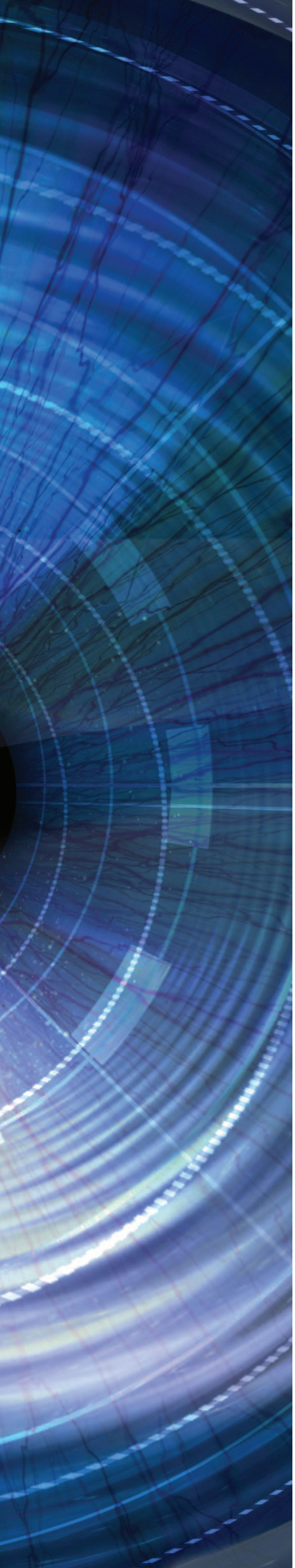

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# Clearly Superior: Epoxies for Optical Applications

*A guide to selecting adhesives for optical applications*

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# Clearly Superior: Epoxies for Optical Applications

## Technology in the optics industry has steadily advanced over the last several years. This can make the adhesive selection process very complex considering the number of factors involved.

Epoxies are frequently used for bonding, sealing, coating and encapsulating applications across optical, opto-electronic, medical and related industries. Given the vast range of properties that epoxy materials offer, perhaps an efficient and effective way to choose a formulation is to explore some of the more significant properties of these systems prior to and after curing. Before curing, these range from color and viscosity to working life and mix ratios. After curing—optical properties, chemical resistance, flexibility and temperature resistance—are among the features of paramount importance in selecting an optical adhesive. Here is an overview on these key characteristics, how to evaluate them and where epoxies can be used.

### One & Two Component Epoxies

Epoxies are arguably the most versatile and widely used polymer for high tech applications. They offer a number of outstanding physical attributes such as high physical strength, good chemical resistance, excellent adhesion to a variety of substrates, broad temperature resistance and the ability to cure in thicker sections for sealing and encapsulation applications. In selecting the best system for a particular application, invariably trade-offs are an important consideration. For example, epoxies can be formulated to be more flexible, but this can compromise some of its temperature resistance. The most basic trade-off is considering when to use a one- or two-part epoxy, and each has its own set of challenges.

For example, two part epoxies must be mixed, which often requires precise measuring by weight of each component; although, some systems are very forgiving and can be mixed by volume. Perhaps its most attractive feature, two component systems cure at ambient temperatures, or faster at elevated temperatures as desired.

On the other hand, one component epoxies eliminate the need for mixing, but they can only cure with the addition of heat (between 250-300°F). Since one part materials require a heat cure, they also offer the tremendous benefit of an unlimited working life at room temperature. By comparison, the working life of two component epoxies is limited. Despite their differences, two component epoxies are used far more regularly in optical applications because of their versatility and ability to cure at room or slightly elevated temperatures. This is particularly significant in optical applications since many of the components involved can be heat sensitive.

***Low viscosity epoxies are easy to apply and feature convenient cures schedules.***

### Curing Epoxies

The curing of epoxies is a polymerization or cross-linking reaction. One part systems require heat curing, typically at 125°C or higher, although some newer systems have been introduced that will cure at 80°C. Moreover, the cure cannot simply be initiated with heat and then left to finish at ambient temperatures. It is important to let the epoxy fully cure with heat, or the curing process will stop.

