Silicones & Phosphors in Solid State Lighting
DoE SSL Manufacturing R&D Workshop             May 2014

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Dow Corning: a company founded on innovation

A passion for innovation started our company...

... and made significant innovations possible throughout the decades

Dr. J. Franklin Hyde
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.
Silicone Solutions for SSL Lamp Assembly

- Adhesives for environmental seals
- Conformal coating
- Thermal interface materials
- LED chip encapsulants
- Reflector materials
- Optics (remote phosphor)
- Secondary optics (diffuser)

Thermally conductive pottant for lighting driver

DOW CORNING Lighting Solutions
Silicone Design, Process and Application Flexibility

Optic design by LEDiL
## High Temperature and Photostability

<table>
<thead>
<tr>
<th>PDMS</th>
<th>PC</th>
<th>PMMA</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
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**Weathering conditions:**

- Initial
- UV/65°C 6000hrs
- 130°C 6000hrs

Lens design by Gaggione; (*) PC and PMMA NON-STABILIZED grades against UV for highest transmission
Silicones, LEDs & Environment Compatibility

Vast Majority of Silicones in SSL are Pt-catalyzed addition-cure systems
✓ Fast thermal cure
✓ No byproducts or out-gassing
✓ Solvent Free

❖ **BUT** inhibited by range of compounds: S, Se, amines, urethanes, some solder fluxes...

❖ Gas permeable: Water Vapor, VOC, O₂ ... **May Quench Phosphor**
✓ Gases escape with heat & light
→ LED recovery

Test for compatibility in application and assembly.
# Methyl & Phenyl Silicones for LED Lighting

## Sulfur Exposure

<table>
<thead>
<tr>
<th>Property</th>
<th>Methyl silicone</th>
<th>Phenyl silicone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref. Index (n)</td>
<td>1.41-1.43</td>
<td>1.53-1.54</td>
</tr>
<tr>
<td>Light Trans.</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Heat Stability</td>
<td>Excellent</td>
<td>Very Good</td>
</tr>
<tr>
<td>Light Stability</td>
<td>Excellent</td>
<td>Very Good</td>
</tr>
<tr>
<td>Liquid Barrier</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Gas Barrier</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>Recomd. Apps.</td>
<td>2nd Optics</td>
<td>Encapsulants</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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![Graph showing the refractive index (n) of methyl and phenyl silicones over the mole fraction of phenyl in organic groups (％).](image-url)
Impacts of Silicone Viscosity, Phosphor Settling & Thermal Conductivity

Application process control for settling, color, and flux via thermal conductivity

- Phosphor temperature can be higher than the Tj due to Stokes heating & insulation from silicone.
  - Unfilled silicone Thermal Cond. ~ 0.1-0.2 W/mK,
  - Excellent wetting to LED die etc. (low resistivity)
- Heat sink from phosphor through the LED die
- High temperatures may quench phosphors and cause color shifts
- Excess heat may damage silicones
  (~200 °C Me, >150 °C Ph)
- Wide range of Silicone viscosities available
  (<2,000 cPs - >40,000 cPs)

Choose phosphor application and silicone for your design and environment
Always Improving: Increased Thermal Stability

Lumen Maintenance with 200 °C Aging

Answering Continuing Call for High Temp Stability
- Increasingly brighter and higher temperature packages.
- Alternative remote phosphor geometries
- Silicone providers responding with new materials to meet the challenge.

Du’v’<0.001 for all samples
Design and Testing by LumenFlow®, Middleville, MI
Summary:

• Silicone clarity and stability (Heat, Light, Mechanical) critical to the success of SSL
• Design freedom with complex designs and functions
• *Must* test for compatibility in assembly and application environment
  – Silicone Pt-cure sensitive to inhibition
  – Silicones permeable to gases which may quench phosphors
• Selection of silicone for your device & assembly will help minimize any issues
• Developing new materials to meet needs of high performance applications

Thank You!

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