Illuminating Innovations™
Silicone Solutions for LED Packaging

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Dow Corning Introduction
Dow Corning is …

- Equally owned by The Dow Chemical Company and Corning Incorporated
- Organized to explore the potential of the silicon atom in 1943
- A global leader in silicone and high purity silicon
  - More than 7,000 products/services
  - Approx 25,000 customers
  - Approx 12,000 employees
  - Strong and healthy financially: $6.43 billion sales in 2011
Dow Corning Worldwide

We help you invent the future.™
Silicones for LEDs
What is Silicone?

Silicones consist of an inorganic silicon-oxygen backbone with organic side groups attached to the silicon atoms.

Combining the flexibility and strength of plastics (which are carbon-based) with the resistance of glass (which is silica-based), delivers the best qualities of both.
Defining Silicones

Glasses are:
- Thermally stable
- Optically excellent
- Complex to process

Organic polymers are:
- Easier to process
- Range of properties
- Less thermally stable

Silicones have properties that combine glass and organic polymers

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Fascinating Silicone™

The missing link

• Combining the characteristics of plastics and glass
Silicones Polymer Properties

This combination of properties is unique among polymeric materials

**Chemical Property**
- Long Si-O bond distance
- Wide bond angle
- High bond energy
- Weak van der Waals’ force
- Organic exterior

**Physical Property**
- Facile bond rotation
- Stable bonds
- Low temperature dependence
- Low viscosity
- Hydrophobicity

**Application/Design Properties**
- Low modulus
- Heat resistance
- Wide working range
- Good workability
- Low moisture absorption
How Are Silicones Special?

High & low temp use

<table>
<thead>
<tr>
<th>Material</th>
<th>High Temp</th>
<th>Flexible to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicones</td>
<td>+150 to 200 °C</td>
<td>-45 to -115 °C</td>
</tr>
<tr>
<td>Epoxies</td>
<td>+150 to 180 °C</td>
<td>-</td>
</tr>
<tr>
<td>Urethanes</td>
<td>+115 to 125 °C</td>
<td>-60 °C</td>
</tr>
<tr>
<td>Acrylates</td>
<td>+85 to 125 °C*</td>
<td>-</td>
</tr>
</tbody>
</table>

*Note: The temperature range for acrylics is approximate and may vary depending on the specific product.
Proven reliability and efficiency across all lighting applications and processes:

- Seal
- Protect
- Adhere
- Cool
- Shape light
Material Needs in LED Components

- Encapsulants requiring high heat and light flux stability
- Improved white reflective materials for LED chip housing
- Materials for phosphor dispersion and light control
- Thermally conductive die attach materials to conduct heat from the LED chip
Encapsulant

Dow Corning Silicone Product Line
Two different types of silicone are commonly used as LED encapsulants: Methyl and Phenyl silicone. What is the difference?

<table>
<thead>
<tr>
<th></th>
<th>Methyl</th>
<th>Phenyl</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Refractive Index (n_p)</strong></td>
<td>1.41</td>
<td>1.53-1.54</td>
</tr>
<tr>
<td><strong>Transmittance</strong></td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td><strong>Light Stability</strong></td>
<td>Excellent</td>
<td>Very Good</td>
</tr>
<tr>
<td><strong>Gas Barrier</strong></td>
<td>Fair</td>
<td>Very Good</td>
</tr>
</tbody>
</table>

Phenyl encapsulants may enhance efficiency of light extraction of LEDs.
Phenyl silicone can provide ~7% more light output compared to methyl silicone.
Both show higher transmittance compared to organic material.
Thermal Stability of Silicone

200h thermal aging test (4mm thickness)

Methyl silicone  Phenyl silicone  Epoxy

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Phenyl silicone shows better gas barrier characteristics than Methyl silicone, which provides better protection of metals used in the LED package.
Phenyl silicone has a better gas barrier property and is more resistant to silver corrosion, which helps maintain light output.

