

Understanding Glass Transition Temperature Measurements of Printed Circuit Boards by DSC

Written by Peg Conn, Senior Director of the Analytical Services Laboratory at Isola and Cassie Volden, Analytical Services Laboratory Manager

DSC, Differential Scanning Calorimetry, measures the flow of heat into or out of a sample compared to a reference. A stepwise change in the heat flow indicates the glass transition. The glass transition is the temperature range in which the amorphous molecules of the resin transition from rigid and brittle to flexible and pliable. This range is represented by a single temperature which is identified by an agreed upon method. Glass and copper do not exhibit this transition; however, their presence can affect the flow of heat into and out of the sample. IPC-TM-650 defines the use of DSC in the measurement of the glass transition temperature and the degree of cure in laminates. The sample is heated through the transition region on the first scan, held isothermally above the glass transition, then cooled and heated through the transition on the second scan. The glass transition temperature is reported as the temperature at the half height between the two steps. The two glass transitions are then compared.

Measurements of a laminate core at the time of manufacturing produces a DSC scan which clearly shows the transition region (**Figure 1**). Printed wiring boards are comprised of various combinations of laminate cores, prepreg and copper. The particular combination of prepreg, core and copper can affect the heat flow in samples measured by DSC causing the different layers of the sample to heat at different rates. This thermal lag causes the transitions of the different layers to appear to occur at different temperatures, is often exhibited in the DSC scans by multiple glass transitions (**Figure 2**), and elongated transition regions (**Figure 3**). Samples with greater thermal lag result in transitions, which are distinct enough to be identified. Lower levels of thermal lag appear as elongated transition regions because the transitions cannot be distinguished.

