RADIOMETRIC DETERMINATION OF THE JUNCTION TEMPERATURE OF AN LED

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Junction temperature *Tj* is an important parameter affecting the lifetime of an LED. In an assembled LED lamp, LEDs are not electrically accessible, thus obtaining *Tj* is challenging. We have studied the relationship between the junction temperature and spectrum for various LEDs in order to develop a method for determining the junction temperature from the LED spectrum.

The high energy side of an LED spectrum is typically expected to follow the Maxwell-Boltzmann distribution [1]. Although the Maxwell-Boltzmann distribution by itself may not be sufficiently accurate for determining the temperature of blue quantum well LEDs, we have studied the possibility of calibrating the measurements to enable accurate determination of the junction temperature of red, blue and white phosphor LEDs.

Various LEDs were extracted from solid state lamps. The junction temperature – voltage characteristics of the LEDs submerged in an oil bath were determined over a wide temperature range of 30 – 150 °C using short current pulses. Spectra of the LEDs were then measured at varied temperatures. Maxwell-Boltzmann distribution was fitted to the 1 % to 70 % intensity region in the high energy side of the LED spectrum. The fit gave the inverse derivative temperature *TID* for the LED. Figure 1 shows an example fit for a set of spectra for a blue LED extracted from a Philips Masterled lamp at various temperatures and the obtained *TID*'s. We also studied the characteristic temperatures *Tc* [1] obtained from the *TID*'s. Generally, *TID* and *Tc* deviate from *Tj*. Figure 2 shows the relationship between the *TID* and *Tj* for six specimens of the blue Philips Masterled LEDs.

There is a linear dependence between the *Tj* and *TID*. The slope is rather similar, 0.804 with a standard deviation of 0.038, for all six LEDs. However, the intercept term is considerably different for all LED specimens varying between -21 and -116 K. These results indicate that *Tj* can be obtained for any of the LEDs from the spectrum using the average of the slopes. One measurement e.g. at the room temperature is needed to fix the intercept term. With these conditions, the standard deviation of the radiometrically obtained temperatures at e.g. *Tj* = 120 °C would be 5 K. We also studied the effect of the current (density) on the temperature determination. Currents were varied by a factor of 2.5. The effect on the inverse derivative temperatures was less than 0.5 % for the blue LEDs.

The measurements were repeated for three red LEDs extracted from an Osram Parathom Classic A80 lamp, and three white LEDs extracted from an Osram Parathom Classic A60 lamp. The slope was 0.826 ± 0.026 for the red LEDs and 0.501 ± 0.029 for the white

LEDs. The intercept terms were 20 – 37 K for the red LEDs and -2 – 42 K for the white ones. Detailed results will be presented in the conference.
We conclude that the Maxwell-Boltzmann distribution works satisfactorily with red LEDs and, with calibration, also with some white and blue LEDs. However, LEDs at different wavelengths need to be calibrated separately because the relationship between the *TID* and *Tj* depends heavily on the wavelength. It also varies from a manufacturer to another and, as was noted with the blue Philips LED, the behaviour may even vary considerably between specimens of similar LEDs. Nevertheless, determination of the junction temperature from the LED spectrum seems to give access to LED lifetime estimation via a new method.

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[1] Z. Vaitonis, P. Vitta, and A. Zukauskas, "Measurement of the Junction Temperature in High-Power Light-Emitting Diodes from the High-Energy Wing of the Electroluminescence Band," *J. Appl. Phys.* **103**, 093110 (2008).

