Study of Thermal Properties of Packaged Light-Emitting Diodes by Transient Junction Temperature Measurement

by

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ABSTRACT

Thermal management is one of the most important problems of high power light-emitting diodes (LEDs). It is one of the main causes affecting the performance of LEDs, such as light output power or external quantum efficiency. Moreover, the LED temperature influences the lifetime of the LED chips, encapsulants as well as the thermal interface material (TIM). Thus, thermal management is always essential for LEDs, especially for high power LEDs.

An electrical measurement approach, namely the forward voltage method, is applied to measure the junction temperature in this Master Thesis, due to its high accuracy, low cost, and an easy measurement procedure. The forward voltage method has two steps: calibration and junction temperature measurement. In the calibration step, the so-called K-factor, which is the forward-voltage temperature coefficient (dV_f/dT), is obtained. The theoretical temperature dependence of the forward voltage is presented. The thermal resistance measured in the steady state and thermal impedance measured in the transient state are two basic parameters that allow us to obtain the thermal characteristics of LEDs.

Analytical calculations of 1D thermal dissipation are presented. An *RC* circuit analogue model shows that the transient response of the junction temperature to a step-function-like injection current is a multi-exponential function of time with each exponential function having a different time constant. These time constants are very different from each other, thus can be easily separated in thermal impedance-versus-time curves when plotted on a logarithmic time axis. The thermal resistance and the thermal impedance of the cooling response to a step-function-like injection current of a flip-chip GaN ultraviolet (UV) LED are measured in this Master Thesis. The junction temperature measurement shows that the thermal resistance from the chip to the heat sink is much smaller than the thermal resistance from the heat sink to the ambient. The thermal impedance measurement shows that two-exponential decay function fits very well with the junction temperature transient decay curves of the sample under test. Fitting parameters for the decay curves yield that the thermal resistance of the gold bumps and the silver epoxy paste dominate the thermal resistance from the chip to the heat sink.