Thermal Transient Testing of LEDs

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Thermal transient testing is a non-destructive way to quickly verify the proper attachment of a two terminal semiconductor die, such as a visible or infrared emitting LED, to a mounting substrate or header. A typical side view is shown in Figure 1. This testing technique can indicate that there may be gaps, voids and/or improperly placed die that could cause premature failure of a device caused by the increased thermal resistance between the die and header. This increase of thermal resistance can cause excessive die temperature, which can cause early failure or increased degradation of a device.

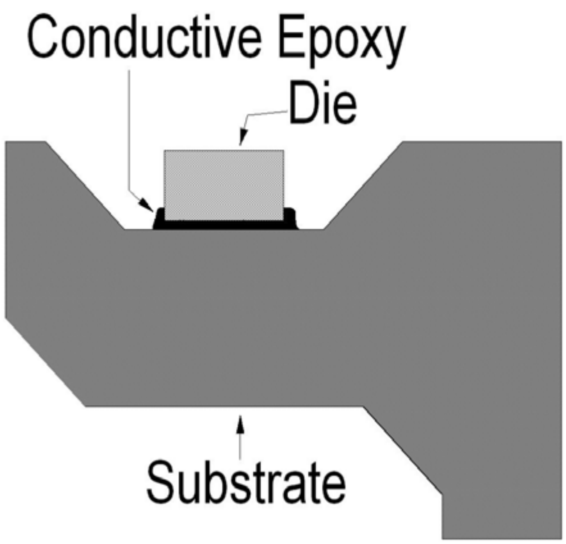

Figure 1 - showing a typical die attachment with conductive epoxy

A non-destructive test method for thermal transient testing is to accurately measure the forward Voltage (Vf) of the die both before and immediately after subjecting the device under test (DUT) to a non-destructive short heating pulse with a small, low-heating measurement current. If a die is improperly attached, it will exhibit a higher thermal resistance between the die and the mounting substrate, which causes the die to heat up more than if it is properly attached. This test method takes advantage of the linear nature of the temperature coefficient (Tc) of the material being tested, which is a change in Vf in semiconductor die with changes in the die temperature. See Figure 2 for a typical waveform. This test method also takes

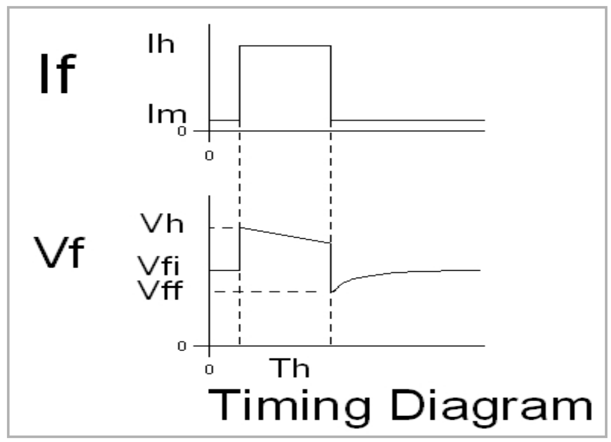

Figure 2 - Showing change in Vf with die heating

advantage of the fact that the thermal mass of a die is typically several orders of magnitude less than that of the mounting substrate. The DUT is initially subjected to a small measurement current, designated Im, that will cause minimal heating of the die, but will be enough to overcome any inherent leakages that may be present. The Vf is measured at the start of a test with the measurement current and saved as Vfi. A short, non-destructive heating current, Ih, is then applied to the DUT. Quickly after removal of the heating current, the measure current is re-applied, Vf is measured again and saved as the final Vf as Vff. A change in forward Voltage, designated ΔVf (Delta Forward Voltage) is calculated by taking the difference between Vfi and Vff. This change in Vf is given by Eq. 1. Typical values for heating period may range from 1 millisecond to over 100 milliseconds. A typical value for Ih would be to use continuous Forward Current (If) current value of the device being tested.

Eq. 1 $$\Delta Vf = Vfi - Vff$$

The ΔVf can be multiplied by the temperature coefficient of the material being tested, and an approximate die temperature rise above substrate temperature may be calculated, as shown in Eq. 2. See Figure 3 for some common temperature coefficients of some semiconductor materials. To calculate the temperature rise of the die, use Eq. 3, which is a combination of Eq. 1 and Eq. 2.

Typical Temperature Coefficient of some Semiconductor Materials

Material	Tc (mV / °C)
Silicon	-2.1
GaAs	-1.4
GaAlAs	-2.33
InGaN	-3.1

Figure 3

Eq. 2 $$\Delta T = \Delta Vf * Tc$$

Eq. 3 $$\Delta T = (Vfi - Vff) * Tc$$

If the Tc of the material is unknown, it may be determined measuring Vf at 2 different temperatures, and putting the values into Eq. 4.

Eq. 4 $$Tc = \frac{(Vf@temp1 - Vf@temp2)}{(temp1 - temp2)}$$

If you need to measure Tc for the semiconductor material being used, be sure to test a number of devices to get a good average Tc value to use, as well as to verify stability of the die material.

More information may be extracted by using the Vf of the heating pulse and the heating current to calculate temperature rise with power dissipation. This test will take longer to conduct as compared to thermal transient testing.

The information contained in this article is a summary of MILSTD 750, method 3101, and which may be referred to for more detail.

Glossary:

ΔT	Change in temperature
ΔVf	Change in Forward Voltage
Ih	Heating Current
Im	Measure Current
Th	Heating Period
Vff	Final Forward Voltage
Vfi	Initial Forward Voltage
Vh	Forward Voltage with Heating Current