

How Does UV Curing Work?

Materials that cure using ultraviolet light provide an extremely convenient *cure on demand* capability. Other compounds that harden, for example, at room temperature must be mixed and used within a certain time to obtain the best results.

Typically there is no mixing required for UV-curing materials, nor is there any requirement to use dispensed material within a short time period. Not only is this more convenient for the user, it also eliminates two potential sources of process variability—meaning more consistent results!

In this document, we'll look at what Ultraviolet light is, how it interacts with UV-curing materials and different types of UV-curing adhesives.

What is UV Light?

Ultraviolet light is a particular portion of the light spectrum, typically considered to be in the wavelength range from 200 nm (nanometers) to 400 nm. Light in this spectral range has many important uses including water purification, semiconductor lithography, sun tanning and, of course, adhesive curing.

[Spectrum graphic]

Since ultraviolet light falls below the visible portion of the light spectrum, we cannot see pure UV light. This can be an important consideration, because another significant property of light is its *intensity*. Special equipment—a radiometer—is required to measure the intensity of UV light. The intensity of light falling on a surface is measured in milliwatts per square centimeter (mW/cm²), or power (mW) per unit area (cm²).

UV-Curing Adhesives

Every high performance adhesive has at least two components to it. An obvious example is the two-part, room temperature curing material already mentioned. A less obvious example would be contact cement, where only a single material is handled. For this kind of adhesive to work, a solvent must evaporate from the product, leaving the actual bonding resin behind. So, the resin is one part and the solvent is the second part.

In an ultraviolet-curing adhesive, there are also two components. One part is the adhesive resin itself and the second part—already mixed in—is called a *photoinitiator*. The secret of the photoinitiator is that it will not react with the resin by itself. The photoinitiator must absorb ultraviolet light before anything can happen. When the UV light is delivered, the photoinitiator will undergo a chemical reaction and produce by-products that cause the adhesive to harden.

Previously, we said that UV light has two important characteristics—wavelength and intensity. For the photoinitiator to react correctly, it must be exposed to light of the correct wavelength *and* of sufficient intensity. Otherwise, the chemical reaction will not

happen, or may not happen completely. The result will be poor or inconsistent adhesive performance.

Types of UV Adhesives

There are a wide variety of UV-curing materials available, for a broad range of applications. UV-curing resins likely have been used to protect laminated flooring you are standing on, or to coat the “peel and stick” labels you use. For our purposes, we will look at two types of high performance, engineering adhesive typically used in product assembly.

The first type of adhesive to become familiar with is an epoxy-based material. While some people use the term *epoxy* as a generic reference to all high performance, engineering adhesives, it has quite specific meaning within the adhesive world. It is also different from other adhesive types, particularly the acrylic-based adhesives that we’ll also look at.

Epoxy adhesives use a catalytic cure mechanism. The *catalyst* is a by-product from the reaction of the photoinitiator to UV light. By definition, a catalyst is something that promotes a chemical reaction, but is *not* consumed in the reaction. One consequence of this is that UV-curing epoxy adhesives can exhibit a *shadow curing* capability—material that is not directly exposed to UV light will cure...sooner or later.

Epoxy adhesives are also easy to modify for special purposes. For example, they can be filled with carbon, silver or gold to provide electrical conductivity. Other additives can enhance thermal conductivity, while maintaining electrical insulation. Additional performance properties of epoxy-based adhesives that can be modified include impact resistance, shrinkage, glass transition temperature, high temperature strength, surface-specific adhesion characteristics and chemical or moisture resistance.

Acrylic adhesives result from an entirely different chemistry and a different type of photoinitiator. Curing of acrylic adhesives results from a *free radical* mechanism. The free radicals are produced by the photoinitiator when it is exposed to ultraviolet light. However, the free radicals *are* consumed in the adhesive cure process, so acrylic adhesives can only cure where UV light is delivered. At least one of the components being bonded *must* be UV-transparent to some degree. Another consequence of this cure mechanism is that *no* shadow cure capability is evident.

