Lumen Maintenance of White Luxeon™ Power Light Sources

The introduction of the Luxeon™ Power Light Source family from Lumileds Lighting brings a higher level of performance for Light Emitting Diode (LED) technology to the marketplace. Now, solid-state Luxeon emitters are available that generate 5 to 50 lumens (depending on color) of luminous flux per emitter. White Luxeon Power Light Sources, which will typically generate 20 lumens per emitter, provide the most lumens per package for any commercially available white solid-state emitter. This application brief has been written to describe the reliability data available for white Luxeon Power Light Sources.

Construction

Traditionally, LED light sources have been constructed using a small LED chip mounted in an optical-grade epoxy package.

The packaging construction of a typical indicator LED is shown in Figure 1.

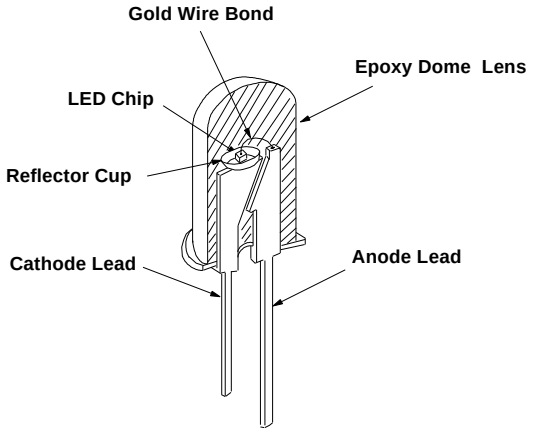


Figure 1

Cross section view of 5mm Indicator LED.

The Luxeon Power Light Source family uses a totally new packaging technology. Luxeon uses a semiconductor chip mounted on a heat-sink slug, which provides much better thermal properties as compared to typical indicator LEDs. Luxeon is available in two configurations. The AlInGaP Luxeon is available in Red, Red-orange, and Amber colors. The InGaN Luxeon is available in White and Blue, Cyan, and Green colors. The improved thermal properties and larger chip size allow the Luxeon to be operated at much higher operating currents than historically possible. Solid state light sources exhibit self-heating with applied power. The self-heating of a conventional 5mm white LED limits the power dissipation and drive current to around 20 mA. At 20 mA, a conventional 5mm white LED generates about 1 lumen of white light. While the Luxeon also exhibits self-heating, its improved thermal properties allow it to be driven at 350 mA, obtaining 20 lumens of white light. Thus, an array of 5mm LEDs would be needed to generate as much light as a single Luxeon Power Light Source. In fact, the Luxeon can achieve much higher lumen density (lm/m^2) than a close-packed array of 5 mm LEDs and thus enables lighting applications never before feasible with LED technology.

The Luxeon Power Light Source also includes many other packaging improvements designed to increase the light output and reliability of the package. The semiconductor chip inside the Luxeon package is optimized for light extraction efficiency, thermal management and current density. The semiconductor chip in the InGaN Luxeon and White Luxeon is soldered to a patented silicon sub-mount chip, which includes electrostatic discharge (ESD) protection. In addition, Lumileds has designed the white Luxeon in such a way as to eliminate several mechanisms that negatively effect lumen maintenance including:

- The Luxeon emitter has a 20X reduction in thermal resistance compared to standard 5mm indicator LEDs. This allows the Luxeon to be driven at currents up to 350 mA.
- Luxeon uses a patented optical coupling silicone encapsulent that does not yellow like optical-grade epoxy resin. This significantly increases the lumen maintenance over the life of the Luxeon.
- Luxeon uses a leadframe material that is protected from discoloration due to oxidation. This also helps improve the lumen maintenance.
- Luxeon uses a silicon, sub-mount chip underneath the semiconductor chip such that die attach epoxy only contacts the silicon chip but not the solid state chip. This also helps improve lumen maintenance.

The packaging construction of the Luxeon emitter is shown in Figure 2.