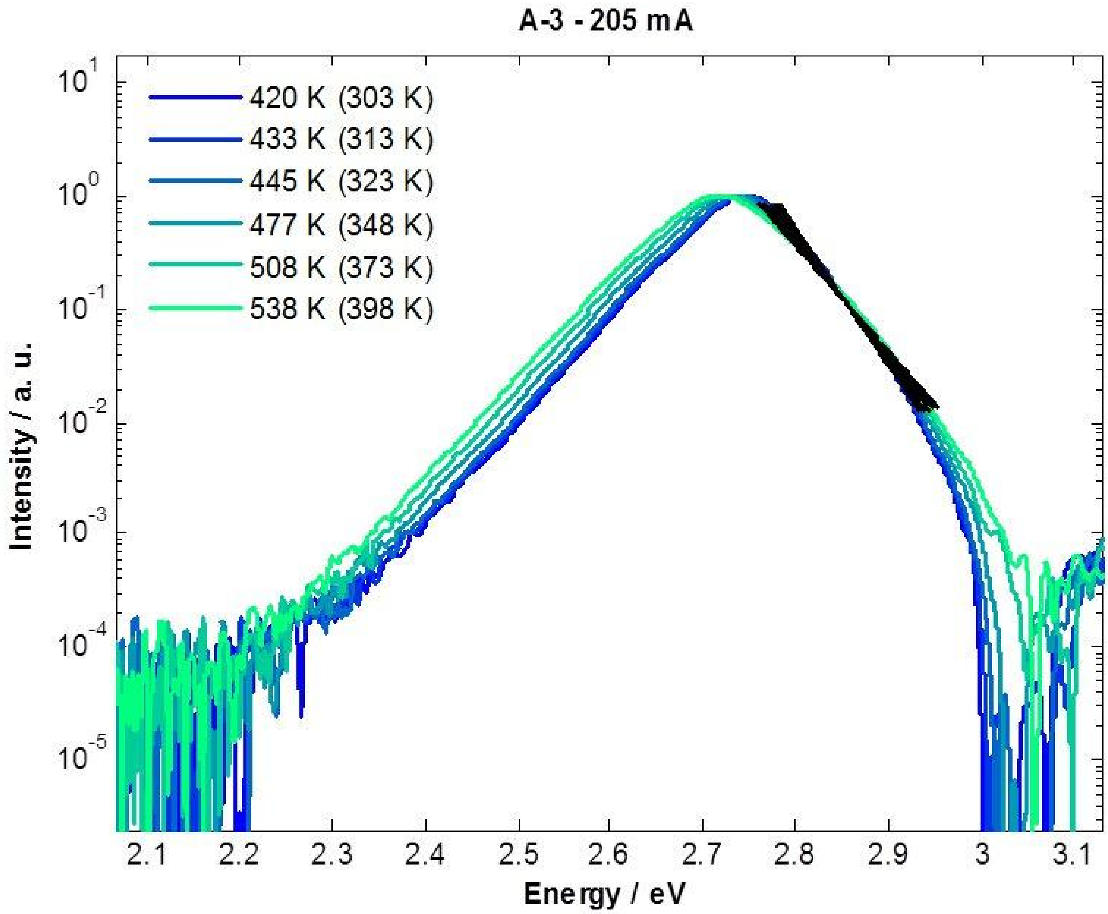

Figure 1. Spectra of a blue LED extracted from a Philips Masterled lamp at temperatures 303 – 398 K (colored lines), fitted Maxwell-Boltzmann distributions (black lines), and the obtained inverse derivative temperatures *TID* (legend). The current of the LED was 205 mA.

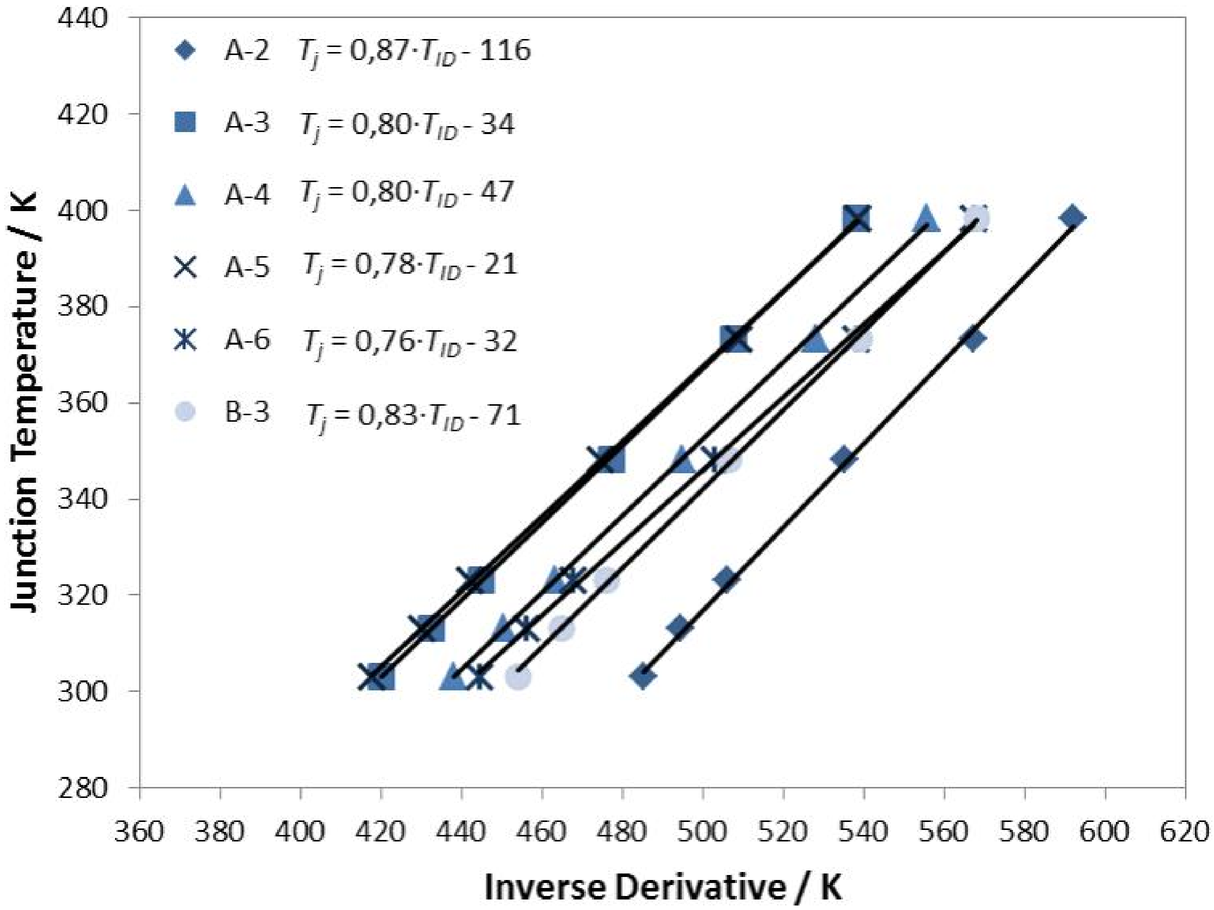

Figure 2. Relationship between the junction temperatures *Tj* and the inverse derivative temperatures *TID* for six blue Philips Masterled LEDs denoted as A-2, A-3, ..., A-6, B-3.