For two part epoxies, cure times can be looked at in three stages:

- Open time: The time that one has to use the material after mixing Parts A and B together
- Handling time: The time it takes for the adhesive to set up so the parts that are being bonded can be moved. This is also known as fixturing time
- Cure time: The time it takes to "fully" cure

Most two part epoxies will "fully" cure at room temperature; depending upon the system, this can often take many days. The speed of cure can be accelerated by adding heat (50-100°C), which results in additional polymerization and gives the epoxy better properties. There are also some highly specialized two part epoxies that require a heat cure, and provide outstanding physical properties that couldn't be achieved by a more conventional epoxy system.

## Important Properties of Epoxies Prior to Curing

While there is a propensity to focus more on the final properties of the epoxy once it is cured, it is just as important to evaluate requirements prior to curing taking place. Some of the more pertinent aspects include color, viscosity and exotherm generation while curing.

Both one and two part epoxies vary in color from transparent to opaque. For optical applications, the tendency is to think that you always need optical clarity, but this isn't necessarily so. There is no hard and fast rule

***Optically clear epoxy adhesives features high bond strength between dissimilar substrates and long term durability.***

for color, it depends on the application. Some applications require a transparent product and for others, amber clear is acceptable as long as there is good light transmission. In still other scenarios, opaque systems are needed. For example, in certain opto-electronic applications, thermal conductivity is the salient property and optical clarity must become a secondary issue, since thermally conductive epoxies are opaque. Another example when optical clarity is not normally required is bonding a mirror to metal, but this doesn't require an optically clear adhesive.

Viscosity is also a critical factor in the epoxy selection process. In certain applications the material should be very thin or watery such as when it needs to enter a narrow gap. In other situations, a more moderate viscosity or even a paste is desirable, which is particularly true for bonding applications. This tends to be the case with one part epoxies, because when heat is added to cure the material, it increases the epoxy's flow. In general, the best viscosity for an application requires careful consideration of the usage itself. The most fundamental decision is whether the end user is bonding, sealing, coating or potting. Then the specifics of the application need to be examined, including the shape of the parts and its dimensions. Ultimately, the choice depends upon a whole host of different factors including dimensions, the nature of the application, how the material will be applied, and what properties are required after cure, among others. There is also an element of subjectivity and the end user's comfort zone in this process, because it may be necessary to employ the trial and error approach to find the viscosity that best suits the application.

Another major factor (often overlooked) that needs to be considered in the selection process is exotherm created when mixing Parts A and B together. Systems that generate lower exotherm when mixed consistently have longer open times, cure more slowly and can be used for thicker encapsulations. Conversely, systems generating higher exotherm have a far more limited working life, cure more quickly and cannot be used in thicker sections. Regarding two part epoxies, engineers commonly say, "Faster is better," but more often than not, this isn't the case. For example, if long open times are needed or thicker sections are being cast, a faster system is a non-starter, because of the higher exotherm of rapidly curing epoxies. One part compounds are inherently higher in exotherm and are customarily difficult to cure in sections up to and beyond ¼ in thick. However, two part materials can easily cure in sections up to an inch and beyond, which makes them more suitable for potting applications. In general though, the larger the mass of epoxy being cured the greater the exotherm.

## Important Properties of Epoxies After Curing

After polymerization, salient issues for epoxies include optical properties such as light transmission at various wavelengths. Light transmission values from 200 nm up

## Epoxies and the Addition of Fillers

The properties of epoxies can be dramatically altered by adding inorganic fillers such as silica, aluminum oxide or silver. Aside from enhancing dimensional stability, increasing hardness and conferring opacity on the epoxy, fillers can also serve to make the polymer both electrically and/or thermally conductive.

to 5 microns are of particular interest to many optical engineers. Nearly all light transmitting epoxies perform well from 350 nm to 2.5 microns. Above 2.5 microns, epoxies vary greatly in their ability to transmit light. Another optical property is index of refraction upon cure. This value normally ranges from 1.5 to 1.65.

Epoxies are exceptionally robust electrical insulators, although they can be formulated to be conductive. As insulators, they offer superb dielectric strength, dielectric constants, volume resistivity and dissipation factors and other electrically insulative properties. Epoxy versatility is exemplified by the fact that these insulators can be formulated to be thermally conductive and electrically insulative or thermally and electrically conductive.