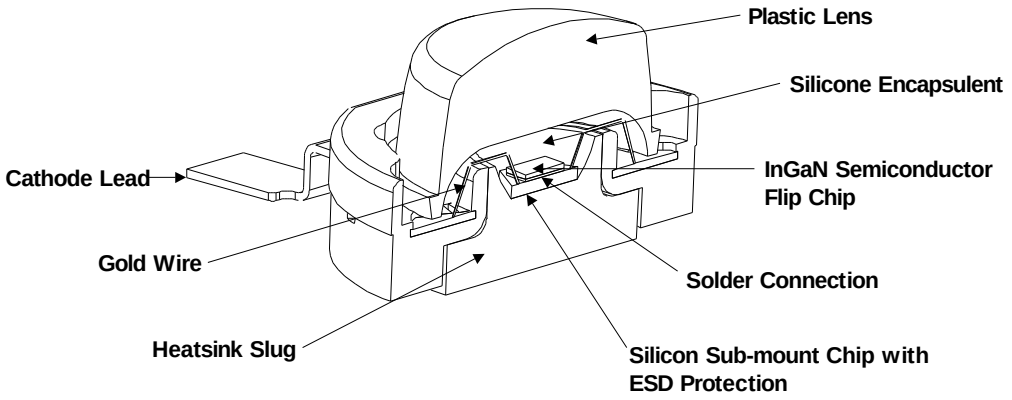


Figure 2

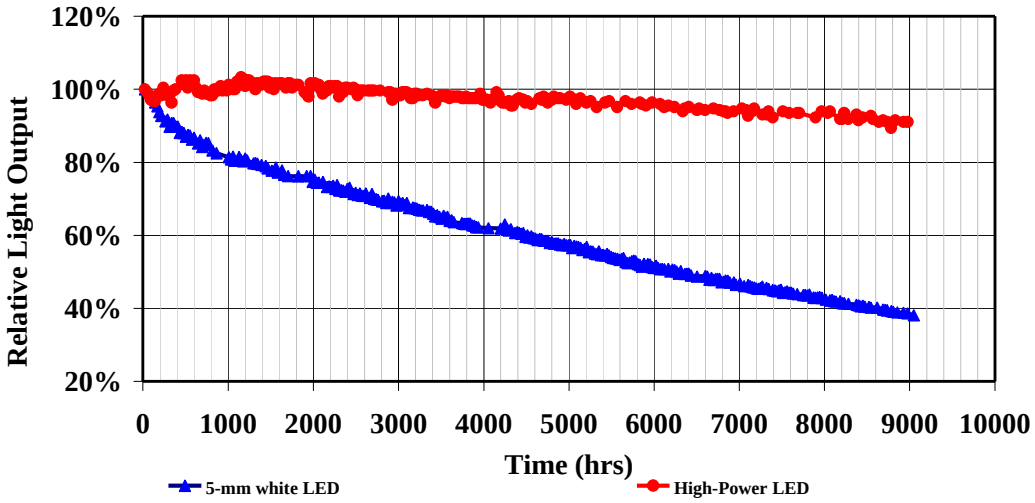
Cross section view of InGaN Luxeon emitter.

Unlike many competitive non solid state light source technologies, the resulting package is mechanically rugged. The Luxeon Power Light Source family, like computer chips, uses a gold wire(s) for interconnection of the semiconductor chip in the AlInGaP Luxeon or the silicon sub-mount chip in the InGaN Luxeon and white Luxeon. This gold wire is mechanically supported by the optical-grade encapsulent and helps provide the mechanical ruggedness and resistance to mechanical shock and vibration inherent in semiconductor technology. This can be contrasted to incandescent and halogen filament light sources, which are prone to breakage.

The operating and storage temperatures of solid state light sources tend to be limited due to the mechanical properties of the encapsulent. At very cold temperatures, encapsulents can become very hard and brittle. Today's encapsulent materials can withstand temperatures below -40ºC, so the lower limit does not restrict very many potential applications. At very high temperatures, the encapsulent can expand and soften. Excessive temperature extremes can cause a large mechanical strain on the gold wire and can lead to premature failure. For these reasons, the maximum internal junction temperature of Luxeon emitters is 120ºC. Luxeon emitters can withstand hundreds of non-operating temperature cycles in the range of -40 to 120ºC. However, the failure rate can be greatly accelerated for temperature cycles at higher and lower temperature extremes.

Lumen Maintenance

Assuming that the system operates within the maximum junction temperature limit, then the most common failure mode of a solid state emitter will be a gradual reduction in light output during the operating time of the semiconductor. The Lighting Research Center recently conducted an independent study on the lumen maintenance of 5 mm white LEDs and high-power light sources. Their results are shown in Figure 3. Note that the light output gradually becomes less over time. The 5 mm white LEDs have reached 50% light output at 6000 hours while the high power white light sources still have 90% light output at 9000 hours.



Lighting Research Center Data - April 2002

Figure 3

Relative light output from 5-mm indicator lamps and high-power illuminator LEDs, as a function of operating time (Narendran and Deng, 2002).[1]

White Luxeon Power Light Sources have also been tested for lumen maintenance at Lumileds. Figure 4 shows the average lumen maintenance at 4000 hours for white Luxeon Power Light Sources driven at 0.35A at 25°C case temperature ($T_J \cong 45°C$). Note that virtually no lumen depreciation occurred after 4000 hours. Figure 5 shows the average lumen maintenance at 2000 hours for white Luxeon Power Light Sources driven at 0.35A at 85°C case temperature ($T_J \cong 105°C$). Note that the lumen depreciation is somewhat higher at elevated temperatures. Additional long-term tests at various ambient conditions are currently underway at Lumileds. Ongoing technological developments are expected to further improve the reliability and lumen maintenance of Luxeon Power Light Sources. As further data becomes available, this application note will be updated with this new data.

