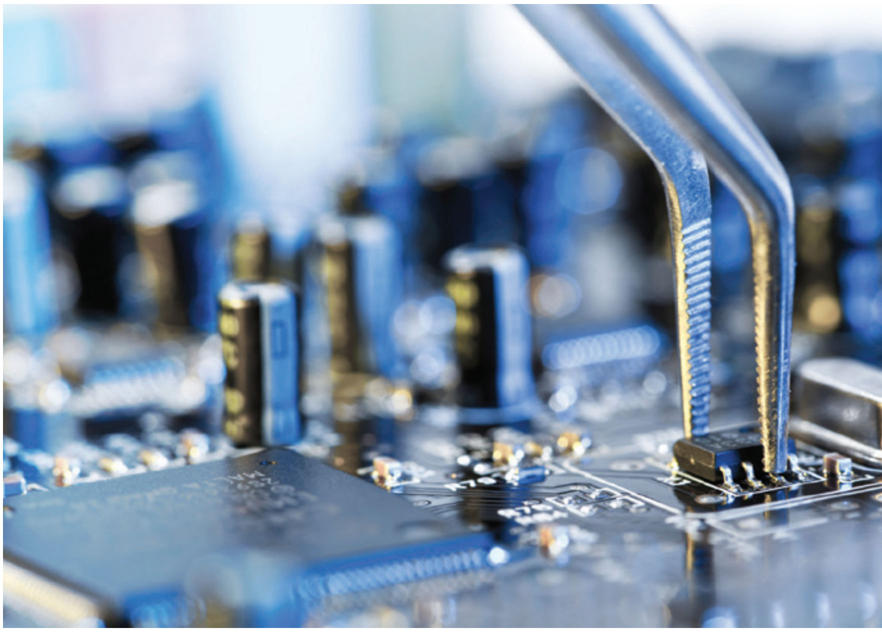

APPLICATION NOTE

Thermal Analysis

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Thermal Analysis Applications in the Semiconductor Packaging Industry

Pyris Diamond DSC

PerkinElmer can provide a complete solution of thermal analyzers for the semiconductor packaging industry

Figure 1 shows different process steps that require materials characterization, materials selection, quality control, process optimization and failure analysis.

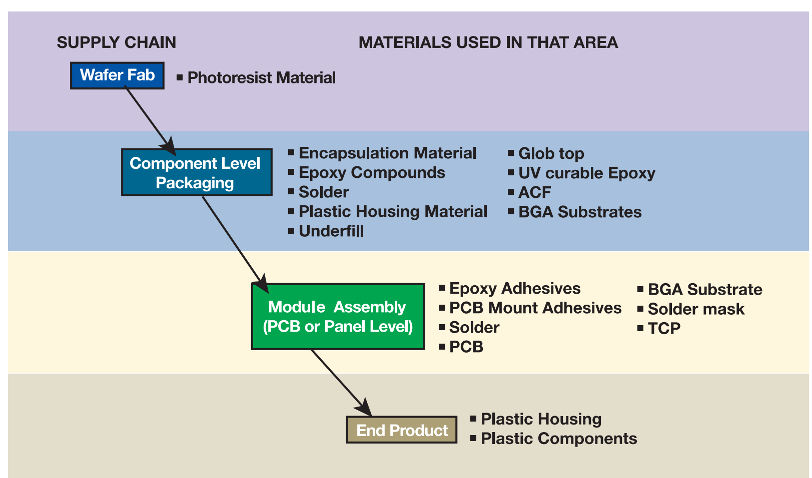

Figure 1. Typical supply chain within the semiconductor business.

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There are many levels of integration of Thermal Analysis in the Semiconductor Packaging Industry. The encapsulation material used is typically an epoxy-based compound (epoxy mold compound, under-fill epoxy, silver die attach epoxy, glob top epoxy, etc.) An epoxy with excellent thermal and dimensional stability, with good outdoor properties, is well suited for these applications. The curing and rheological behavior are important to ensure consistent process and quality of the components produced. Often a process engineer will be faced with questions like:

a) What is the process window for a particular compound?

b) How do I control that process?

c) What are the optimized curing conditions?

d) How can I reduce my cycle time?

The wide offering of PerkinElmer Thermal Analyzers can provide the answers process engineers are looking for.

Differential Scanning Calorimetry (DSC)

This technology is best suited to analyze the thermal behavior of epoxies as shown in Figure 2. The measurements provide information about the glass transition Tg, the starting temperature of the curing reaction, the heat of cure and the end temperature of the process.