Figure 1

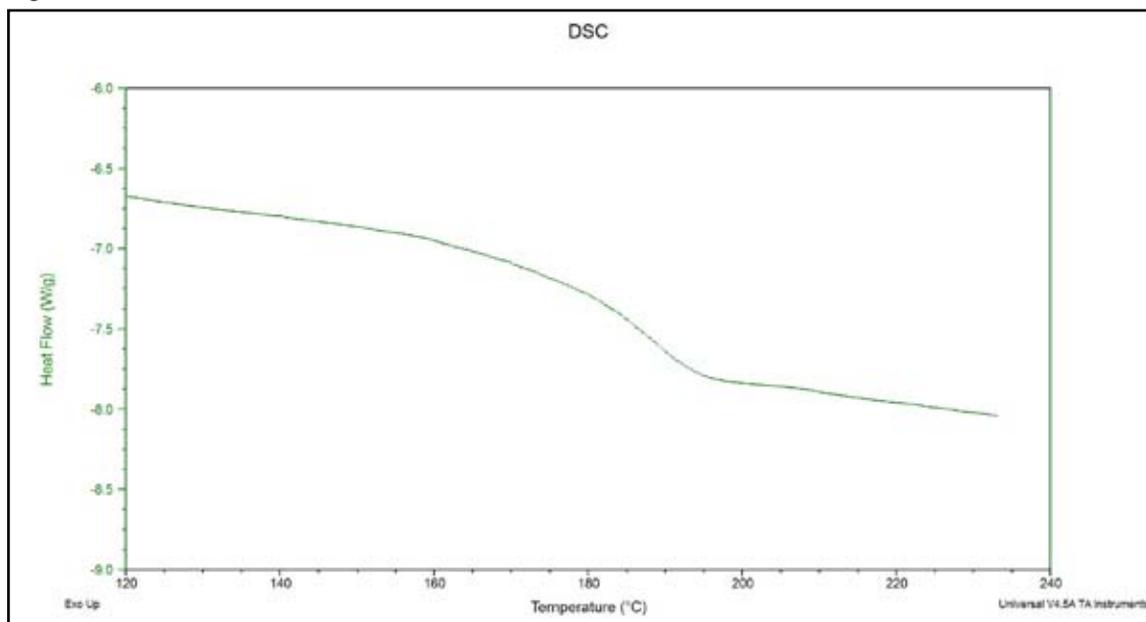


Figure 2

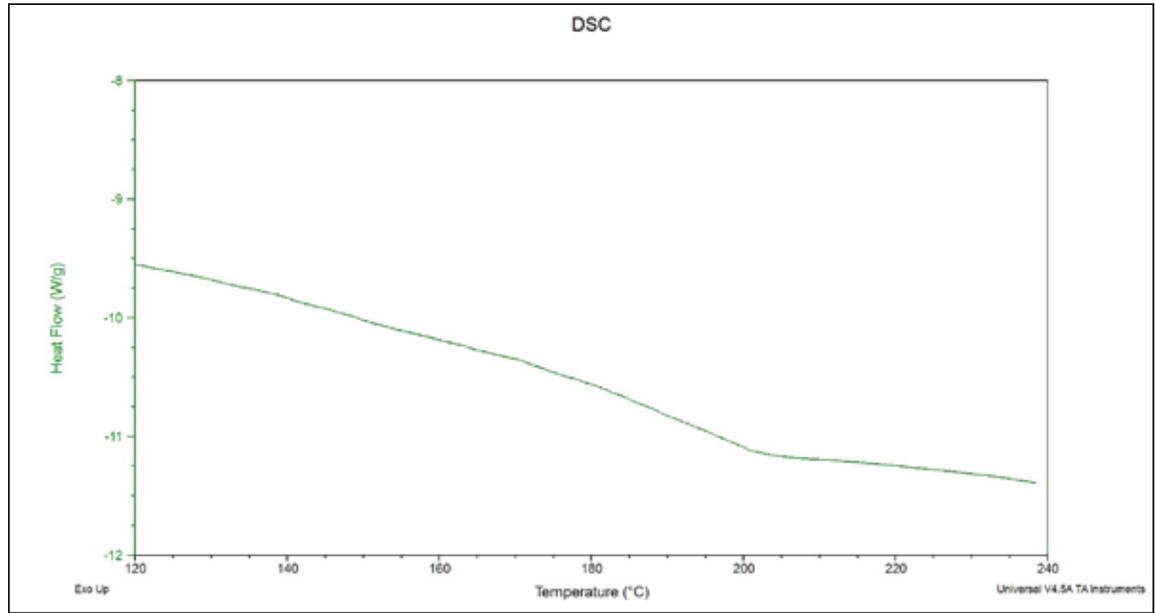
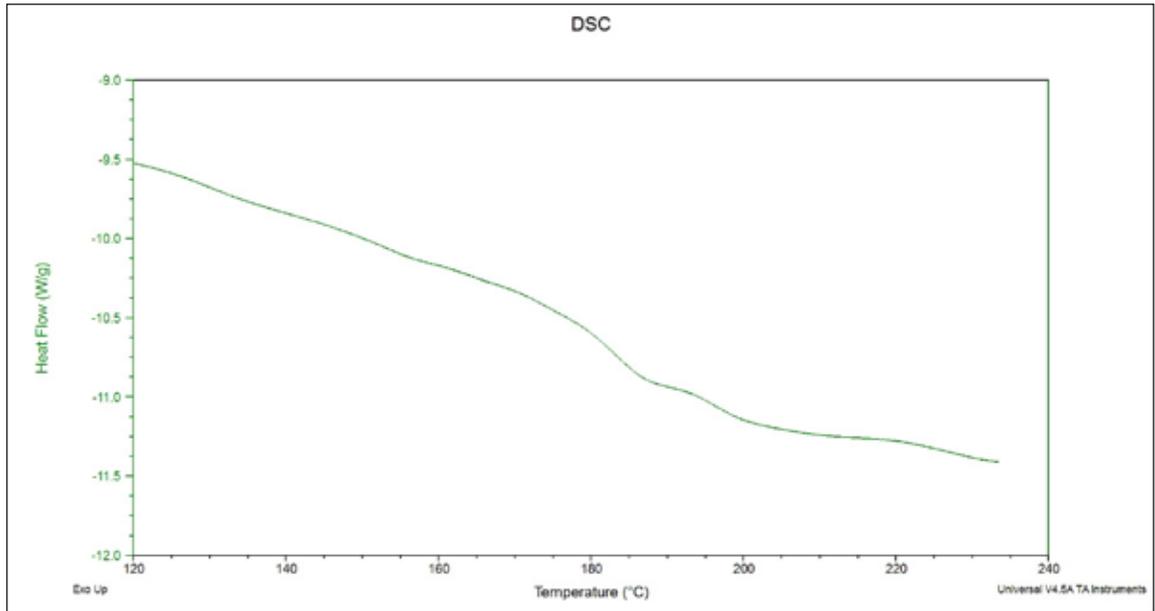


Figure 3



Thermal stress can also affect the glass transition measurement. When a printed wiring board is processed, the temperature profile can induce stress in the molecules. This stress is present in the first scan of the DSC and can also appear as dual and elongated transitions. When the sample is held at an isothermal temperature above the glass transition region, the molecules are able to relax and the stress is relieved.

The combination of phenomena described above can result in scans that exhibit the following results:

First Scan	Second Scan
Dual Transition	Dual Transition
Dual Transition	Elongated Transition
Elongated Transition	Elongated Transition

Sources:

Turi, Edith A. *Thermal Characterization of Polymeric Materials*. 2nd ed. Vol. 2. San Diego: Academic, 1997. Print.

Waguespack, Louis. "Differential Scanning Calorimetry: Basic Theory and Applications Training." Texas Theory and Applications Training. Lone Star College, Houston. 25 June 2012. Lecture.

Glass Transition Temperature and Cure Factor by DSC. IPC-TM-650 Test Methods Manual. TM 2.4.24.5. Rev. C. 12/94