings</th>
<th>Weight</th>
<th>Weight Savings</th>
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<tr>
<td></td>
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<td>Aluminum</td>
<td>$ 1.88</td>
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<td>$ 0.94</td>
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<td>$ 18.05</td>
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<td>$ 2.26</td>
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<td>$ 0.38</td>
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<td>$ 1.31</td>
<td>$ 0.17</td>
<td>$ 0.13</td>
<td>$ 0.02</td>
<td>$ 0.01</td>
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<td>$ 1.05</td>
<td>$ 0.15</td>
<td>$ 0.03</td>
<td>$ 0.01</td>
<td>$ 0.01</td>
<td>$ 0.01</td>
<td>$ 0.03</td>
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<td>$ 2.24</td>
<td>$ 7.75</td>
<td>$ 0.97</td>
<td>$ 3.09</td>
<td>$ 0.54</td>
<td>$ 0.48</td>
<td>$ 36.15</td>
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### PolyOne Material

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermo-Tech</th>
<th>PVC-MS140</th>
<th>PVC-MS180</th>
<th>Acrylic V0450</th>
<th>PVC-MS240</th>
<th>PVC-M820</th>
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<td>$ 0.03</td>
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### Secondary Work

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<tr>
<th>Material</th>
<th>trimming/machining</th>
<th>point</th>
<th>assembly</th>
<th>Secondary sub-total</th>
<th>Secondary Total:</th>
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<tr>
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<td>20%</td>
<td>35%</td>
<td>2%</td>
<td>$ 13.24</td>
<td>$ 20.58</td>
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<td>$ 4.65</td>
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<td>$ 13.24</td>
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<td>$ 0.44</td>
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<td>$ 13.24</td>
<td>$ 20.58</td>
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### Production

<table>
<thead>
<tr>
<th>Material</th>
<th>conversion costs</th>
<th>cycle time</th>
<th>Production sub-total</th>
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<td>$ 22.74</td>
<td>$ 18.41</td>
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### Tooling Costs

<table>
<thead>
<tr>
<th>Material</th>
<th>Current Material</th>
<th>tooling investment</th>
<th>parts amortized</th>
<th>2 cavity injected mold tooling</th>
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<tr>
<td></td>
<td></td>
<td>$ 100,000</td>
<td>$ 500,000</td>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PolyOne Material</td>
<td>$ 230,000</td>
<td>$ 2,000,000</td>
<td>$ 0.08</td>
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</tbody>
</table>

**From 18 lb to 6 lb / luminaire = 67% weight reduction**

**From $73 to $47 / luminaire = 36% cost reduction**
Collaborate for Best Results

- Property profile fit
- Availability
- Innovation

Successful polymer component

Material Selection
- Performance
- Regulatory
- Innovation

Design

Production
- Manufacturability
- Consistency
- Innovation

Collaborate for Best Results

February 2015

PolyOne Corporation
Metal to Polymer Conversion Demonstration

**Design Goals:**

- Convert off-the-shelf down-light
- Use only engineered polymers
- Measure lumen performance
- Demonstrate heat removal
- Estimate savings potential
Polymer Conversion – Teardown
Polymer Conversion – Trim Ring
Polymer Conversion – Heat Removal Design

Table for $\lambda = 2...20 \text{ W/mK}$, (values below for 10 W/mK)

- Max. system temperature
- Min. system temperature

Temperature (°F)

Conductivity (W/mK)

Max. system temperature
Min. system temperature

Figure 1: Thermographic representation of heat removal design.

Figure 2: Graph showing temperature distribution across different conductivity values.
Polymer Conversion – 3D Prototyping
**Polymer Conversion Results**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light (lumens)</td>
<td>Equivalent</td>
</tr>
<tr>
<td>Board Temperature (°F/°C)</td>
<td>127°F (53°C) ... 146°F (63°C)</td>
</tr>
<tr>
<td>Weight (lb.)</td>
<td>-54%</td>
</tr>
<tr>
<td>No. of Components (#)</td>
<td>-31%</td>
</tr>
<tr>
<td>Tooling Life (# units)</td>
<td>10X</td>
</tr>
<tr>
<td>Component Cost Savings (est.)</td>
<td>36% savings</td>
</tr>
</tbody>
</table>
Polymer Conversion Best Practices

**Design**
- Create compelling look; NOT a drop-in replacement
- Simplify, consolidate, differentiate

**Material Selection**
- What are your performance needs?
- Consider regulatory requirements

**Production**
- Don’t let tooling be a hurdle
- Utilize latest computer prototyping tools

*Participate with someone who completely understands polymer design and processing*
Let Us Help You...

- Place your business card in the fishbowl
- Five drawn receive a free polymer conversion consultation
Questions?

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