Thermal Management of LEDs in Automotive Applications

Long popular with automotive design engineers for lighting inside the car, including dashboard, vanity, and accessory lighting, LEDs are now in use outside, including turn signals, running lights, tail lights, brake lights, and headlights. LEDs are popular because they provide:

- Enhanced reliability and durability
- Reduced power consumption
- Compact form factor
- Improved contrast and color accuracy
- Illumination at greater distances
- Full brightness within nanoseconds

The small size and distinctive look of LED lighting allows automotive design engineers to be more creative in their approach to how car headlights look and function. As a result, they can explore alternative types of headlamps that not only combine high beams, low beams, running lights, fog lights, and turn signals, but even lights that corner, like those in a new Audi A8. However, all this functionality comes at a price. Brighter, more functional, LED systems require more power, and get hot very quickly. Design engineers must contend with both power management and heat dissipation to successfully incorporate LEDs into their designs.

Fabrico can help design engineers working in transportation to select and effectively use the thermal interface materials (TIMs) their LED lighting applications require.

More Light, More Heat

Heat is the bane of LEDs, shortening lifetime, damaging brightness, degrading efficiency, and diminishing color – all unacceptable consequences in headlights, tail lights, turn signals, and brake lights, where safety concerns are paramount.

LED manufacturers have developed LED drivers to control current so that as temperatures rise, less current is sent to the LED.
In addition to controlling power, LED light manufacturers are also investing in ways to dissipate heat from the LED. An incandescent Xenon bulb, which an LED headlight would replace, eliminates heat through radiation. LEDs require a more circuitous path. An LED and its driver circuit need heat dissipation incorporated into their design so that heat can be taken away from the LED and thermal runaway avoided.

**Dissipating Heat**

There are numerous ways to manage and dissipate heat:

- Thermally conductive adhesives
- Metal and metal-clad substrates
- Thermal interface materials
- Liquid coolant
- Heat sinks
- Fans

LED lighting system designs for automotive rarely have room for liquid cooling or fans. In general, they rely on heat sinks, heat tubes, thermal interface materials, and thermally conductive adhesives to efficiently dissipate heat.

Material and adhesive manufacturers are working on new materials to use both as a substrate and a TIM.

Substrates can include thermal clad laminates that incorporate metal or metal foil, dielectrically formulated polymer (which can include prepreg), thermally conductive inorganic fillers, and a metal base which is often aluminum or copper.

TIMs typically sit between the LED and the heat sink and eliminate any air between the two. The surfaces of these two devices are usually characterized by a microscopic surface roughness where contact often only happens at high points. The gaps form air-filled voids. Air is a very poor conductor of heat and adds resistance to the heat flow. TIMs are good conductors of heat and help improve heat flow while filling these gaps.

Thermally conductive materials used as TIMs come in two basic forms: wet dispensed and fabricated. Fabrico can help design engineers select the form that will work best in the application and manufacturing process.

**Wet Dispensed**

Thermally conductive, wet dispensed materials include adhesives, encapsulants, gels, compounds, and phase change materials.

**Adhesives**

- One- and two-part silicones with fast thermal curing or RTV curing that resist humidity, provide good dielectric properties, and are low stress and noncorrosive;
- Filled acrylic polymers that are highly conformable and slightly tacky;
- Epoxies for applications requiring high adhesive strength, good surface wet-out, and gap fillers.

**Encapsulants**

- Two part silicones, with a flowable liquid that cures to a flexible elastomer at a constant cure rate.

**Gels**

- Two-part silicone-based formulations loaded with conductive fillers, offering low to moderate viscosity, long working times, fast thermal cure, good dielectric properties, and low stress and corrosion.

**Compounds**

Sometimes referred to as “form-in-place” compounds, they include:

- Non-curing, thermally conductive silicone RTVs (room temperature vulcanizing materials) that can be used to form thermal paths where the distance between an LED and a cold surface is variable;
- High thermal conductivity and high temperature stability.
Phase-change materials
- Performance of a thermal grease after they reach melt temperature with high viscosity and good gap filling;
- Some compressive force required to form a very thin bond line.

Solder and solder hybrids
- Low-melt metal alloys that flow at room temperature and provide a very thin bond line.

