Heating Curve Analysis

A Heating Curve is a plot of semiconductor device junction temperature as a function of time, starting as close to the initial time of power application as possible out to some point corresponding to a desired reference. The fact that heat generated in the semiconductor device junction area takes a finite time to propagate from the junction outward results in the shape of the Heating Curve.

Figure 1 shows a simple device/package/heat sink structure – one that closely approximates package configurations for a high-power LED, a rectifier diode, a power transistor, or even an integrated circuit. In most cases for this structure, nearly all the heat generated in the junction pass through the structure elements to the heat sink.

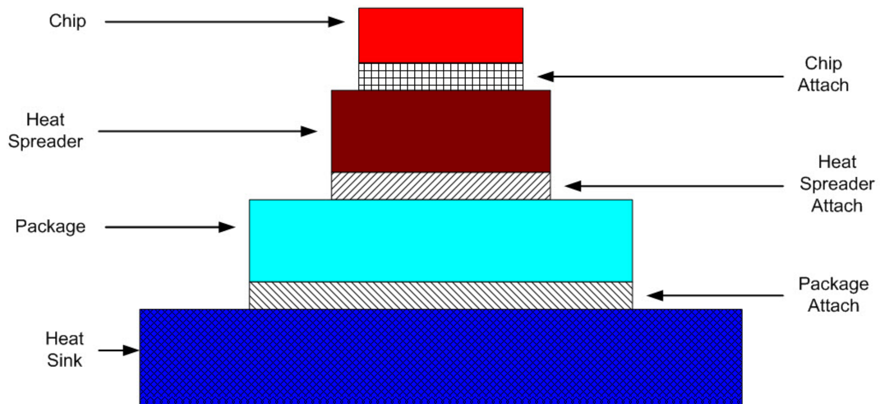

Figure 1

Each major element – chip, heat spreader, package - in the heat flow path is successively bigger. The combination of volumetric size and material attributes (i.e., thermal conductivity, thermal capacitance, etc.) determines how much time it takes for the heat to travel through the material to the next material in the path. Each element will maintain a relatively constant temperature across it until the thermal time constant of the element is overcome.

The minor elements in the heat flow path – chip attach, heat spreader attach, and package attach materials – are usually kept as thin as possible, thus allowing the heat to pass quickly through the material.

The impact of the differences between the major and minor elements in the heat flow path become apparent when the junction temperature (or related parameter based on the junction temperature, like thermal impedance) is plotted as a function of the time the heat is applied. An example of Heating Curve generated for the Figure 1 structure is shown in Figure 2.

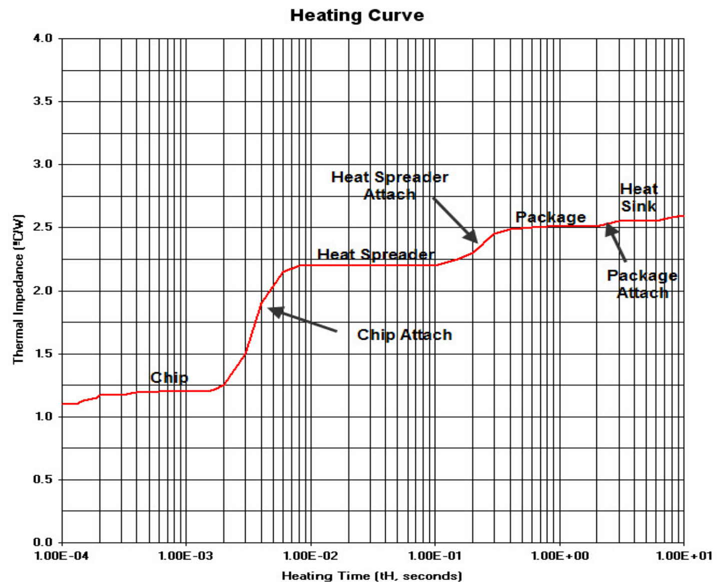

Figure 2

THERMAL ENGINEERING ASSOCIATES, INC.
www.thermengr.com

2915 Copper Road
Santa Clara, CA 95051
USA

Phone: 650-961-5900
FAX:: 650-323-9237
E-mail: info@thermengr.com

Heating Curve Analysis (cont'd)

The Heating Curve shown was generated for an LED mounted on a ceramic heat spreader which was in turn mounted on an aluminum plate. The ceramic served not only to spread out the heat laterally but to also electrically isolate the LED from the aluminum plate. The finned heat sink was approximately four times larger than the aluminum plate in X-Y dimension and approximately 15 times thicker than the plate; the heat sink core was approximately twice as thick as the plate.

The power applied to the LED during the measurement was 5W. The light conversion efficiency for this device was 10%; this was determined by a separate measurement using an integrating sphere for the light power output. The thermal impedance data was corrected to account for the light power output reduction in Heating Power.

As would be expected from this structure with heat flow in only one path, the Heating Curve shows four distinct plateaus, each corresponding to one of the major heat flow elements. The impact of the minor heat flow elements is shown as the transition between the major elements.

The impact of each minor element is measured by subtracting the thermal impedance at the start of the transition from the value at the end of the transition. For example, the thermal impedance associated with the chip attach is 0.98ºC/W. Similarly, for the heat spreader attach the value is 0.3 ºC/W and for the package attach the value is 0.04 ºC/W. Based on these values, it appears that the total device thermal impedance (2.51 ºC/W) could be considerably lower if a better chip attach was realized. The Heating Curve Analysis provides a way to determine the impact of package assembly materials and techniques in a fast and convenient way as the measurement is electrical and no package modification is required.

It should be noted that the Heating Curve shown is for a specific device and measurement setup. Not all devices will exhibit a curve that so clearly shows the major and minor heat path elements. In many cases, the distinctions between elements in the heat flow path will not be easily discernable with out setup modification, experimental package assemblies, and/or extensive data analysis.

For further information on how the thermal measurements are made, pleases refer to the following

-- **An Introduction to Diode Thermal Measurements (version 6)**

-- **Measurement of junction temperature confirms [Laser Diode & LED] package thermal design**

-- **TB-04 HEATING CURVES AID THERMAL CHARACTERIZATION**