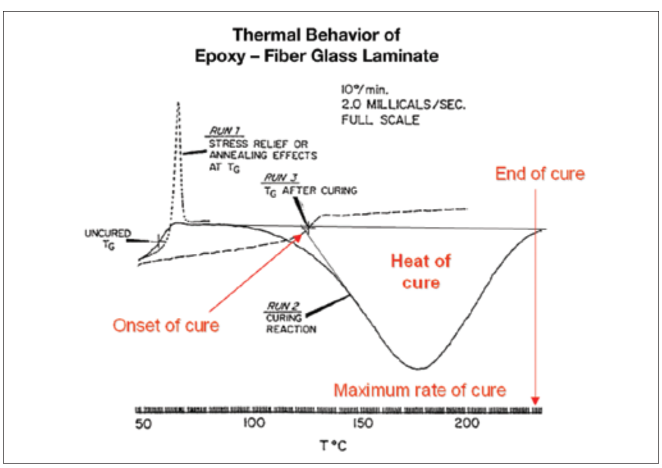

Figure 2. DSC thermogram showing curing behavior of an epoxy compound.

The DSC can be used to display the Tg temperature as it develops as a function of curing time (Figure 3) at a given temperature.

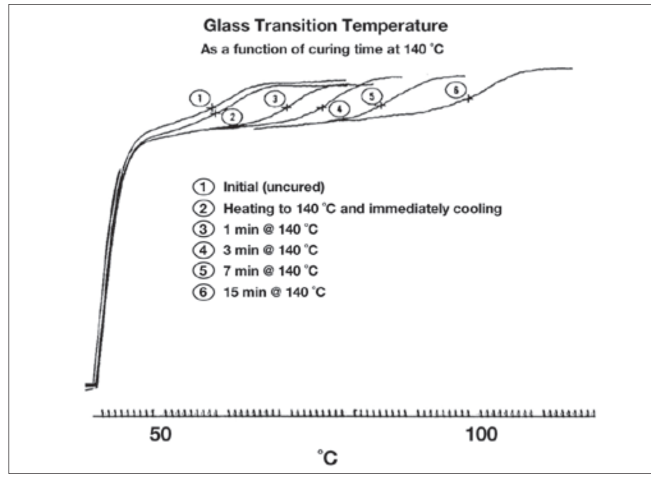

Figure 3. DSC thermogram showing Tg progressively increased with prolonged cure time.

The glass transition temperature Tg is a good measure of cross linking density of an epoxy compound. In fact, a process engineer can determine the process window most appropriate for a particular epoxy compound by plotting Tg versus the time of cure at different curing temperatures (Figure 4).

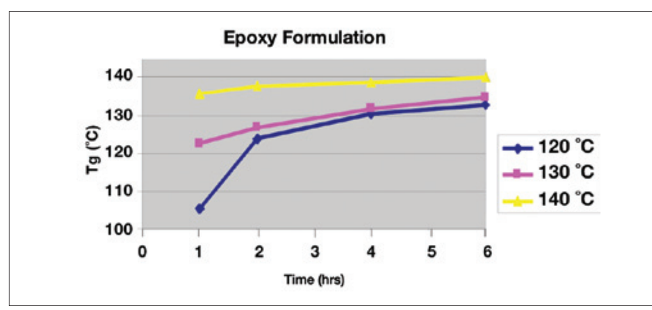

Figure 4. Tg versus time of cure at different cure temperature.

In cases where a process engineer has no access to these data, the manufacturing procedure often results in low quality products. An example is shown in Figure 5.

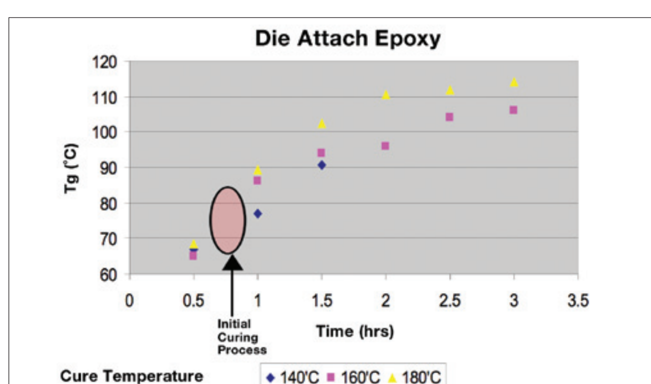

Figure 5. Tg versus cure time at different cure temperature.

In this case manufacturing used a curing condition for a silver die attach epoxy that was found to be at the rising part of the Tg versus time curve (initial curing process). These conditions yield a high degree of variation with slight changes in cure time or cure temperature.

As a result, the component has a high degree of failure of delamination between the lead frame and semiconductor chip. Best process conditions can be determined by generating this Tg versus temperature/time curve using a power compensation DSC, such as the double furnace DSC from PerkinElmer. Even the glass transitions of highly filled silver die attach epoxies can be detected. The data provide excellent information to optimize a manufacturing process.

