

Telcordia (Belcore) Testing – Useful Guidelines for Reliability Assurance Of Passive Optical Components

How best to apply them to adhesive assembly applications

Introduction

Dymax, a leading developer of high performance, optical adhesives endorses the use of Telcordia (previously known as Belcore) Requirements, including GR-1221-CORE, to help assure optimum durability of bonded optical devices. GR-1221-CORE and associated specifications were written primarily for standard 1 and 2 part and UV curable epoxy adhesives. *They state that it is solely 'the Optical Device Manufacturer's responsibility to define acceptance and pass/fail reliability criteria for conformance testing of each passive optical component'.*

Telcordia (previously known as Belcore) is an outgrowth of AT&T's Bell Laboratories; an organization dedicated to developing testing which it finds helps assure the practical, useful life of certain manufactured devices. GR-1221-CORE relates to long term (25 year) performance of Passive Optical Components. It opines extremely helpful requirements to manufacturers for the development of reliability assurance tests for their passive optical components. The stated key concern behind the development of the guidelines is "the ability of the optical device to function satisfactorily for long periods under adverse environmental conditions".

Adhesive properties are a function of complete cure. Cure is under the absolute control of the optical component manufacturer and is also a function of the individual assembly. For these reasons, Belcore does not approve specific adhesives *per se*, but does qualify and even certify certain specific epoxy adhesives assuming that they are properly cured.

A Short Summary of Adhesive Related Guidelines

GR-1221-Core states that the ultimate qualification of an epoxy type adhesive is the responsibility of the fabricator of the optical system. Qualification depends upon maintaining optical integrity throughout an appropriate test regimen. Accelerated environmental tests are described in 6.2.1 – 6.2.10. It recommends that a chosen test regimen be constructed upon expected conditions and stresses over the long term (25 year) life of a system and/or device.

Completed device testing includes:

- ❖ Mechanical Shock (Impact Testing)
- ❖ Variable Frequency Testing
- ❖ Thermal Shock Testing
- ❖ High Temperature Storage Testing (Dry Heat - 85°C)
- ❖ High Temperature Storage Testing (Damp Heat - 85°C/85% Relative humidity)
- ❖ Low Temperature Storage Testing
- ❖ Temperature Cycling Testing
- ❖ Cyclic Moisture Resistance
- ❖ ESD Testing (Completed device only)

Section 4.4 of GR-1221-CORE requires that adhesives have a T_g of at least 95°C as measured by Differential Scanning Calorimetry (DSC). This requirement is born of a concern that (epoxy) adhesives may soften at elevated temperatures and may fail to provide the structural support necessary to maintain the functioning of the device. Many Dymax OP™ adhesives have a T_g over 95°C.

However, the potential for component movement during adhesive cure and thermal cycling may be of more direct concern. DSC is commonly used to determine the T_g of epoxy resins. However, DSC is more difficult to use with polymers that are neither highly cross-linked nor highly crystalline because the less energetic transition peak is often lost in other peaks generated by the test. Thus, DSC can be a poor technique to use with many urethanes, silicones, and UV-cured polymers that are not epoxies. We believe that Thermal Mechanical Analysis (TMA) is more productive because it measures movement directly. DSC is only an inferential technique for predicting movement; typically in cases where the adhesive bears a structural load.

Applying Dymax No Shrink™ Technology

The guidelines were written prior to the development of high performance UV curing optical adhesives. GR-1221-CORE assumes the need for one or two component epoxy-type adhesives that rely on a glass transition temperature (T_g) higher than the operating temperature of an optical device to assure low movement and low stress.

Many systems and devices do not require high T_g . Numerous optical applications use adhesives with T_g 's well below 95°C and where the optical integrity of the device remains intact over its lifetime under adverse environmental circumstances.

The emergence of new patent applied for high performance UV curing technology provides protection against both (adhesive induced) stress and movement almost regardless of T_g . These adhesives represent new non-epoxy and UV curing technology whose formulation strategies yield characteristics of lower shrinkage, stress and movement upon thermal excursions. As measured by TMA, these adhesives exhibit lower total movement after temperature cycling compared to epoxies.

