Measuring LED Lens Surface Temperature with Thermocouples

LED reliability depends on keeping systems below certain temperature thresholds, which requires accurate measurement of system operating temperatures; however, current methods using thermocouples to measure the lens temperature in high radiant flux environments can lead to large measurement errors. Most of the error is due to absorption of visible radiant energy by the thermocouple. The LRC conducted a study to understand the problems in using thermocouples to measure LED lens surface temperature and to find a solution to improve measurement accuracy.

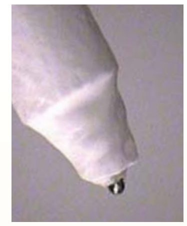
Testing measurement accuracy

LRC researchers used an infrared (IR) imaging camera and J-type thermocouples to verify their hypothesis that a thermocouple-measured lens temperature would have a positive error when visible radiation was present but a similar temperature measurement to the IR camera if no visible radiation was present. Measurements were taken of a multi-chip LED package with a single primary lens at both the LED package's case temperature location (no visible radiation) and at the lens' geometric center (visible radiation present). The results verified that the thermocouple absorbed some amount of the visible radiation, leading to a higher measured temperature than that measured by the IR imaging camera (Table 1).

Table 1. LED package lens temperatures at the lens' geometric center (GC; visible radiation present) and at the reference case temperature location (Tc; no visible radiation), measured with an IR imaging camera and a J-type unshielded thermocouple with no thermal interface material. The numbers in parentheses indicate the deviation of the thermocouple temperature measurement from the IR imaging camera-measured temperature.

Drive current (mA)	IR camera @ GC avg. temp. (°C)	Thermocouple @ GC avg. temp. (°C)	IR camera @ Tc avg. temp. (°C)	Thermocouple @ Tc avg. temp. (°C)
1000	100.1	110.5 (+10%)	47.0	47.2 (+1%)

Improving accuracy with shielding



Thermocouple with shielding

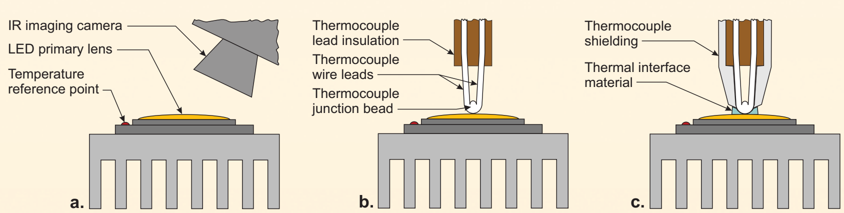
To reduce the thermocouple's absorption of visible radiation emitted from the LED primary lens, LRC researchers used a highly reflective, commercial grade pipe thread sealant, polytetrafluoroethylene (PTFE), to shield the thermocouple lead wires. The PTFE material was used to wrap the thermocouples from the thermocouple junction up to a length sufficient enough to shield the lead wires from visible radiation. The thermocouple junction was left exposed in order to minimize the negative error from increasing the thermal resistance via heat conduction between the primary lens surface and the thermocouple junction. Thermal adhesive tape and a silicone elastomer with matching refractive index to the primary lens were used as thermal interface materials to further reduce measurement errors. Lens temperature measurements were taken again using the IR imaging camera and the shielded thermocouples. The results showed that the shielded thermocouple measurements were similar to those of the IR imaging camera within ±2°C (Table 2).

For details

Perera, I.U., N. Narendran, and Y. Liu. 2013. Accurate measurement of LED lens surface temperature. *Proceedings of SPIE* 8835: 883506. www.lrc.rpi.edu/programs/solidstate/pdf/Perera-SPIE-2013a.pdf.

Table 2. Temperature measurements with PTFE-shielded thermocouples and alternative thermal interface materials. The numbers in parentheses indicate the deviation of the thermocouple measurements from the IR imaging camera-measured temperature values.

Drive current (mA)	IR camera temp. (°C)	PTFE-shielded thermocouple with thermal tape (°C)	PTFE-shielded thermocouple with silicone (°C)
1100	96.4	98.1 (+2%)	98.2 (+2%)



Experimental setup for IR imaging camera and thermocouple temperature measurements: (a) IR imaging measurement; (b) thermocouple with no lead wire shielding and no thermal interface material at the junction bead; (c) same as (b) with thermocouple lead wire shielding and thermal interface material at the junction bead.

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