

When to Use a Light Curing Assembly Process

A Review and Update

Introduction and History

The introduction of UV light curing Aerobic Acrylic Adhesives and their economic advantage of instant cure upon exposure to light, secured their adoption by a number of manufacturers in the early 1980's. Though UV inks and coatings began their market penetration early in 1970, the use of structural adhesives for parts assembly, began in earnest in North America with the successful use of aerobic acrylic formulations in early 1983 for the bonding of glass head lamps.

Because of their compelling process cost reduction features and wide range of properties, use of light curing structural adhesives swept across the industrial spectrum. By 1990, industries as diverse as aerospace electronics, automotive, industrial electrical, medical device, appliance, stemware, architectural, art glass and crystal assembly, to name a few, began to utilize light curing processes. Some typical current applications include:

Table I

Typical Aerobic Acrylic Adhesive Applications
Glass and plastic headlamp assembly
Electrical sealing and tacking
Optical lens assembly
Microelectronic assembly
Disk drive voice coil bonding
Bonding of metal and plastic housing
Medical Disposable Device assembly
Coil terminating
Tamper proofing
Stemware assembly
Speaker software assembly

Technical Considerations For Using Light Curing Technology

Complete "Line Of Sight" Exposure Is Ideal

Complete "line of sight" exposure of the photocuring resin to the light is an ideal cure condition for a photocuring assembly and process. This means that light can pass through a clear surface that does not block, or minimally blocks, transmission of the light, or that a layer of resin is completely exposed to light. Recent innovations in photocuring technology, moreover, have enabled cures through clear, UV blocked plastics and glass. These innovations in photoinitiator chemistry allow utilization of broader spectrum wavelengths by the resin for curing. The photoinitiators are able to effect cures in the visible wavelengths (400 - 500 nm)

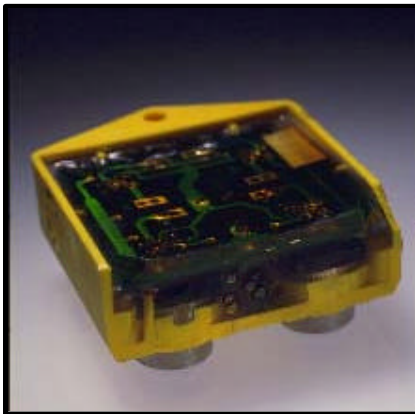
as well as in the UVA, UVB, and UVC range (254 - 365nm). Many resin formulations are available that are capable of cures in 1 to 30 seconds of layers 1/4 of an inch thick.

Though many light curing resins are capable of cures to several inches, the time this requires makes them noncompetitive for most applications. It is usually much more economical to use slower curing, and less expensive epoxy, or other resins for cures requiring many minutes.

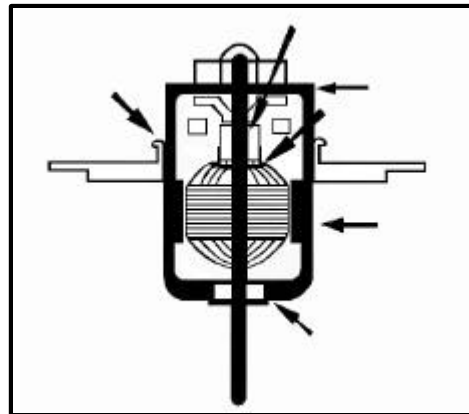
Partial Line Of Sight Exposure May Be Sufficient For Some Applications

Though complete line of sight light exposure is an ideal condition for a light curing application, there are some successful applications for light curing adhesives where light exposure is partially blocked. This is because some UV curing resins also have other, secondary curing mechanisms that will work in some applications. For example, UV curing catalysts have long been combined with activator and heat curing catalysts in a variety of resin formulations. More recently, two-part light curing systems, and light curing systems that also cure upon exposure to oxygen and moisture have been developed. These systems are practical where light curing is the primarily curing mechanism, and the majority of the resin volume is light cured. Examples of some successful dual cure resin applications are shown below:

UV + Two-Part Cure Chemistry For Potting



UV + Activator - Flange Bonding



In the potting application shown above, a printed circuit board is potted to a depth of nearly 1/2 inch using a two-part acrylic resin. The first quarter of an inch or more is cured by exposure to the light. The remaining resin which seeped underneath the PCB and out of “line of sight” of the light cured some 20 minutes later at room temperature as a result of the two-part chemical reaction.

Both a UV cure mechanism and activator were used to bond the epoxy coated metal flange onto an epoxy coated motor housing. The multicuring adhesive, which completely filled the joint and formed a fillet at the top of the joint, was cured in seconds with UV light to secure the flange in place. Within less than one minute, a mechanical, in line test was able to detect a

significant strength build up within the opaque joint where activator curing of the adhesive bond was occurring.