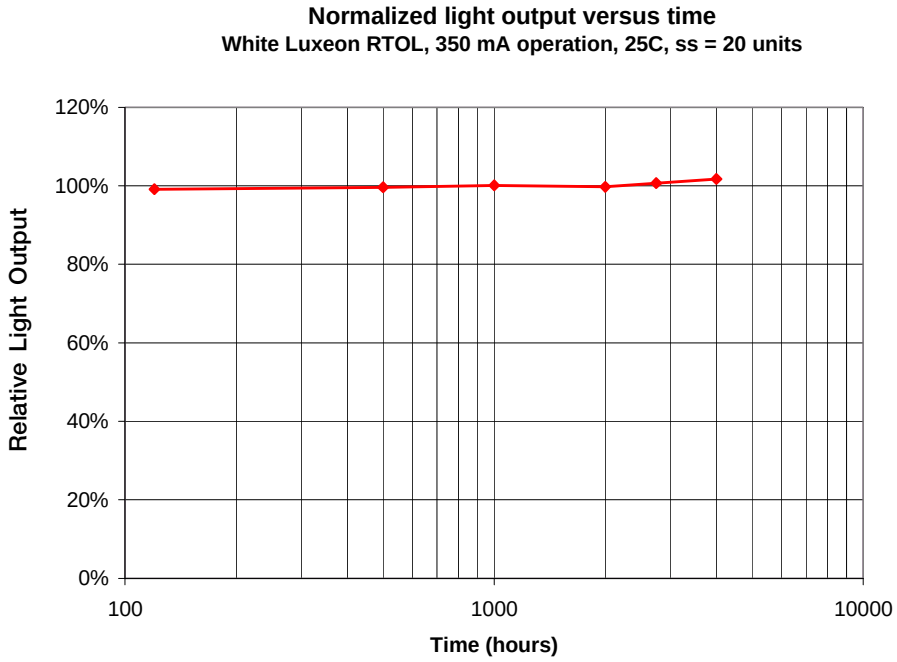


Figure 4

Relative light output for white Luxeon Power Light Sources driven at 0.35A, 25°C case temperature ($T_J \cong 45°C$).

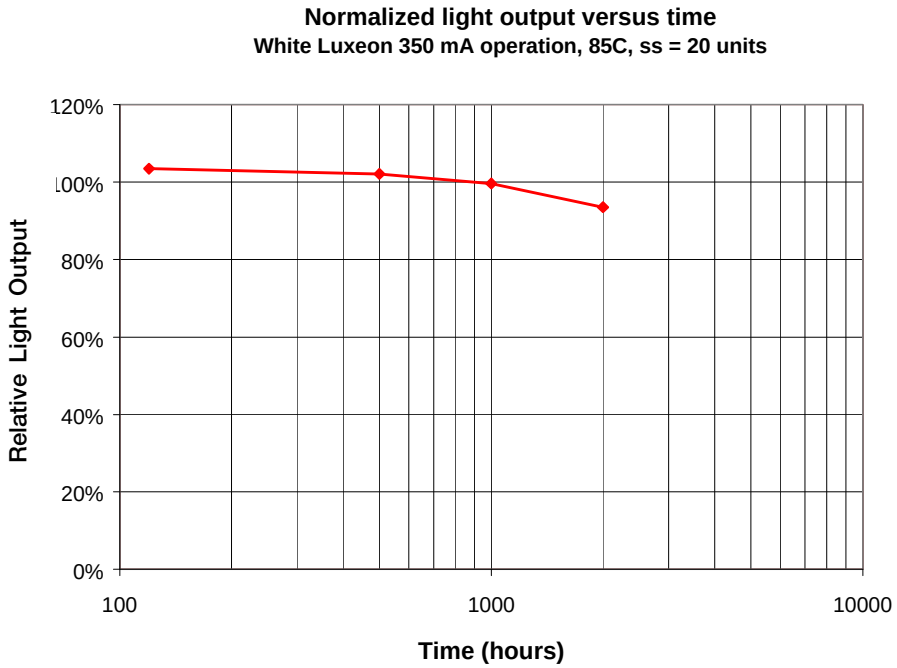


Figure 5

Relative light output for white Luxeon Power Light Sources driven at 0.35A, 85°C case temperature ($T_J \cong 105°C$).

References

1. Nadarajah Narendran and Lei Deng 2002, "Performance Characteristics of Light Emitting Diodes," Proceedings IESNA Annual Conference, 2002.