Replacing Traditional Materials with Polymers for Next-Gen LED Luminaires

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Agenda

1. LED luminaire market opportunities
2. Polymer conversion examples from other industries
3. Polymer conversion roadmap by LED component
4. Application benefits and case examples
5. Polymer conversion implementation best practices
LED Luminaire Market To Grow 12% CAGR thru 2018

Commercial, Industrial, Outdoor and Architectural > 60% Market

Source: Strategies Unlimited, Strategies in Light NA, February 2014
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 & Mfg. Represent 65-75% of Luminaire Cost

Source: Internal PolyOne analysis
Polymer Conversions Common for Durable Applications

Transportation

- Weight reduction
- Corrosion resistance
- Under hood chemical and temperature resistance
- Paint avoidance

Appliances

- UV resistance
- Chemical resistance
- Component consolidation
- Scuff and dent resistance
Modern Materials Enhance a Classic

1965 Mustang

2014 Mustang
Polymers Provide a Sustainable Solution

- Parts manufactured with polymers have a lower carbon footprint throughout the supply chain vs. metals
- Carbon footprint $\approx$ greenhouse gas emissions

Source: Hammond and Jones, Inventory of Carbon & Energy (ICE) Version 2.0, University of Bath, 2011
Engineered Polymers Can Reduce Weight Up to 85%

- Advantage during shipping, installation and maintenance
- Reduce freight, labor, support and material consumption
LED Luminaire Component: Lenses

- Housing
- Reflector
- Heat Sink
- Lens
## LED Luminaire Lenses

### Current Materials

- Glass
- Conventional transparent plastics

### Typical Requirements

- 90%+ transmission
- Optimize transmission vs. hiding power
- No color shift over time
- Glare management
- Heat resistance
- Scratch resistance
- Flame retardant

### Engineered Polymer Solutions

- PC, PMMA (acrylic), PVC
- Diffused grades or diffusion concentrate

### Engineered Polymer Benefits

- Enhance light appearance
- Meet longevity & other requirements
- Variable diffusion properties
- Part consolidation, simplify production
- Lower total cost
High Performance Diffusion Resin Examples

% Transmission of Arkema Diffusion Resins

<table>
<thead>
<tr>
<th>Resin</th>
<th>Percent Transmission</th>
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<tbody>
<tr>
<td>PRD 994</td>
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<tr>
<td>Diffuse V045-68193</td>
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<td>Diffuse V045-68192</td>
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<td>Diffuse V045-68194</td>
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Hiding Performance of Arkema Diffusion Resins

<table>
<thead>
<tr>
<th>Resin</th>
<th>Relative Hiding Performance</th>
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<tbody>
<tr>
<td>PRD 994</td>
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<tr>
<td>Diffuse V045-68193</td>
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<tr>
<td>Diffuse V045-68192</td>
<td>80</td>
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<tr>
<td>Diffuse V045-68194</td>
<td>70</td>
</tr>
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</table>

Source: Arkema Inc.
LED Luminaire Component: Reflectors
## LED Luminaire Reflectors

### Current Materials
- Coated metals (aluminum, steel)
- Reflective plastics

### Typical Requirements
- 90%+ reflectivity
- Heat tolerance
- Light tolerance
- Flame resistance
- Minimize secondary processing
- Minimize environmental impact

### Engineered Polymer Solutions
- PBT, PCT, PVC, PC, PC/ABS, ABS
- Pre-colored or color & additive concentrate

### Engineered Polymer Benefits
- Meet reflectivity, diffusion & other requirements
- Avoid plating and coating operations
- Integrate thermal conductivity
- Consolidate parts, simplify production
- Lower total costs
Polymers Can Be Formulated For High Reflectance

- Very reflective across key wavelengths
- Up to 97% reflectance
- High opacity – no light leakage through material or connections
- White vinyl formulation
- Extruded part
- Long-term aging performance
- Durability during handling
LED Luminaire Component: Housings

- Housing
- Reflector
- Heat Sink
- Lens
## LED Luminaire Housings

### Current Materials
- Coated metals (copper, brass, bronze, nickel, SS)
- Conventional plastics

### Typical Requirements
- Long-lasting aesthetics
- UV and IR tolerance
- Corrosion resistance
- Chemical resistance
- Scratch resistance
- Impact resistance
- High strength
- Waterproof

