Tomorrow's Products ▶ Shipped Today

Adhesives for Fiber Optic Assembly

Our thanks to Loctite for allowing us to reprint the following white paper.

By Edward A.Y. Fisher, Application Engineering Manager & Joshua G. Sherwood, Market Application Engineer

Adhesives play a pivotal role in the assembly of fiber optic components due to their high performance on glass, metal, ceramic and most plastic substrates, excellent chemical and solvent resistance, and electrically insulating properties. As adhesives can bond dissimilar materials quickly, efficiently, and cost-effectively, they have enabled the production of many optical components that would have been impossible using mechanical fastening methods.

Adhesive technology has been used in fiber optics assembly since its inception, bonding optical connectors, fibers, lenses, prisms, and other components. Initially, only epoxy technology was used, primarily in the connector market. Today, adhesives are highly engineered products available in a number of different technologies ranging from heat cure epoxies to light cure acrylics, to help fabricate fiber optic assemblies.

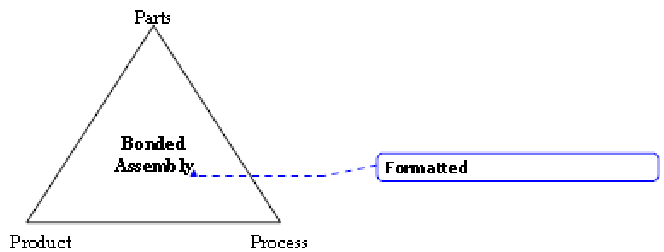
By choosing the correct adhesive, manufacturers can speed the manufacturing process, lower costs and even improve and enhance reliability and performance. By their very nature, adhesives allow devices to be made stronger, faster, and more cost-effectively, living up to the most basic demands of the marketplace.

Adhesives offer several major benefits over other assembly methods. They distribute stress load evenly over a broad area, reducing stress on the joint. They can be used inside a joint where they are invisible within the assembly or externally in overmolding and doming applications where they protect and reinforce critical components. Adhesives resist flex and vibration stresses, and form a seal as well as a bond, protecting the internal components from harsh environments. They join irregularly shaped surfaces more easily than mechanical or thermal fastening, add negligible weight to the assembly, create virtually no change in part dimensions or geometry, and quickly and easily bond dissimilar substrates and heat sensitive materials. Adhesives are one-size-fits-all, and assembly can be easily automated.

Limitations of adhesives include the amount of time it takes for the adhesive to fixture and strengthen fully (except light curing products), surface preparation requirements, and the potential need for joint disassembly.

Design Considerations

When selecting adhesives, manufacturers should consider the three aspects of a bonded assembly -- the parts that make up the component, the assembly process, and the adhesive -- and how these three variables will affect device production.



To select an appropriate adhesive for an application, a designer should consider how the device will be assembled, and what substrates will be bonded. It is also critical that the adhesive specified during the design phase is appropriate for the production process.

At minimum, the following questions should also be asked when specifying an adhesive:

- Does the design include difficult to bond substrates like gold plate, polypropylene or nylon?
- Are there dissimilar metals that may cause thermal expansion problems when heated?
- Are any of the parts UV absorbing requiring a visible light curable adhesive?
- Do I have shadowed areas that will not see light?
- Will surface treatments (plasma, corona treatment) enhance bonding?
- Will the substrates and adhesive perform properly in the end use environment?
- Are there temperature sensitive substrates that can't tolerate heat making the selection of a heat cure or a light cure adhesive inappropriate?
- What Kind of joint stress will the assembly see? Tensile? Compressive? Peel?

Available Adhesive Technologies

Out of the multitude of adhesives currently available, there are five families that are most commonly used in fiber optic assembly. Each of these families offers a unique combination of performance and processing benefits. Manufacturers that dedicate significant up-front time to researching and selecting the proper adhesive for an application will save significant time and expense later in manufacturing and reliability.

Long the workhorse of the fiber optic industry, **epoxies** are common one or two-part structural adhesives that bond very well to a wide variety of substrates, are low outgassing, and shrink minimally upon cure. The major disadvantage of epoxies is that they tend to cure much slower than other adhesive families, with typical fixture times between 15 minutes and two hours. Two-part epoxies must also be thoroughly mixed to ensure best performance.

Epoxies are a favorite in fiber optic assembly due to their high glass transition temperature (Tg) and low shrinkage properties. Available in small package sizes, easy-to-mix two-part "bi-pack" epoxies are extremely popular as they minimize adhesive waste and accommodate small production runs. One-part, pre-mixed heat cure epoxies are also popular, although work life is short once the adhesive is removed from cold storage. Dual cure (UV and/or heat) epoxies are also available for increased processing speeds. As production volumes increase, assemblers can use larger volume side-by-side static mix products.

Two-part epoxies are used extensively in bonding fiber to ferrule. They are also used for potting electronic components, bonding dissimilar materials like ceramic or glass to aluminum. Epoxies can also be used to bond secure strain relief boots and secure fiber onto packages.

One-part, solvent free **light curable acrylics** now offer performance benefits comparable to epoxies and in a fraction of the time. While early light curable acrylic adhesives had low Tg's, high outgassing and high shrinkage values that make them unsuitable for use in critical fiber optic devices, today's light cure technology offers Tg's greater than 100°C, shrinkage of less than one percent, and very low outgassing values. Because cured acrylic adhesives are thermoset plastics, they offer superior thermal, chemical and environmental resistance.

