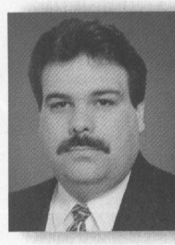


From The Lab

By Bob Neves

The "TLA's" of Thermal Analysis

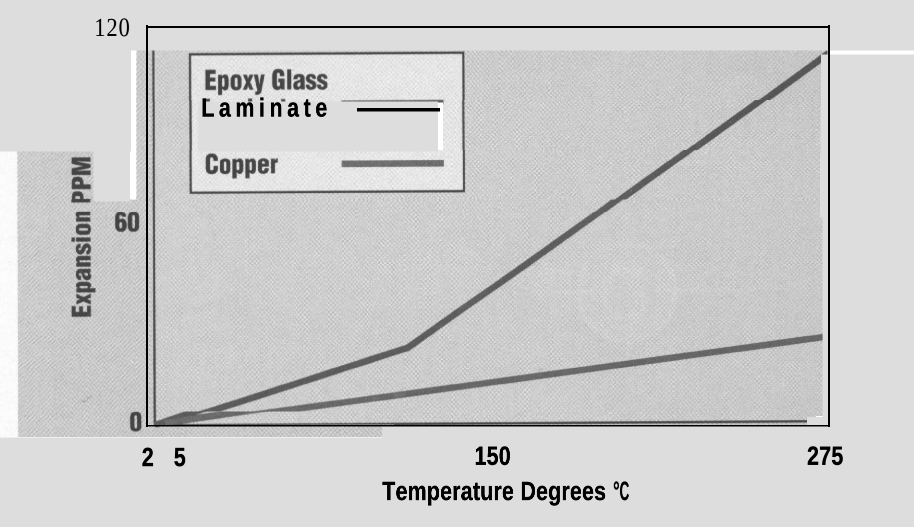
Three letter acronyms (TLA) are spoken with reverence around the industry as if there is some mystical content associated with them. The testing end of the business is littered with all sorts of TLAs. In this month's column I will try to de-mystify the TLAs associated with Thermal Analysis (TMA, DSC, DMA, TGA, CTE and T-sub-G). Subsequent columns will explore other mystical acronyms.

T-sub-G (expressed Tg)

T-sub-G (expressed Tg) is not a true TLA in the purest sense, but it should have been. It has all of the earmarks of a good TLA (ambiguity, mysticism and a sense of importance). Tg is an acronym for Glass Transition Temperature (why it wasn't named GTT is beyond me). The Glass Transition Temperature, despite its name, has nothing at all to do with the glass reinforcement material in the PWB. This magical point is the temperature where a polymeric matrix (resin system) changes from a hard, glassy state to a softer, rubbery state. The Hard Glassy State (HGS) is traditionally stable and exhibits low expansion rates. The Soft Rubbery State (SRS) is less stable and has higher expansion and lower thermal transmission rates. This Tg point can be measured by mapping either the thermal or mechanical characteristics of the polymer. It must be noted that each of the tools used to measure Tg will likely give a slightly different result, so it is prudent to note the method by which Tg was obtained.

There are many benefits to higher Tg, but also several drawbacks. A higher Tg means greater chemical resistance, increased hardness, increased brittleness and lower overall expansion rates. This also corresponds to decreased drill efficiency, higher tendency for cracks or chips, higher cure temperatures and increased resistance to desmearing and hole preparation chemicals.

Figure 1. Expansion of Copper vs. Z-Axis Expansion of Epoxy Glass Laminate



Coefficient of Thermal Expansion (CTE)

Coefficient of Thermal Expansion or CTE is defined as the rate at which a material expands when exposed to temperature changes. The CTE is expressed in ppm/'C (parts per million per degree centigrade). In regular terms, 1 ppm can be changed to 0.0001% of total observed dimension (length, width and thickness). Translated, a material rated at 300 ppm/'C would change 0.03% in dimension for every degree change in temperature. On a 0.100" thick board over a 100°C temperature range, you would have a 3% total thickness change which equates to 0.003". Glass, copper, nickel and gold all have fixed expansion rates for temperatures up to their melting point, while PWB resin systems expand at one rate before Tg and then at a rate of up to 10 times that beyond the Tg point. What does this mean to you? Well, the copper in the PTH barrel has an expansion rate of =17ppm/°C, while the PWB composite around it has a rate of ~ 50ppm/°C before Tg and ~350ppm/'C after Tg. The result is strain on the plated-through hole due to the mismatch of expansion (see Figure 1). On our previous 0.100" thick example which had a 130°C Tg resin system, the actual material expansion at a solder temperature of 230°C would be ~0.004" while the copper would have expanded less than 10 percent of that.