### Engineered Polymer Solutions
- PC, PC/ABS, PVC, composites
- Pre-colored or color & additive concentrate

### Engineered Polymer Benefits
- Lightweight, attractive designs
- Meet longevity & other requirements
- Integrate thermal conductivity
- Electrically insulative
- Consolidate parts, simplify production
- Lower total costs
Housing Performance is Key to Outdoor Luminaire Reliability

The distribution of failures for one manufacturer’s family of outdoor luminaires

- Housing: 31%
- Driver (Power Supply): 52%
- Driver (Control Circuit): 7%
- LED Package: 10%

Source: US DOE Solid State Lighting Technology Fact Sheet, August 2013
Polymers Are Stronger Than You Think

- Polymers can have better mechanical properties on a weight basis
- Design freedom and flexibility of polymers can meet performance objectives

Integrated Multi-Material Part Examples

- Filled olefin
- Reinforced olefin
- TPE overmolded gasket
- TPE overmolded joint
- Encapsulated glass
- Rigid vinyl molded around glass
LED Luminaire Component: Heat Sinks

- Housing
- Reflector
- Heat Sink
- Lens
# LED Luminaire Heat Sinks

## Current Materials
- Metals (aluminum)
- Ceramic composites

## Typical Requirements
- Heat transfer to meet temperature target
- Electrically conductive or insulative
- Minimize 2nd processing
- Ease of manufacturing
- Desired aesthetics
- Flame resistance

## Engineered Polymer Solutions
- Thermally-conductive engineered materials
- PA, HTN, PBT, PPS, PC, TPU

## Engineered Polymer Benefits
- Lightweight, attractive designs
- Meet heat transfer and lighting regulations
- Electrically conductive or insulative
- Part consolidation, simplify production
- Lower total cost
Heat Sink Design: Key to LED Luminaire Longevity

Many Systems Limited by *Convection*, not Conductivity

Aluminum is more conductive than thermally-conductive polymers but may be over-engineered for the application.

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal Conductivity (W/mK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum (cast)</td>
<td>90+</td>
</tr>
<tr>
<td>Iron (cast)</td>
<td>55</td>
</tr>
<tr>
<td>Thermally-conductive polymers</td>
<td>2-25</td>
</tr>
<tr>
<td>Conventional plastics</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Metals

Limited by Convection

Excellent Conductivity

Conventional Plastics

Limited by Conductivity

Adequate Conductivity

Thermally-Conductive Polymers

Matched Convection

Heat
## Thermal Simulation Example

<table>
<thead>
<tr>
<th>Conductivity (W/m.K)</th>
<th>1</th>
<th>10</th>
<th>15</th>
<th>100</th>
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</thead>
<tbody>
<tr>
<td>Heat source (W)</td>
<td>3 x 1.8W</td>
<td>3 x 1.8W</td>
<td>3 x 1.8W</td>
<td>3 x 1.8W</td>
</tr>
<tr>
<td>Convection (W/m².K)</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Max temperature (°C)</td>
<td>150</td>
<td>107</td>
<td>105</td>
<td>101</td>
</tr>
<tr>
<td>Delta vs Aluminum (°C)</td>
<td>49</td>
<td>6</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

| Convection (W/m².K)  | 10    | 10    | 10    | 10    |
| Max temperature (°C) | 127   | 88    | 86    | 81    |
| Delta vs Aluminum (°C)| 46    | 7     | 5     | 0     |

LED Lamp Specifications:
- Ambient temperature = 27°C (static)
- Heat source LED = 3 x 1.8 W
- Maximum junction temperature = 120°C

Source: Static steady-state simulation using SolidWorks® Premium
Conductive Polymer Performs Equal to Aluminum

120°C “Maximum Junction Temperature”

Conductive Polymer

Convection coefficients:
- 7 W/m²K
- 10 W/m²K
- 15 W/m²K
## Summary: Benefits of Engineered Polymers

### Reduce Cost per Lumen
- Material savings
- Scrap reduction
- Secondary operation elimination
- Cycle time reduction
- Parts consolidation
- Logistics savings
- Manufacturing efficiencies