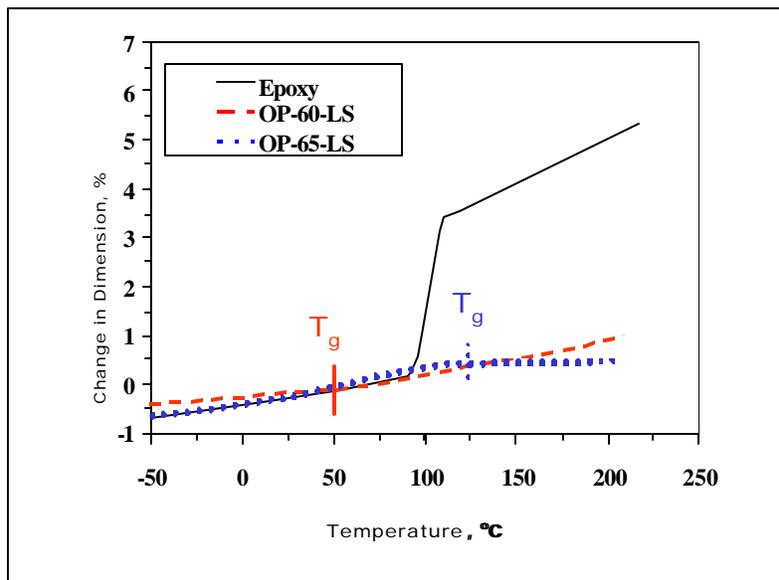


Figure 3 - TMA Curve

High T_g Epoxy Moves More Than Either Low T_g Or High T_g Dymax Optical Adhesive During Thermal Cycle

Figure 3, compares two adhesives. DYMAX OP-60-LS with T_g of 50°C compared to that of a leading epoxy with a T_g of 100°C, both measured by TMA. If we play by (epoxy) “rules,” then we assume the high T_g epoxy moves less under thermal cycling than does the OP-60-LS. Rather than assuming the answer, we instead measured the motion of two cured adhesive films by TMA. The films were both roughly 1,000 nm thick.

The change in dimension is plotted as a percent of the thickness to account for the small difference in film thickness. The data shows:

1. When cooled to -40°C , the Dymax OP-60-LS contracts less than the epoxy.
2. When heated to 100°C , the Dymax OP-60-LS expands the same amount as the epoxy.
3. The epoxy moves more in going through the T_g than it does over the rest of the curve.
4. The T_g motion of the OP-60-LS is negligible when measured on the same scale.
5. The total motion of the OP-60-LS from -40 to 200°C was 1%. The epoxy moved 7%.
6. The T_g of the epoxy was much higher than that for OP-60-LS.

The significance of the results of this measurement is that the point of the transition, T_g , is less important than what happens at the transition. Clearly, if an optical device operating temperature is below 95°C , either adhesive performs adequately. The selection rationale becomes simply the speed and cost of cure. However, if the operating temperature is over 95°C , the new technology adhesive gives much less movement and much lower stress than do optical epoxies, in addition to being more cost efficient.

THE EFFECT OF GLASS TRANSITION TEMPERATURE

Some polymers have larger dimensional changes at the Glass Transition Temperature (T_g), than do urethane/acrylic polymers as used in DYMAX LCA's.⁽²⁾ A resilient adhesive can exhibit both low stress and low TOTAL MOVEMENT. Table 4 compares published data from a leading optical epoxy supplier compared to selected DYMAX LCA's. DSC techniques tend to report the highest T_g . However, since the most important property of interest to designers is movement and not heat absorption, TMA is the favored test method for optical design. Looking at the final column, the CTE from -45°C to $+200^{\circ}\text{C}$ is a measure of the TOTAL MOVEMENT, regardless of T_g over the operating temperature range. The smaller the number, the smaller the movement between parts.