Typical Properties Help to Guide “Use” Decisions

Typical properties of a photocuring resin help identify when the resin is suitable for a particular application. The ranges listed below are typical for light curing acrylic resins and most UV epoxies:

Typical Properties Ranges for UV Curing Structural Adhesives

Ranges For Typical Properties	UV Adhesives & Thick Layer Resins
Cure depth	1-100 mils typical thickness used
Cure speed*	1 to 30 seconds cures “typical”
Viscosity	10 - 200,000 cP
Adhesion to metals, plastic & glass	Frequently to 4,000 psi or substrate destruction
Clarity	Water white to straw, or translucent; colors and fluorescent grades available
Surface dryness/slickness	Dry surface cures
Moisture resistance	Good to excellent
Hardness (Shore A&D)	A 30 to D 80
Resistance to thermal shock under load	Good to excellent
Thermal Range	-85°F to 325°F
Solvent resistance	Good to excellent

* See Cure Speeds with various lamps shown below.

Chart I

Cure Rates of Light Curing Adhesive & Coating With A Range Of UV Curing Lamps

Lamp/Type	Moderate Intensity UV Flood	Higher Intensity UV Flood	High Intensity UV Spot	Very High Intensity UV Spot	Conveyorized Beam 2 x 1200-EC High Intensity	Conveyorized Electrodeless Lamps
Spectral Output of Lamps (nanometers)	300-500	200-500	200-500	200-500	200-500	200-500
Nominal Intensity (mW/cm²)	20-60	175-225	1000-2000	1800-5000	225-275	1700 - 2000
Typical Adhesive Cure Rate						
(UV/Visible Cure Adhesive)						
Between Surface Cures (Glass)	1-4 sec	1-3 sec	<1-2 sec	≤ 1 sec		3-5 feet/min 5-20 feet/min
On Surface Cures*	40-240 sec	10-40 sec	2-10 sec	1-5 sec		1-3 feet/min 3-10 feet/min
(UV Cure Adhesive)						
Between Surface Cures (Glass)	2-6 sec	1-4 sec	1-3 sec	≤ 2 sec		2-4 feet/min 5-15 feet/min
On Surface Cures	30-600 sec	20-50 sec	3-5 sec	1-3 sec		1-2 feet/min 1-10 feet/min

Ranges represent the fastest and slowest cure times of Dymax formulations under the stated lamps.

*Some formulations never achieve a dry surface cure, though most do. The time range stated represents the fastest to the slowest curing products.

Typical Successful Application for Photocuring

UV structural adhesives are used mostly in bonding or “thick layer” sealing and coating applications as opposed to UV ink and thin layer coating applications. This is due to the fact that many of the applications for which they were designed are bonding applications with mechanical load bearing requirements, or else thicker layer encapsulation, or sealing for environmental protection or mechanical requirements of the assembly. The applications in which they have been successful can be classified and described as follows:

Bonding - where at least one surface transmits UV light

Tacking - where a small spot of adhesive - 1/4 to 1/8 of an inch thick - holds a wire or other component in place


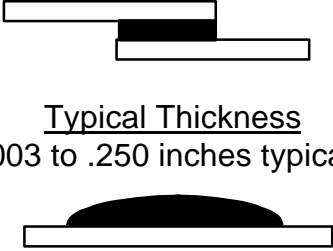
Sealing - where adhesive bridges gaps between substrates forming bonds which seal one area from another to prevent exposure to air or moisture

Potting - where a shallow cavity is filled for a variety of purposes such as tamper proofing, sealing, aesthetics, or ruggedizing

Encapsulating - where a thick layer of resin is domed over a small component or chip usually for environmental protection, or a decorative application such as dome coating; depths for 1/16 to 1/4 of an inch are typical

Conformal Coating - refers to coating components on a printed circuit board; usually this is a complete coating on one or both sides, but may only be used in discrete areas; thickness is usually .003 to .005 mils

Light curing Aerobic Acrylic adhesives do not make good inks or thin coatings of less than about three mils in thickness. This is because they are designed for optimum speed of cure at thicknesses as shown in the above application types. Conversely, ink and coating systems, are designed to cure in the 5 to 20 micron range and at run rates of several hundred to 1200 feet per minute. These requirements dictate significant formulation and curing differences.