The use of DSC technology allowed optimizing the curing conditions for this epoxy by switching to 160 ˚C for 2.5 hours. This change stabilized the process and resulted in consistent Tg values. At this manufacturer the DSC is not only used for process optimization but also used as a quality control tool by monitoring the Tg of the cured product.

Another DSC application is the determination of the melting point of solder alloys. Tin alloys containing 3 wt% Copper (Cu), Silver (Ag) or Bismuth (Bi) are analyzed with DSC. The results shown in Figure 6 indicate that different compositions have very different melting points. The alloy with silver has the lowest melting point at the same concentration of 3 wt%.

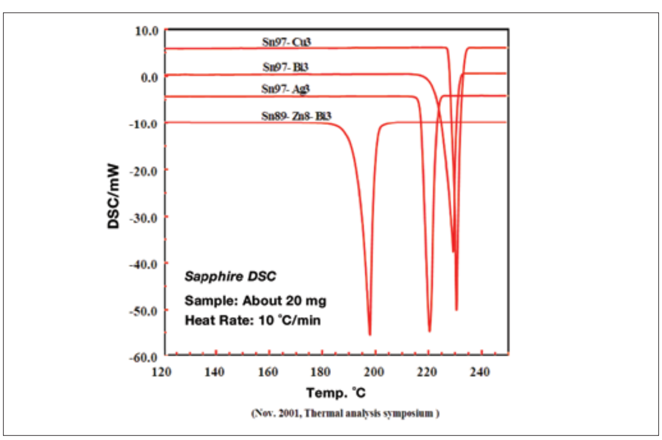

Figure 6. DSC: Melting point analysis of different solder alloy after exposure to different moisture environments.

Thermogravimetric Analysis (TGA)

For a design engineer, PerkinElmer thermal analyzers can provide great insight into material selection. For instance, the PerkinElmer® Pyris™ 1 TGA (Figure 7) can detect very small weight changes and can be used to measure important material parameters like outgassing properties and thermal stability. This will indirectly affect the components solderbility performance. Figure 8 shows two epoxy encapsulation materials having different performances in terms of outgassing at 230 ˚C and 260 ˚C. A higher degree of weight loss (outgassing) indicates that the epoxy encapsulant, which is in contact with the lead frame, will have a higher probability of epoxy-leadframe separation.

Figure 7. PerkinElmer Pyris 1 TGA.

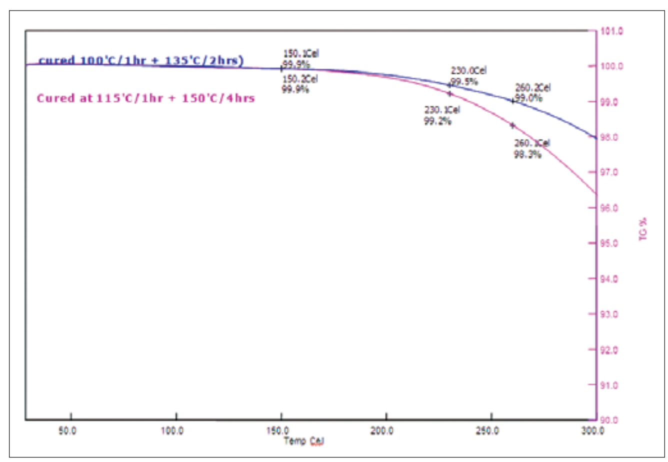

Figure 8. TGA results showing different outgassing performance for two materials.

Thermo Mechanical Analysis (TMA)

TMA accurately measures dimensional changes in a material when the material is subjected to a temperature program. For a cured epoxy system, the output from TMA will be the coefficient of thermal expansion (CTE) and glass transition temperature. The CTE of the epoxy is a very important parameter because a fine gold wire is embedded in the epoxy compound and a high CTE may cause the wire to break prematurely when the electronic component is subjected to repeated temperature cycles. The deflection point between the different coefficient of thermal expansion can be defined as the glass transition temperature (Figure 10). TMA is also used to determine the softening point of plastic components and the melting point of solder.

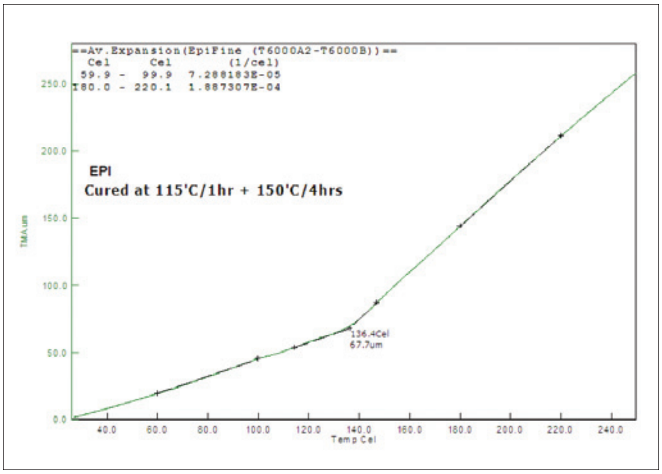

Figure 9. Diamond TMA showing a typical TMA plot.