Chemical resistance is another strong suit of epoxies. They can withstand harsh environments when exposed to water, fuels, acids, bases and numerous solvents, many of which are aggressive.

One paramount reason that epoxies are extensively used is their ability to withstand a wide range of temperatures. In fact, select ones can resist cryogenic conditions while others are functional at higher temperatures up to 500-600°F. Additionally, many epoxies excel in applications involving rigorous thermal cycling.

In optical applications, epoxies are especially noteworthy for being low outgassing. This is highly desirable in applications involving lenses, semiconductors, optical components and vacuum applications. Many epoxies pass the NASA low outgassing test based on ASTM C-595, which is tested under vacuum conditions. Other epoxies that have not been tested are usually considered "generically" low outgassing.

Hardness is another example of epoxy versatility. While epoxies are associated as being rigid, there are many formulations that offer varying degrees of toughness and flexibility. Flexible epoxies are particularly useful for bonding dissimilar substrates in conditions where rigorous thermal cycling is taking place. Rigidity is desirable in situations demanding dimensional stability, machining and polishing.

## Conclusion

In summary, when choosing an epoxy for an optical application the properties after cure are of paramount importance, but the characteristics of these systems prior to cure cannot be underestimated. For the success of the application, carefully evaluate the trade-offs and prioritize the properties, both before and after cure.

For further information on this article, for answers to any adhesives applications questions, or for information on any Master Bond products, please contact our technical experts at Tel: +1 (201) 343-8983.

# POPULAR PRODUCTS FOR OPTICAL APPLICATIONS

## *Two Component Epoxies —*

| Master Bond Grade | Mix Ratio, by Weight | Viscosity, RT, cps | Cure Schedule, °F | Service Temperature Range, °F | Color | Applications |
|---|---|---|---|---|---|---|
| EP30 | 4:1 | Part A: 400-900 Part B: 280-500 | 75°F: 24-48 hours 200°F: 2-3 hours | -60°F to +250°F | Clear | Low viscosity, room temperature curing epoxy adhesive/sealant. 100% reactive. High strength bonds and excellent dimensional stability. Chemically resistant. |
| EP37-3FLF | 1:1 | 1,400-1,500 | 75°F: 2-3 days 200°F: 2-3 hours | 4K to +250°F | Clear | Highly flexible, impact resistant, optically clear epoxy system. Resistant to thermal cycling. Low exotherm. Superb potting and encapsulation compound. High peel and shear strength properties. |
| EP30HT | 4:1 | Part A: 55,000-110,000 Part B: 250-500 | 75°F: 24-36 hours 200°F: 2-3 hours | -60°F to +400°F | Clear | High temperature. Bonds well to glass. Exhibits excellent chemical resistance to acids and bases. Superior dimensional stability and low shrinkage upon cure. Resists 1,000 hours of exposure to 85°C/85% humidity. |
| EP21TCHT-1 | 100:60 | Part A: >150,000 Part B: >50,000 Mixed: thixotropic paste | 75°F: 24-48 hours 200°F: 2-3 hours | 4K to +400°F | Gray | NASA low outgassing certified, high temperature resistant thermally conductive epoxy. Cryogenically serviceable. Halogen free. |
| EP21LSCL-1 | 100:60 | Part A: 1,800-2,500 Part B: 600-1,200 Mixed: 1,000-2,000 | 75°F: 3-5 days 200°F: 3 hours | -60°F to +250°F | Clear | For bonding, coating, sealing and casting. Offers outstanding non-yellowing characteristics. Low viscosity. Exceptionally long open time. Can be utilized in thicker encapsulations. |

## *One Component Epoxies —*

| Master Bond Grade | Viscosity, RT, cps | Cure Schedule, °F | Service Temperature Range, °F | Color | Applications |
|---|---|---|---|---|---|
| Supreme 10HT/S | Thick paste | 45 minutes @ 275-300°F | 4K to +400°F | Silver gray | One part, heat cured structural epoxy with long working life. Excellent shear and peel strength. Cryogenically serviceable. Heat resistant. Screen printable. Low volume resistivity of less than $<10^{-3}$ ohm-cm. |