**Sulfur Corrosion**

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>20 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl silicone</td>
<td><img src="MethylSilicone.png" alt="Image" /></td>
<td><img src="MethylSilicone20.png" alt="Image" /></td>
</tr>
<tr>
<td>Phenyl silicone</td>
<td><img src="PhenylSilicone.png" alt="Image" /></td>
<td><img src="PhenylSilicone20.png" alt="Image" /></td>
</tr>
</tbody>
</table>

**Test condition**
- 1.2 g of sulfur powder in a 450 ml bottle
- Aged at 80°C for 20 hours
- 5050 PKG

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Two-part optical encapsulant

Part A

Part B

Mix Parts A and B (Typically mixed with Phosphor)

A + B Mixed

Dispensing

Cured by Heat

Cured

Process – Dispensing
Process – Compression Molding

1. Release film loaded
   - Upper Mold
   - Release Film
   - Lower Mold (Main Cavity)

2. Film set on bottom by vacuum
   - Vacuum

3. Substrate placed on upper mold
   - Substrate
   - Vacuum

4. Silicone dispensed
   - Silicone
Process – Compression Molding

5. Pre-heated (Degassed)

6. Mold clamped and silicone cured

7. Mold opened and finished

Vacuum

Full Clamp

Compression Molding System

Lens Array

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Silicone White Reflector

Dow Corning Silicone Product Line
Silicone White Reflector

Silicone-based Reflector for LED
- Superior thermal reliability
- High light reflectivity
- Fast cure for high throughput molding process
- Compatibility with silicone encapsulant

Reflector of LED Package
# Silicone White Reflector

## Thermal Stability of Silicone Reflector

<table>
<thead>
<tr>
<th></th>
<th>Reflectance After 180°C Aging</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 hours</td>
</tr>
<tr>
<td>Silicone</td>
<td></td>
</tr>
<tr>
<td>Epoxy</td>
<td></td>
</tr>
<tr>
<td>Liquid Crystal Polymer</td>
<td></td>
</tr>
<tr>
<td>Nylon</td>
<td></td>
</tr>
</tbody>
</table>

Silicone has superior thermal stability and resistance to yellowing.
Silicone reflector shows stable reflectance at visible wavelength during aging at 180°C.
Process – Transfer Molding

1. Spray releasing agent and place lead frame

2. Dispense silicone

3. Mold close, plunger up and cure silicone

4. Mold open and finish
Process – PMC and Packaging

Post Molding Cure and Packaging

1. Post molding cure and deflash

2. Chip bonding and wiring

3. Encapsulation and dicing

Test Conditions
- Molding: 130°C/3 min
- Post cure: 150°C/2 hrs
- Deflash: ED water jet

Molded Silicone Reflector
Silicone Applications in LED Lighting Assembly
Example of Applications (Lamps)

Remote Phosphor technology has many patents from different companies. Dow Corning is not responsible for the use of this technology, or any IP related subject.
Example of Applications (LED Luminaires)

- PCB Conformal coating
- LED chip encapsulants
- Thermal interface materials
- Sealants for dust and moisture protection
- Secondary optics (lenses)
- Adhesives for environmental seals
- Internal driver
- Thermally conductive encapsulants for power components
- Thermal pottants for heat control
Optical Materials for Lamps and Luminaires

Moldable Optical lenses

Remote Phosphor; Diffuser

Light Guides

White Reflector

Silicones benefits across the entire lighting value chain
- Thermal stability
- Transparency
- Photo stability
- Enhanced light output efficiency
- Easy processability
- Lower cost of ownership
- Enhanced Protection
- Enhanced reliability and lifetime
# Thermal Challenges for Materials in Lighting

<table>
<thead>
<tr>
<th>Light</th>
<th>Energy</th>
<th>Incandescent (60 W)</th>
<th>Fluorescent (Typical linear CW)</th>
<th>Metal Halide</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Visible Light</td>
<td>8%</td>
<td>21%</td>
<td>27%</td>
<td>20-30%</td>
</tr>
<tr>
<td></td>
<td>IR</td>
<td>73%</td>
<td>37%</td>
<td>17%</td>
<td>~0%</td>
</tr>
<tr>
<td></td>
<td>UV</td>
<td>0%</td>
<td>0%</td>
<td>19%</td>
<td>0%</td>
</tr>
<tr>
<td>Heat</td>
<td>Convection and Conduction</td>
<td>19%</td>
<td>42%</td>
<td>37%</td>
<td>70-80%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

- Adoption of LM-80 and LM-79 standards changing expectations for materials technology development
- Materials that are acceptable at t=0 may not be acceptable at t=6000 hours

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Dispensable / Printable Pad Concept

• A fabricated pad is one that is coated onto some kind of liner, cured and then cut into pieces for use such as a gap pad (below left).

• A dispensable pad is a pad that applied to the application substrate in it’s wet state and cured in place (below right). Pad may be screen/stencil printed or dispensed.
Thank you

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