Unlock Luminaire Design and Performance Possibilities

David Stonecipher, Global Industry Director
Brian Everett, Creative Design Manager
Eduardo Alvarez, Industry Manager
Dave Persing, Industry Manager

February 2015
Agenda

• The Market Challenge
• Leading by Design
• Material Selection Considerations
• Production Scale-Up and Best Practices
MARKET CHALLENGE
The Lighting Market Challenge

- The lighting industry is at a crossroads and is driven by new technology and new competitors (such as electronics firms).
- Lighting manufacturers are under tremendous pressure to stand out from the crowd and please their demanding consumers.

Technology Revolution  →  Demanding Consumers

New Competitors  →  Lighting Manufacturer

Costs & Prices Dropping
Costs & Prices Are Projected to Drop

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

• LED lamp costs (red line) expected to drop 55% and luminaire costs (blue line) to drop 30% by 2017

How Will You Lower Costs?

Luminaire Cost Savings Opportunities

• As you see below, raw materials make up an estimated 45% of total luminaire costs, with manufacturing accounting for 28%, on average.
• If you can switch to alternate raw materials and/or lower cost manufacturing processes, you can make a big difference in your overall luminaire cost.

Source: Internal PolyOne analysis
LEADING BY DESIGN
What If

• You could understand what your customers really want and build that into your products?
• 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 Revolutionized Industries

- Modern materials have enhanced this classic automobile!
- These new materials not only improve longevity, but they reduce weight and improve sustainability

1966 Mustang

Real wood, real metal, real leather that can fade, scratch, crack and rust

2015 Mustang

Engineered woods, metalized polymers, and soft touch thermoplastics that enhance this classic!
Collaborate for Best Results

- Introducing a successful polymer component requires product designers, material experts and production managers to work together from the beginning of the project.

Successful polymer component

- Performance
- Regulatory
- Innovation
Design Philosophy

- Involve the design team as early as possible in your project to allow the greatest flexibility in solutions and unique design aesthetics.
**Design Process**

- Understand your manufacturing options – EVERY application has more than one solution. Let product needs and wants drive the solution!
Design for the “Future”

- Solve today’s problems but keep awareness on future needs
- LED products are meant to last a decade or more – Are you anticipating for the ability of retrofitting or later add-ons?
- Take advantage of emerging technologies today
Design for Operational Efficiency

- One of the biggest advantages of converting to engineered polymers is the ability to eliminate post-process finishing, saving time and money!
- There are design options to fit every need – from high gloss to matte finishes, to metallic looks and paint-“like” aesthetics, all with limitless color options
Part Finish: Printed Films

- Replicate natural materials with printed films for unique aesthetics
- Reduce manual labor costs and assembly times via lamination or thermoforming processes
Part Finish: Hydrographics

• Apply appearances, such as woodgrain, to the polymer part that would normally not be achievable any other way
MATERIAL SELECTION CONSIDERATIONS
Collaborate for Best Results

- Property profile fit
- Availability
- Innovation

Successful polymer component

Material Selection

Design

Production

- Performance
- Regulatory
- Innovation
Use “System Thinking” During Material Selection

- Review the technical needs of a luminaire as a whole system while optimizing the material selection decisions for sub-systems and components
- Consider material interactions with the operating environment, electrical hardware and controls/networking software
LED Luminaire Lenses

- Lenses protect the interior of the luminaire from the environment and modify the beam to shape it, delivering light where it is intended
- Engineered polymers offer a continuum of performance choices, illustrated by the slider bars below

**Light Transmission:**
- Clear
- Diffusion

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

**UV Performance:**
- Indoor
- UL746C f1

**Impact:**
- > Glass
- Vandal proof
LED Luminaire Lenses

- Traditionally, glass was the material of choice for lenses, but it is heavy, fragile and if untreated, generates high losses.
- Several polymer families offer very high clarity and can be modified with diffusion agents to adapt the optical properties by application to prevent glare.