Fabrico can help integrate wet dispensable materials into an existing production line using dispensing equipment to provide an efficient and cost-effective solution for thermal management in LED manufacturing.

Fabricated Materials
Unlike wet dispensable materials, fabricated TIMs are solids that have been laminated and die-cut to a specific shape for easy application. These materials can be applied cold, pre-cured, cut-to-fit, and with a release liner for easy handling. Since they can be highly compressible on both sides, they are excellent at filling gaps on even the most irregular surfaces and won’t pump-out or dry-out.

Fabricated materials include adhesive tapes, phase-change materials, thermal insulating pads, and gap filler pads.

Adhesive tapes
- Silicone treated polyester transfer tapes with high mechanical strength, good surface wet-out, and good shock and vibration performance;
- Acrylic soft tapes that are flame retardant with good gap filling and thermal transfer;
- Acrylic- or silicone-based pressure-sensitive adhesive (PSA) tapes that bond heat sinks securely to power dissipating components.

Phase-change materials
- High thermal grease performance in a “peel-and-stick” format;
- Compression brings the surface together and causes material flow.

Thermal insulating pads
- Silicone- or acrylic-based, providing superior thermal performance with or without bonding;
- Very high dielectric strength and volume resistivity.

Fabricated TIMs have been laminated and die-cut to a specific shape for easy application.

Gap filler pads
- Pads that can be cut into complex shapes;
- Thermally conductive pads that incorporate EMI absorbing characteristics.

Choose an Experienced Converter/ Materials Supplier
Working with an experienced converter and materials supplier, like Fabrico, is critical to successful thermal management for LED applications.

From identification and selection of the appropriate materials and adhesives, to slitting, layering, laminating, precision die-cutting, and packaging of the finished product, an experienced converter can provide the design, prototyping, testing, and manufacturing knowledge to complete advanced LED automotive lighting system designs.

Tier 1 and Tier 2 automotive suppliers working with HB LEDs depend on Fabrico to provide:
- Precision die-cutting, multi-layer laminating, and slitting to tight tolerances;
- Access to a range of thermal management solutions;
- Testing capabilities.

Fabrico provides servo driven rotary die-cutting, CNC die-cutting, laser die-cutting, and water jet cutting to meet the complex specifications of thermal management for electronic components. For example, a servo driven rotary die-cutter can maintain tight tolerances ranging from 0.015” to +/- 0.005” at speeds up to 500 fpm, and is ideal for the complex, multi-layer die-cutting, and lamination that a thermal interface pad or tape may require.
Tier 1 and Tier 2 automotive suppliers are looking for precision die-cutting, multi-layer laminating, and slitting to tight tolerances.

For complex foam tape die-cutting, water jet technology provides clean edges with no distortion. Laser die-cutting, kiss-cutting, slitting, and laminating can also be used in converting applications.

Fabrico has a fully equipped test laboratory that can ensure that customer materials meet designed-in specifications before they move to the factory floor, often eliminating the need to test materials at the customer’s facility. The test lab offers:

- Accurate and precise part dimension measurement and verification;
- Adhesive/release liner to determine converting properties and high speed application characteristics;
- Material strength measured to ensure that material meets application requirements;
- Static shear testing to measure the cohesive strength of the adhesive to withstand a fixed load over time;
- Material weight measurement to determine adhesive coating weight;
- Microscopic imaging to determine differences between adhesive and material over time;
- Dielectric testing to determine a material’s electrical insulation properties;
- Thermal testing for materials and adhesives;
- Resistance and voltage testing to provide a complete profile of the electrical properties of a material or adhesive.

About Fabrico
Fabrico’s materials converting capabilities include: custom design solutions for applications that require slitting, laminating, and die-cutting. Laser die-cutting, kiss-cutting, and water jet cutting are available depending on the application and materials being used.

With more than 30 years of materials experience, Fabrico engineers also understand the impact of a material selection on the overall manufacturing process, and design material systems that optimize production efficiency and improve overall cost-effectiveness.

Material Partners
Fabrico has strategic relationships with world-class materials suppliers, such as 3M, Loctite®, and Adhesives Research to assist its customers in selecting the best material for the intended use and to expedite materials sourcing. Whether adhesive films or liquids, all critical material properties are considered in every Fabrico project, including chemical, thermal, and moisture resistance.