Traditional light cure adhesives required UV light to cure but today visible light curing products have taken over but any adhesive in dark or shadowed areas still remains uncured. However, some light cure acrylic formulations are available with a secondary cure mechanism (such as exposure to heat or chemical activators) that allows adhesive in shadowed areas to cure completely. As cure is on demand, light cure acrylics offer extended open times for positioning and repositioning parts. These adhesives offer high bond strength to a wide variety of substrates, and are available in ranging degrees of flexibility from soft elastomers to glassy plastics. All this, coupled with cure times of just two to 60 seconds, makes light curable acrylics an attractive alternative to epoxy technology.

The clarity of light cure acrylics allows their use in the light path to bond glass ferrules and for direct fiber attach. They are also used in V-groove bonding, lens bonding, critical laser alignment, potting fiber bundles and leads, coating ribbon cables and block bonding/sealing.

For bonding dissimilar substrates like glass to metal, the best option to ensure a robust assembly is **silicone** technology. Silicones are flexible, rubber-like materials that cure at room temperature, exhibit excellent resistance to heat and moisture, and bond a wide variety of substrates. The pliability of silicones over a broad temperature range (-40 to 250°C) makes them an ideal stress absorber. Today there are light cure, dual light/moisture cure, heat cure and two-part silicone technologies to compliment the older RTV chemistry. Moisture cure silicones require a minimum amount of ambient moisture to ensure best performance.

Silicones are used to bond ceramic and epoxy glass boards to metal packages, toughen tall components, gasket and seal packages, and pot components exposed to extreme temperature swings.

High strength, one-part **cyanoacrylates** or instant adhesives are commonly used as processing aids in fiber optic assembly. While their structural bonding properties are inadequate for most fiber optic assemblies (as they do not adhere well to glass and have poor high temperature resistance), these adhesives excel at temporarily tacking down fiber, components and boards while the permanent adhesive is curing. These adhesives achieve fixture strength in just seconds and full strength within 24 hours. Cyanoacrylates are also used in fiber optic assembly for locking screws, tamper proofing set screws and bonding boots to ferrules.

Traditional **anaerobic** adhesives, also known as threadlockers, are single-component adhesives that remain liquid when exposed to air. Once confined between metal substrates in the absence of oxygen, anaerobic adhesives cure or harden into tough thermoset plastics that provide excellent environmental and temperature resistance. These adhesives are ideal candidates for bonding fibers to ferrules, due to their fast fixture time (minutes) and high ultimate strength. Anaerobics are also used in the traditional way to "lock" down lids in devices and to tamper proof set screws, ensuring that factory settings can't be changed and helping to void any warrantee claims for products have been opened by the user.

Typical Properties of Adhesives					
	Light Cure Acrylics	Epoxies	Silicones	Anaerobic	Cyanoacrylates
Refractive Index	1.51	1.56	N/A	N/A*	N/A*
Tg (°C)	50-100+	50-150+	<-40	100 - 130	100 - 130
CTE (ppm, below Tg)	90-120	250-400	250-400	90-120	90-120
Outgassing (%TML/%CVM)	1-4 / 0.06-0.25	2-5 / 0.1-0.7	1.5- 2.0 / 0.7-1.5	Strength Dependant	5-6 / 0-0.001
Shrinkage (%)	2.25 or less	1.5 or less	0-3	5-13	5-15

*Not typically used in the bond line

Key Specifications

Three main adhesive properties are key to the successful application of an adhesive -- glass transition temperature or Tg, outgassing, and 85%RH/85˚C testing. These properties are called out in Telcordia specification GR-1221.

Glass Transition temperature is the temperature at which an adhesive transforms from hard and glassy to soft and rubbery. Tg can be measured in three ways: dynamic mechanical analysis (DMA), thermal mechanical analysis (TMA) or differential scanning calorimetry (DSC). All three techniques are accepted in the industry and all three give different results based in spectra interpretation.

DMA is generally accepted as having excellent repeatability with good dependability. Regardless of technique, the Telcordia specification calls for a minimum Tg of 95˚C. A high Tg does not guarantee a "pass" in heat/humidity aging. Cyanoacrylate adhesives can have Tgs much higher than 95˚C, yet will fail in a hot, moist environment. For cyanoacrylates, high Tg does not equal high performance. There are low Tg (60˚C) light cure acrylics that have outstanding adhesion to glass and will not lose adhesion after 2000+ hours of damp heat testing.

Outgassing is also a key performance criteria identified by device manufacturers. Without industry guidance, most engineers gravitate towards the known, namely the NASA outgassing specification for total mass loss and collected volatile condensable materials. It is up to the end user to determine the acceptable outgassing levels for an adhesive. A low outgassing adhesive tested at 85˚C for a couple of hours seems more realistic than the NASA test of 24 hours at 120˚C in a vacuum. Those with hermetically sealed packaging may need to use low outgassing products that meet the NASA specification in order to avoid adhesive condensation on sensitive optics.

The final and most important performance criterion is the very aggressive damp heat or 85%RH/85˚C test, the key criteria in obtaining Telcordia certification. The high test temperature will cause materials with a Tg at or below 85˚C to become soft and rubbery, allowing moisture to penetrate the adhesive bond line, resulting in a delamination of the assembly at the adhesive/substrate interface. This test is considered one of the toughest in the industry and is used in the fiber optics market and other communications markets as the benchmark for determining the life of the device.

Other adhesive performance criteria that may affect an assembly are product shrinkage upon cure, optical clarity and transmission (if the adhesive is in the light path), viscosity (for processing), thermal expansion and hardness.

If properly selected, adhesives can deliver easily assembled, high performance fiber optic devices that will offer years of predicable service and reliability.

LOCTITE®

1547 N. Trooper Road • P. O. Box 1117 • Worcester, PA 19490-1117 USA
Corporate Phone: 610-825-4990 • Sales: 800-832-4866 or 610-941-2400
Fax: 800-854-8665 or 610-828-5623 • Web: www.techni-tool.com