Glass Replacement Example
- The photo below shows a glass lens and four metal ring segments that hold it in place.
- Replaced these 5 parts and 8 bolts with ONE lens held in place with pressure fits. The diffusion finish was achieved without etching or secondary operations.
- Achieved 50% weight reduction and 60% costs savings.
LED Luminaire Lenses – Examples

Automotive PC headlamp. 
*clarity, temperature, impact*

Extruded PC profile
*clarity, flex during installation*

Extruded acrylic table top lamp
*diffusion, glare, tooling cost*

Precision molded acrylic optical arrays
*clarity, consistency, optical properties*
LED Luminaire Reflectors

- Reflectors shape, direct and concentrate the light created
- For LED light sources, reflectors also help mix and soften the individual spots or LED chips that emit the light
- Since light from LEDs does not radiate significant heat, it is possible to use a variety of polymer materials

Reflectivity:

- Specular
- Diffuse

Flammability:

- UL94-HB
- UL94-5VA

Coating:

- Opaque white
- Chrome/Metalized

Temperature:

- RTI 75C
- RTI 130C
LED Luminaire Reflectors

- Coated metals (white painted or highly polished) are used often for LED reflectors today
- A very opaque, white polymer can be extruded, coextruded or injection molded to achieve high 90s reflectivity
- For narrow focused beams, polymers can be vacuum metalized or chrome plated
- The polymer material is colored throughout so light will not leak and it will not dent or chip as it is being handled in assembly or installation

Metal Replacement Example
- Conducted a mold flow analysis to study which material would fill the part geometry best and to manage weld line placement
- Selected an inherently flame retardant vinyl material that was pre-colored in a reflective white. The part comes out of the injection machine ready for assembly with no secondary operations needed
- Achieved 50% weight reduction and 60% costs savings
Reflectors – Metalized or Opaque White

White vinyl reflectance curve
*UL94 5VA, mid-90s reflectivity*

Metalized in-mold labeling
*highly reflective film integrates into the part*

Vacuum plated PBT/glass
*high HDT, smooth, chemical resistance*

Molded acrylic lamp reflector
*greater than 96% reflectivity*
LED Luminaire Housing

- Housings offer the biggest opportunity for brand differentiation
- Engineered polymers provide a wide array of alternatives to fit the needs of many designers as indicated by the sliders below
- The materials will provide needed strength, impact, flame retardancy and electrical insulation properties

Temperature:
- RTI 75C
- RTI 130C

Flammability:
- UL94-HB
- UL94-5VA

Color:
- Opaque white
- Metallic

Weatherability:
- Indoor
- UL746C f1
LED Luminaire Housing

• Materials can be precolored or colored via masterbatch to obtain different appearances with minimal manufacturing complexity
• Unlike metals that need to be coated, painted or polished, many plastic parts are ready for assembly right after molding
• The electrical components inside are insulated as most plastics are non-conductive
• Unlike metals, most polymers will not interfere with remote lighting control signals

Metal Replacement Example
• Gaskets were over-molded into rigid components to ensure sealing, consolidating two components and avoiding a manufacturing step
• This avoids corrosion damage or chipping paint, extending weatherability and durability
• Achieved 50% weight reduction and 60% costs savings
Housing – Metal to Plastic Conversion

Co-extruded linear pendant
*Rigid vinyl with clear acrylic*

Thermally conductive housing
*Electrically conductive and isolative*

Encapsulated metal heat sink
*Vinyl, weatherable, WiFi signals*

Two shot molding
*Incorporate gasket into clear clamshell housing*
LED Luminaire Heat Sink

- LEDs do not radiate heat, so LED luminaires need to manage heat by conducting and conveying it away – minimizing chip temperature is critical to lumen performance and longevity
- The improving efficacy of LED chips and increasing use of lower power modules allow for redesigned heat sink solutions

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

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

**Electrical:**
- Insulative
- Conductive

**Processing:**
- Extrusion
- Injection
LED Luminaire Heat Sink

• Good thermal performance is based on the three ‘C’s
  ➢ Conductivity
  ➢ Contact
  ➢ Convection

• Many systems are limited by convection – how much heat can be removed by the surrounding air

• Engineered polymers can be thermally conductive but electrically insulative, enabling new design approaches

Metal Replacement Example

• Replaced aluminum with a thermally-conductive polymer while maintaining the existing geometry of the heat sink

• Constructed a thermal model to show that the LED board junction temperature would remain acceptably low

• Achieved 45% weight reduction and 20% costs savings
Many Systems are Convection Limited

- Metals have high conductivity
- Conductivity often exceeds convection = over-engineered
- **Result:** Cooling capacity is limited by convection rate

- Plastics are heat insulators
- Heat concentrates in a limited area and can’t escape
- **Result:** Low cooling rate, high temperatures cause failure

- Conductivity close to convection rate
- Efficient transfer of heat
- **Result:** Effective cooling meets desired performance
Thermally-Conductive MR16 Example

- Finding: Increasing thermal conductivity beyond 20 W/mK does not further reduce the LED junction temperature.