### Differentiate via Design Freedom
- Custom and innovative shapes
- Colorability
- Light tolerance and weatherability
- Chemical & corrosion resistance
- Thermally conductive or insulative
- Electrically conductive or insulative
- Flame retardant
- Sustainability
- Lightweighting
Case Study: Kruunutekniikka Oy Coolics™ Fixtures

### Financial Impact

<table>
<thead>
<tr>
<th></th>
<th>Impact</th>
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<tbody>
<tr>
<td>Weight reduction</td>
<td>33% vs. die-cast aluminum</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>13% productivity savings</td>
</tr>
<tr>
<td>Recycling scrap in production</td>
<td>33% scrap cost savings</td>
</tr>
<tr>
<td>Overall cost saving</td>
<td>13% cost reduction per unit</td>
</tr>
</tbody>
</table>

### Needs

- Design electrically-isolative heat sink that maintains LED temperature
- Reduce manufacturing cost through process flexibility
- Enable design freedom to help consolidate parts
- Comply with application requirements

### Solution

- Replaced aluminum heat sink with thermally-conductive polymer
- Utilized conventional injection molding processes
- Developed unique multi-material design to help integrate parts
- Complied with LED lighting standards

www.coolics.fi
Case Study: Industrial High Bay Downlight

Needs

- Reduce the weight and total cost of the entire luminaire
- Eliminate or reduce secondary operations
- Consolidate parts and connectors
- Create a high quality, unique design that helps increase sales

Solution

- Replaced aluminum housing and reflector with injection-moldable vinyl
- Redesigned heat sink and utilized thermally conductive polymer
- Replaced glass lens with acrylic polymer
- Eliminated painting, consolidated parts and simplified assembly

Financial Impact

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Weight reduction</td>
<td>60% vs. aluminum and glass</td>
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<tr>
<td>Primary Manufacturing</td>
<td>49% productivity savings</td>
</tr>
<tr>
<td>Secondary Manufacturing</td>
<td>90% step elimination savings</td>
</tr>
<tr>
<td>Overall cost saving</td>
<td>39% cost reduction per unit</td>
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</table>
Case Study: 4 Foot Linear Pendant

Needs

• Reduce weight of current profile while meeting UL requirements
• Utilize existing end caps and minimize changes to assembly process
• Provide a family of products from base components to simplify operations
• Reduce painting secondary operation

Solution

• Developed polymer extrusion that meets UL 94 5VA
• Retained injection molded end caps that fit existing assembly process
• Replaced glass with thermoformed sheet to allow multiple diffusion levels
• Provided desired base color

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Financial Impact

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<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Weight reduction</td>
<td>40% vs. extruded aluminum/glass</td>
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<tr>
<td>Manufacturing</td>
<td>35% avoiding paint in base color</td>
</tr>
<tr>
<td>Product variations</td>
<td>80% lower lens tooling cost</td>
</tr>
<tr>
<td>Overall cost saving</td>
<td>30% cost reduction per unit</td>
</tr>
</tbody>
</table>
## Polymer Conversion Implementation Best Practices

### Design
- Prioritize business improvement opportunities and set goals
- Simplify design and consolidate parts to take advantage of polymers
- Use computer-aided design to help define critical requirements

### Prototype
- Consider regulatory requirements when choosing materials
- Utilize rapid prototyping techniques (CNC machining, 3D printing)
- Determine optimum processing methods

### Produce
- Don’t let tooling be a hurdle – costs similar to metal but last longer
- Determine global supply chain roles and responsibilities
- Demand scale-up assistance through final assembly

*Participate with someone who completely understands polymer design and processing implications*
Benefits of Working with PolyOne

Design
• Market and regulatory insights to help guide strategy and reduce risks
• Design modeling to validate technology and push differentiation
• Design simplification to achieve lightweighting and lower total costs

Prototype
• Selection & supply of advanced materials to meet performance targets
• Use of rapid prototyping techniques to minimize design costs
• Expertise in thermoplastic processing to avoid secondary operations

Produce
• Access to supply chain resources to accelerate speed to market
• On-site technical assistance to shorten cycle times and reduce scrap
• On-time delivery of in-spec products for hassle-free operations
Questions?

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