Dynamic Mechanical Analysis (DMA)

Internal package stress is also critical information when selecting a material. The combination of the DMA and TMA technique can provide quantitative information on bulk material internal stress. DMA measures the viscoelastic properties of a material and it provides the modulus value of the material at different temperatures as shown in Figure 10. As material goes through thermal transitions, the modulus value changes allowing an analyst to easily point out the thermal transitions like Tg, crystallization or melting.

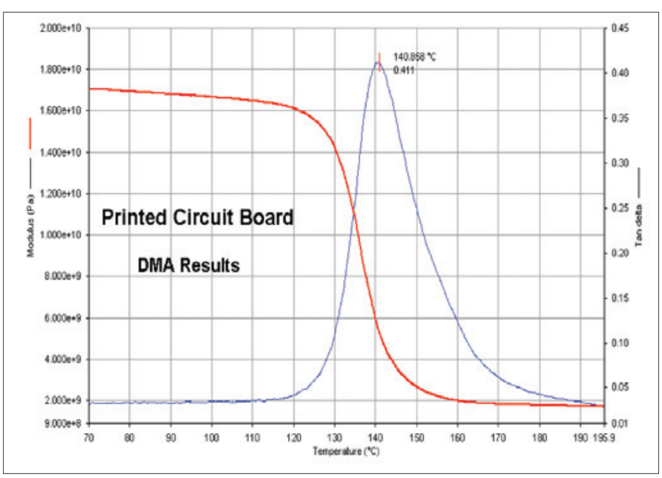

Figure 10. Showing a typical DMA plot.

Thermal analyzers are used for ASTM® and IPC material standard tests, quality control and material development. Figure 11 shows one of the IPC tests which involves thermal analyzers. The PerkinElmer DMA is widely used for semiconductor applications.

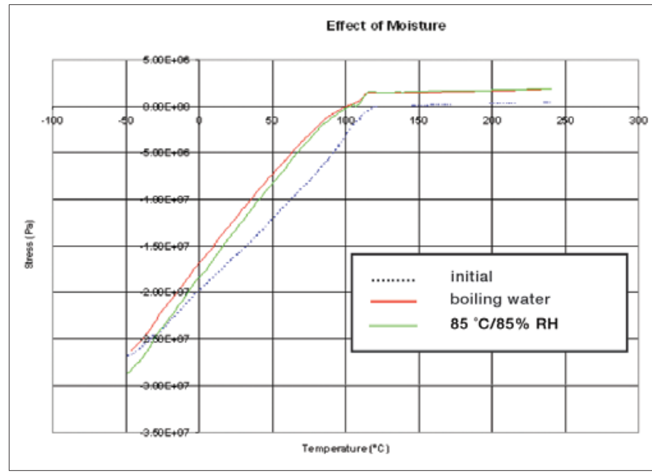

Figure 11. DMA: Showing the internal stress of clear molding compound.

Summary

Thermal analyzers are an essential tool in the semiconductor packaging industry. Not only are they important in the design and development phase, but thermal analyzers can also be used for failure analysis and quality control purposes. Many Standard Methods describe the use of Thermal Analysis (Figure 12). With PerkinElmer Thermal Analyzers, users can optimize processing conditions and select the right material for the required performance, ensuring semiconductor businesses put out a high quality product. These analyses can lead to great cost savings – making Thermal Analyzers an absolute "must have" in testing equipment!

	Problems	Properties	Analysis	Standard Method
Lead Free Process (Temp. Range from 240-270 °C)	Delamination	CTE Decomposition Temp. Glass Transition Temp.	TMA TGA DSC TMA DMA	IPC TM-650 2.4.24.1 ASTM D3850 IPC TM-650 2.4.25C IPC TM-650 2.4.24C IPC TM-650 2.4.24.2
	Through Hole Reliability	CTE (Z-Axis)	TMA	IPC TM-650 2.4.24.1
	Bad Thermal Stability	Glass Transition Temp. Moisture Content Decomposition Temp. Modulus	DSC/TMS/DMA TGA TGA DMA	IPC TM-650 2.4.25C IPC TM-650 2.4.24C IPC TM-650 2.4.24.2 IPC TM-650 2.4.24.4
	Size Stability	CTE (XY-Axis)	TMA	IPC TM-650 2.4.24C

Figure 12. Thermal Analyzers used for Standard Methods.

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