Thermal Mechanical Analysis (TMA)

One way to measure both Tg and CTE is by measuring the actual expansion vs. temperature by Thermal Mechanical Analysis (TMA). This technique is accomplished by placing a sample of the material into a small heating chamber or oven with a quartz rod placed on the material surface. As the oven is heated, the material begins to expand, moving

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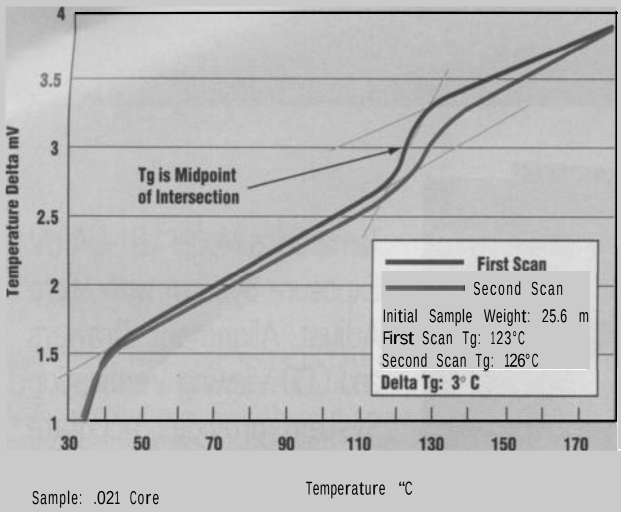

Figure 2 DSC Analysis

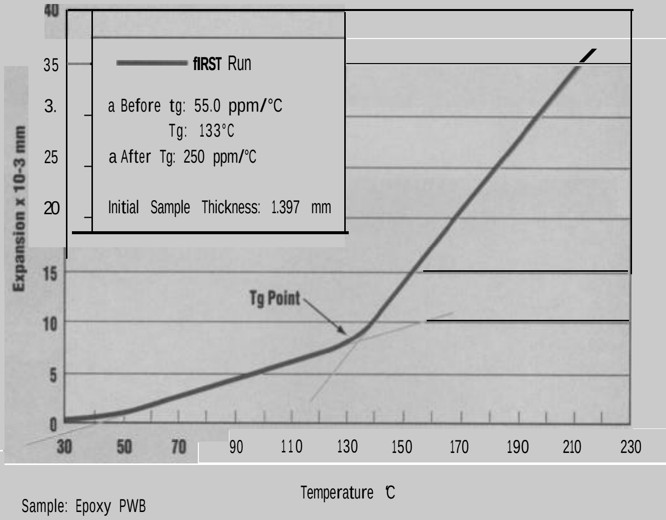

Figure 3 TMA Analysis

the quartz rod along with it. At the other end of the quartz rod is an extremely sensitive gauge that can detect and plot the movement of the quartz rod. These movements are then plotted against temperature and the CTE and Tg can be calculated from the resulting plot (see Figure 2). Quartz has an extremely low CTE, and effectively transfers all of the expansion from the sample to the gauge.

The TMA is also capable of performing the Time to Delamination test. During this test, the sample is prepared identically as described above. The sample temperature is raised to 260°C and held there until material delamination occurs. The time is recorded from the moment the sample reaches 260°C until the time delamination occurs. This value can give insight into the bonding structures of the polymer and the capability to withstand prolonged soldering operations.

Dynamic Mechanical Analysis (DMA)

Another wav to observe the mechanical changes which occur in the material is to observe the way the material transmits force. This technique functions like the five metal balls on string I used to play with when I was a kid. You know the ones where you pull back the first ball and let it strike the group and only the last ball moves away. The force is translated through the balls and comes out the other side. This technique for measuring this transmitted force is called Dynamic Mechanical Analysis (DMA). During DMA analysis, the sample is clamped between a force generator and a force detector. The force generator applies either a torsional or compressive force to the sample which is then transmitted through to the force detector. This entire test set-up is then placed inside a precisely controlled heating chamber which is heated up through a given temperature range. As the temperature increases and the material reaches the Tg point, the ability of the sample material to transmit force changes and is recorded by the DMA. This relationship can be plotted to show the temperature where the change occurred, thereby giving the Tg point.

Differential Scanning Calorimetry (DSC)

The mechanical properties of a polymer are not the only ones that change around the Tg point. During the glass transition phase, a polymer either absorbs or gives off heat due to the nature of its internal matrix structure. This heat flow can be measured by using a technique called Differential Scanning Calorimetry (DSC). The principal of DSC involves placing a small aluminum container which carries a sample into a heating cell next to a similar heating cell that contains an empty aluminum container. Heat is added to both of the cells at the same rate while the actual temperature in the sample "cell" is compared to the temperature in the empty "cell." The difference between these two temperatures is plotted, and when the sample material begins to absorb or give off the heat being added, the change in heat flow is detected and plotted (see Figure 3). This change can be observed from "initiation" through "endpoint" of the heat flow change. The Tg is determined by calculating the midpoint between the initiation and endpoint on the heat flow curve generated by the DSC. This process can then be repeated on the same sample to assess the degree of cure or Cure Factor of the material. The Cure Factor is defined as the difference between the Tg of the second and first runs.

Thermogravimetric Analysis (TGA)

Thermogravimetric Analysis (TGA) is a measure of the weight loss or gain of a sample as it is exposed to precisely controlled temperature environments. This technique is primarily used to characterize the decomposition, evaporation or dehydration of a sample material. The TGA unit is basically an analytical balance surrounded by a precisely controlled furnace which is capable of producing temperatures to upwards of 1000°C. The TGA can be used to accurately check both moisture of materials (105°C) and volatile content of prepreg (163°C or 230°C) by checking the overall weight loss at those temperatures and comparing it to initial weight. The TGA can also be used to check mate rial decomposition vs. temperature. The results of this decomposition test can give information on polymer bonding quality and expected life when compared to a known curve or material.

TLA's are a-okay

The next time someone "drops" one of these TLA's, you can properly act like you know what they're talking about! Don't let the names or acronyms fool you. These are very straight-forward analysis tools that, when properly applied, can give you a wealth of information about your product! If you have TLA's that confuse you, drop me an e-mail at BobNeves@TheTestLab.com or better yet, visit our new World Wide Web site at http://www.thetestlab.com.