

Analyze and Understand the Properties of Epoxy Based PCB using Multifrequency Analysis by DMA

Introduction

Epoxy resins come in many varieties and are used for various applications. Known for their high performance, epoxy resins are used as building blocks for adhesives,

coatings, reinforced plastics, and composite materials such as fiberglass and carbon fiber, which remain intact under intense conditions. Epoxies are thermosetting polymer resins where the resin molecule contains one or more epoxide groups. The chemistry can be adjusted to perfect the molecular weight or viscosity as required by the end-use. This allows epoxy resins to be used in a wide variety of applications.

Epoxy resins have a wide range of applications including overmolding integrated circuits, coatings for surfaces, barrier for electrical components and LEDs, high-tension electrical insulators, wetting out fiberglass, and adhesion for structural components, etc. Epoxy resins play an important part in the electronics industry, they are used in the production of insulators, motors, transformers and generators. Moreover, epoxy resins are ideal for their use as a barrier to protect electronics from environmental elements like dust, moisture and short circuits. They are also used in the manufacturing of adhesives, plastics, paints, coatings, primers and sealers, flooring and materials that are used in building and construction applications, therefore it is important to analyze and understand the properties of epoxy resins.



PerkinElmer DMA 8000

This application note demonstrates the ability of DMA to characterize the mechanical properties of an epoxy based printed circuit board (PCB) using a PerkinElmer® DMA 8000. The modulus of the PCB is measured providing an important parameter for the manufacturer. In addition, the glass transition temperature is accurately measured, which gives information about the viable temperature range in which the material can be used.

Experimental

Dynamic Mechanical Analysis (DMA) is one of the most appropriate methods to investigate relaxation events. The stiffness of the material is also measured, which can have an impact on the utility of the material in the real world. The glass transition (T_g) is a key process in any material and can be observed with ease by DMA. Three Point Bending geometry is considered the most suitable geometry when an accurate modulus is required. As there is no “clamping” of the sample, the influence of the instrument on the measurement is at a minimum. DMA works by applying an oscillating force to the material and the resultant displacement of the sample is measured. From this, the stiffness can be determined and the modulus and $\tan \delta$ can be calculated. $\tan \delta$ is the ratio of the loss modulus to the storage modulus. By measuring the phase lag in the displacement compared to the applied force it is possible to determine the damping properties of the material. $\tan \delta$ is plotted against temperature and glass transition is normally observed as a peak since the material will absorb energy as it passes through the glass transition.

The interest in measuring physical properties of PCBs has increased in recent years as the industry prepares for the use of lead-free solder in manufacture. European legislation dictates that electrical equipment sold after mid-2006 should not contain any lead soldering. This challenge has resulted in new materials being investigated in the manufacture of PCBs. Both the stiffness (and modulus) of the material at different temperatures and the glass transition temperature are crucial parameters for any material used as an electrical component.

Temperature scan of PCB.

The sample was mounted in the 3-Point Bending clamps and cooled to -150 °C prior to starting the DMA experiment.

Equipment	Experimental Conditions
DMA 8000 1 L Dewar	Sample: Epoxy based PCB
	Geometry: 3-Point Bending
	Dimensions: 17.5 (l) x 6 (w) x 1.5 (t) mm
	Temperature: -150 °C to 250 °C at 3 °C/min-1
	Frequency: 0.1, 1.0 and 10.0 Hz

Results and conclusion

Figure 1 shows the glass transition of this material as a peak in the $\tan \delta$ and a drop in modulus. A clear frequency dependence is seen confirming the transition as a relaxation. The modulus of the material before and after this transition is relatively constant at approximately 2.3×10^{10} and 5.0×10^9 Pa respectively. The glass transition temperature, as defined by the peak in the $\tan \delta$, is shown to be between 142.6 °C and 151.8 °C depending on the frequency.

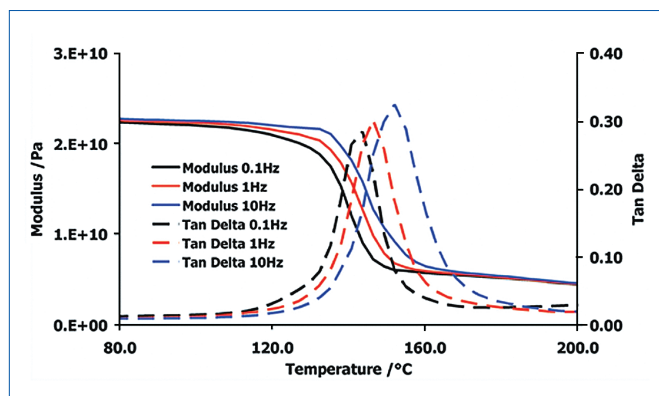


Figure 1. Sample fixture for tension mode.

These data were collected from a starting temperature of -150 °C. By increasing the scale of the lower temperature data it is possible to observe another relaxation event (as shown in Figure 2). This δ transition is clearly a relaxation as a frequency dependence is seen in both the modulus and $\tan \delta$ data. This demonstrates that DMA is an excellent technique to monitor these lower temperature transitions.

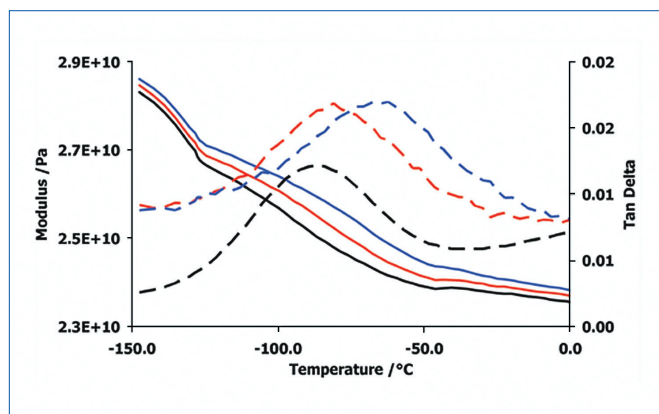


Figure 2. Displacement from aluminum sample.

By selecting 3-Point Bending as the geometry of choice, it has been possible to demonstrate that an accurate modulus can be obtained for this epoxy based PCB material. The glass transition temperature can be easily characterized as well. In addition, a δ relaxation is identified due to the sensitivity of DMA to observing this type of event. The instrument used for this experiment can go as low as -190 °C so even lower temperature transitions can be observed with ease.