Table 4. Data comparison of leading optical epoxy supplier vs. selected No Shrink™ UV curing adhesives

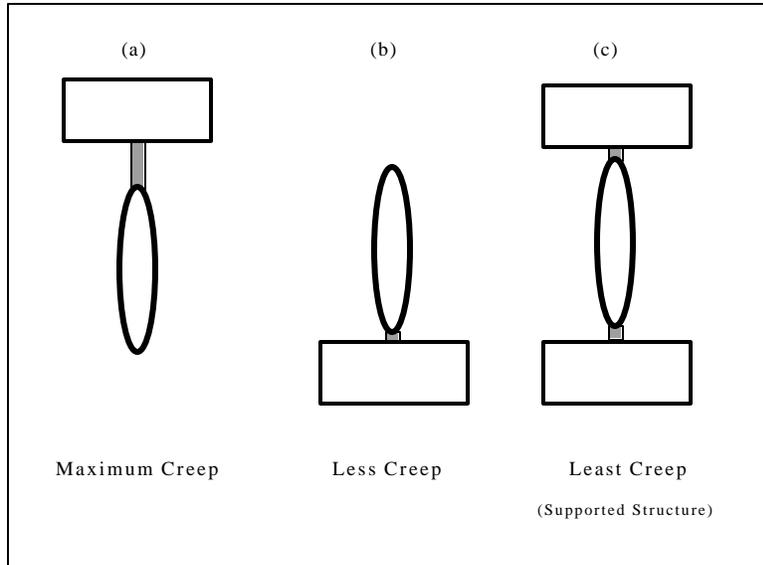
	Glass Transition (T_g)		CTE ($\times 10^{-6}$) (by TMA)	CTE ($\times 10^{-6}$) (by TMA)	TOTAL MOVEMENT ($\times 10^{-6}$) (by TMA) **
	(by DSC)	(by TMA)	Alpha 1	Alpha 2	-45 to 200
Optical Adhesives					
High T_g positioning "Red" Epoxy (heat cure at 150°C)	120°C^*	90°C^{**}	56.0	139.0	87.0**
Commercial UV Curing Epoxy	116°C^*	57°C^*	58.0	156.0	110 (est.)
OP-61-LS Positioning Adhesive	Over 120°C	65°C	27.0	121.0	74.0
OP-66-LS Positioning Adhesive	None detected	125°C	27.0	66.0	50.0
OP-4-20632 Light Path Adhesive	NM	100°C	45.0	105.0	90

NM = Not measured * Published values ** Tested value

- (2) A more complete discussion of T_g , CTE and Total Movement can be found in "Movement between Bonded Optics", Nicole Langer and Dr. John Arnold, September 13, 2001, DYMAX Corporation.

Design Can Be As Important As Adhesive Selection

Indeed there are constructions where a T_g of 95°C is critical. Applications that are prone to creep at higher temperatures in certain joint configurations may require high T_g adhesives. As stated in GR-1221-CORE above the T_g , the adhesive may be softer and more prone to deformation and strain. Often, the proper joint design will fix this problem. Figure 4 shows three possible joint configurations. Regardless of the T_g of the adhesive, the second and (even better), the third design minimizes alignment problems from thermal creep. These designs will also minimize part shift during adhesive cure. The new types of adhesives that exhibit very little to no movement over a temperature range avoid the concern altogether. (Figure 3).



High T_g adhesives can defeat alignment creep only to their T_g . Joint design can also defeat creep and is recommended in applications when the adhesive T_g will be exceeded.

Figure 4

Summary

Basically, T_g is only a characteristic temperature. The glass transition temperature may be neither a complete indicator of movement nor of optical performance or durability. We have presented several papers describing alternative methods.

Comparing T_g 's among adhesives is useful but only if the adhesives are of extremely close chemical composition. TMA should be used instead of DSC because it directly measures movement. Some applications really do require high T_g . Dymax provides a line of optical adhesives that are excellent candidates for Telcordia (Bellcore) testing. Properly selected for the application and adequately cured, Dymax optical adhesives maximize manufacturing efficiency and productivity while exhibiting superior endurance and performance characteristics compared to other adhesive resins.

This paper states the findings and opinions of the Dymax Corporation. While it was reviewed by Telcordia, this paper does not necessarily reflect the views of Telcordia Technologies.

White Papers are available that discuss Dymax's new adhesive technology in more depth:

www.dymax.com/pdf/stress_in_bonded_optics.pdf (Minimizing stress.)

www.dymax.com/pdf/movement_between_bonded_optics.pdf (Minimizing movement.)

To download Dymax Optical Adhesives Selector Guides:

www.dymax.com/products/optical/fiber_optic_selector_guide.asp (For Fiber Optics)

www.dymax.com/products/optical/selector.asp (For Lens bonding and Optical Laminating)