Modification of properties in acrylic adhesives is more often conducted at the chemical level, through changes in formulation or combination with other base resins. Wide ranging properties can include impact resistance, surface insensitivity, environmental resistance and others. The emergence of *urethane acrylate* adhesives, as well as *acrylated epoxies*, begins to make simplistic adhesive classifications more challenging.

UV Cure Conditions

Previous research has demonstrated that adjusting cure conditions can favorably impact the performance properties of many UV-curing adhesives. Critical applications may require a sequence of curing steps—involving different intensities of light and duration of

exposure—in order to optimize results. Less sensitive applications will also benefit from ensuring that cure conditions are suitable and consistent from one period to the next.

Curing equipment should be engineered to ensure repeatability in critical UV parameters, such as intensity and duration of exposure. The ability to adjust the spectral profile of a UV light source can also be very important, as different adhesives may respond more favorably to different spectral inputs. Similarly, when working with a variety of bonding surfaces—notably plastics—changing the UV output profile can avoid excess heating of the surface.

Conclusion:

The use of ultraviolet light to cure adhesives brings many benefits to product manufacturers. Among these are ease of use, process consistency and flexibility, reduced environmental considerations and the availability of high performance materials.

When suitable material selections are made and understood, best practices for adhesive curing are implemented, and process monitoring and feedback are in place, the potential for consistent, high yield product assembly is significantly enhanced. One part of this is understanding the factors that affect process reliability and adhesive performance.

EXFO (Toronto) has been building UV light sources for almost twenty years and understands the issues associated with adhesive curing and process requirements across a broad range of industries. Product information is available through our web site at <http://www.exfo.com>.

UV Light: Frequently Asked Questions

Q: Which adhesive is the right one for my application?

A: There is such a wide variety of adhesives available, and coupled with the fact that individual applications can have varied requirements, it is impossible to recommend one material, or family of adhesive, for general use. The adhesive specification process is similar to any other product design approach. Beginning with a list of requirements, suitable potential candidates should be identified through research. Contact adhesive manufacturers for recommendations and technical data. Compare performance characteristics with the identified requirements and develop a short list of candidates.

With this information, an assessment program can be started to verify the suitability of the adhesives for an application. Further process development should include issues such as adhesive dispensing, fixturing of components, surface preparation and cleaning, curing conditions, process monitoring and environmental testing. A well-developed adhesive process specification will support the important manufacturing objectives of performance, consistency and reliability.

Q: Can a customer UV-cure a material that is under an opaque surface, but exposed at the edges?

A: This may be possible when using the appropriate kind of adhesive. Catalytic-cure adhesives—typically an epoxy-based material—can be used in this fashion, because the catalyst is *not* consumed in the adhesive cure process. Delivering UV light to the exposed edges will create the catalyst to begin the reaction. Eventually, the reaction will progress through the full volume of adhesive, though completion may not occur for hours or days.

Free-radical curing materials—most often acrylic adhesives—are more challenging in this regard. Reaction will only take place where the adhesive is exposed to UV light, meaning that only the edges will cure. If the adhesive also has a secondary heat curing capability, the customer might use UV light to “tack” a component in place and later heat the assembly to complete the adhesive cure. Without a secondary cure mechanism, however, a free-radical curing compound will *not* become hard where it is not exposed to UV light.

A third potential solution to this problem lies in a group of adhesives known as *delay-cure* materials. These are materials that can be activated by UV light, but begin curing slowly. For a specific combination of light intensity and exposure time, there will be a working time that you can use to place the components in position. Higher intensities and longer times result in shorter working times for the adhesive. Some trial-and-error evaluation will have to be done to find the appropriate combination for your application.

Q: Is there a safety hazard in working with Ultraviolet light?

A: Like many other industrial process components, due care and caution are required when working with UV light. Most countries have Health & Safety legislation that requires the time weighted average (TWA) exposure of workers to be kept below a certain value.

Casual use of ultraviolet light may only require personal protection, such as appropriate safety glasses. On-going use of high intensity UV light, or exposure to light below a certain wavelength may require more systematic protection measures. Check your local safety legislation for specific requirements.