Curves show evolution of temperature at two different air speeds as conductivity increases.

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.
Redesign Heat Sink to Optimize Impact

<table>
<thead>
<tr>
<th>$\alpha = 5 \text{ W/m}^2\text{K}$</th>
<th>Aluminum</th>
<th>Thermal Polymer Same Design 10 W/mK</th>
<th>Thermal Polymer Redesigned Part 10 W/mK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Temperature</td>
<td>52</td>
<td>63</td>
<td>53 °C</td>
</tr>
<tr>
<td>Min Temperature</td>
<td>50</td>
<td>48</td>
<td>51 °C</td>
</tr>
<tr>
<td>Weight</td>
<td>11.6 lb</td>
<td>6.2 lb</td>
<td>2.0 lb</td>
</tr>
</tbody>
</table>

- Redesign heat sink to fully take advantage of polymer materials
- Results: An additional 70% weight savings and 20% cost savings
Economic Value Summary

- Overall summary of the glass and metal replacement examples as shown on the previous slides
- Used Economic Value Estimation tool for luminaires

<table>
<thead>
<tr>
<th>Weight Savings</th>
<th>Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>From 18 lbs. to 6 lbs. per luminaire = 67% weight reduction</td>
<td>From $73 to $47 per luminaire = 36% cost reduction</td>
</tr>
</tbody>
</table>
PRODUCTION SCALE-UP AND BEST PRACTICES
Collaborate for Best Results

- Property profile fit
- Availability
- Innovation

Successful polymer component

- Performance
- Regulatory
- Innovation

- Manufacturability
- Consistency
- Innovation
**LED Lighting Metal to Polymer Conversion**

**Design Goals:**

- Convert off-the-shelf down-light
- Use only engineered polymers
- Measure lumen performance
- Demonstrate heat removal
- Estimate savings potential
LED Lighting Teardown – Recessed Down-light

Existing Design

- Die cast Al heat sink
- Cumbersome design
- Painted bezel
- Sub-optimal materials

Existing Polymers

- Foamed EVA gasket
- Polycarbonate lens
- PET film reflector
- PPO driver housing
Convert Trim Ring to Vinyl

Existing powder coated steel bezel required multiple operations and secondary processes.

New vinyl design offers molded-in features, flow analysis and tooling capable of over 1 million parts.
Convert Heat Sink to Therma-Tech™

Existing aluminum heat sink had limited design freedom and required multiple secondary processes.

Four design iterations optimized heat flow and manufacturing with minimal material usage and no machining.
Manufacturing and Tooling Optimization

3D printed parts created to test form and fit, finalize CAD models, and optimize and cut tooling
## Successful 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 ((\degree F/\degree C))</td>
<td>127(^\circ)F (53(^\circ)C) to 146(^\circ)F (63(^\circ)C)*</td>
</tr>
<tr>
<td>Weight (lb.)</td>
<td>-54%</td>
</tr>
<tr>
<td>No. of Components (#)</td>
<td>-31%</td>
</tr>
<tr>
<td>Secondary operations</td>
<td>Eliminated painting &amp; assembly steps</td>
</tr>
<tr>
<td>Tooling Life (est. # units)</td>
<td>10X</td>
</tr>
<tr>
<td><strong>Component Cost Savings (est.)</strong></td>
<td><strong>36% savings</strong></td>
</tr>
</tbody>
</table>

* Depending on thermally conductive grade chosen
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*
Questions?

David Stonecipher, Global Industry Director
david.stonecipher@polyone.com
440-930-3323

Brian Everett, Creative Design Manager
brian.everett@polyone.com
314-569-7432

Dave Persing, Industry Manager
david.persing@polyone.com
440-930-1958

Eduardo Alvarez, Industry Manager
eduardo.alvarez@polyone.com
203-239-9629 x2019