<p>Typical Inks & Coatings</p>	<p>Structural Adhesives, Sealants & Encapsulants</p>
<div style="text-align: center;">  <p><u>Typical Thickness</u> 5-50 microns</p> <p>(*special applications to 300 microns)</p> </div>	<div style="text-align: center;">  <p><u>Typical Thickness</u> .003 to .250 inches typical</p> </div>

Typical cure rates of structural adhesives and thick layer coatings as shown above are in the 1-30 second time frame, depending upon the resin formulation and the curing system chosen. (See Adhesive Cure Rate; Chart I)

Economic Considerations for Photocuring

When they were first introduced, photocuring resins attracted a great deal of attention because of their cure in seconds, instead of minutes or hours as was the case with many traditional resins. As use of photocuring adhesives has become more common in industrial applications, many more ways in which they lower manufacturing costs have become apparent. Below are listed a number of reasons why photocuring is being adopted in favor of conventionally cured resins:

Light Curing Yields Reduced Cost Per Unit And A Net Economic Advantage
Faster production rates
V.O.C. reduction - improved air quality
Lower rejects
Properties not matched by other materials
All in line process (100% Q.C.)
Space savings
Lower labor cost
Less waste
Easier to use/control
Eliminate costly fixtures and jigs
Room temperature cures save energy

Each of the above listed factors represents hundreds of cost savings examples from across the industrial spectrum. Three examples from different industries will illustrate ways in which individual manufacturers have realized significant cost savings from use of light curing technology.

Tail Light Manufacturer Reduces Manufacturing Space, Scrap and Labor Content

Because of the fast cure of the UV/Visible adhesives compared with a two component silicone, a midwestern automotive parts supplier was able to reduce significantly the space required for their manufacturing operation. This leading vendor to the automotive industry was charged with providing the tail light for a 1999 model luxury vehicle. The application involved bonding a red polycarbonate lens to a clear acrylic diffuser. Though both plastics blocked all but 2% of the ultraviolet light, the visible cure capability of the resin allowed polymerization through the clear polycarbonate lens. In addition to opening up additional floor space to allow for expansion, the change to the photocuring resin eliminated the waste and scrap that resulted from producing defective parts, and dramatically lowered the total labor content of the process.

UV/Visible Adhesive Speeds Catheter Manufacturing Process

A German manufacturer of catheters was seeking a bonding process that could improve the speed of it's catheter assembly operation from several minutes to under 10 seconds. Upon submission of a light curing adhesive, it was discovered that the UV

blocking capacity of the plastic was slowing the adhesive's cure rate so that it would not cure in the 10 second time frame which the manufacturer's UV curing equipment could provide. A new, UV + visible light curing adhesive was developed that increased the cure speed, allowing the desired 4-6 second cure time. Because the speed of cure of the adhesive was brought into an acceptable range for the catheter manufacturer's assembly process, cures could be effected without additional capital expenditure for higher intensity, or additional curing equipment.

UV Adhesive Imparts Higher Quality For Tweeter Assembly

A West Coast manufacturer of tweeter assemblies found that a flexible UV curing formulation used to tack a Kapton voice coil to a Titanium tweeter delivered a better frequency response than an alternative and more brittle cyanoacrylate adhesive, resulting in a better quality product for the manufacturer. In addition to providing a superior quality product, the UV adhesive also eliminated waste and scrap due to it's long shelf life compared with the alternative cyanoacrylate. Because the UV adhesive was easy to automate, it lowered labor content as well.

Some Common Misconceptions For Not Using Photocuring Technology

With all of the new applications and advantages of photocuring there remain some misconceptions regarding the economics of their use. These may be summarized in the table below.

Misconceptions	Light Curing Facts	Perspective
Materials more costly than alternatives	Yes - compared to epoxies, urethanes and solvent based resins; but they are competitively priced with silicones and cyanoacrylates	Material cost is <i>usually insignificant</i> compared with processing cost savings or other advantages provided
Equipment costly	Most Standard Curing Equipment Cost Between 3K -20K; Custom equipment is typically 10K - 75K	Compared to heat curing equipment, dryers and environmental scrubbers, cost can be far less
Difficult to cure pigmented products	Yes, but can be done; limited to thin layers	application possibilities are limited to about 1/16"
Limited to Line of sight cure	Usually, but secondary cures are available	Secondary cures are only of use where light is the primary cure and light cured resin is the majority of the cured resin volume
Too complicated	Perception is lessening with growing use and education	Hundreds of UV processes have simplified production and saved manufacturers millions of dollars over the past 20 years
Hard to apply at 100% solids (high viscosity)	Equipment is improving and dispensing high viscosity is not as much of an issue	Excellent valves are capable of spraying even high viscosity gels
Limited range of properties	Broad range of properties is reflected by broad range of applications	See Typical Properties Chart

Summary

Because of the compelling economic advantages of photocuring, the number of subassemblies that are manufactured using a photocuring process continues to grow. With continued expansion of the markets and applications for light curing products, more and more

manufacturers of both the resins and equipment are available to provide both products and services to meet the expanding demand.