COMPREHENSIVE GUIDE TO

DYMAX UV LIGHT-CURING TECHNOLOGY

Contents

Section 1: Dymax Corporation

1.1 About Dymax

Dymax Corporation was founded in 1980. The first products developed and sold were based on its patented two-part structural acrylic adhesive systems, primarily to the automotive market. Within several years, Dymax introduced the first practical, structural-strength UV-curable adhesive.

Today, Dymax has over $30 million in annual revenue and over 270 employees globally. Approximately 50% of sales are to countries outside of the United States. Dymax Corporation is ISO 9001 certified. The corporate headquarters is in Torrington, Connecticut with wholly owned subsidiaries in Germany, Ireland, Hong Kong, Korea, and Singapore as well as venture partners, representatives, and distributors worldwide. This expansion into Europe and Asia has allowed Dymax to better support and supply the growing number of manufacturers in these regions.

* Note: Light-Curable Materials, or LCMs, is a general term for the technology described in this guide. Past papers and literature authored by Dymax and other companies have more specifically referred to this technology as Light-Curable Adhesives, or LCAs. Recent advances in light- curing technology have created new classes of materials, such as thick-layer coatings, gaskets, sealants, potting and encapsulating systems and dome coatings. Throughout this guide, LCMs will be used to better describe the broad range of products now available.

Dymax Corporate Headquarters in Torrington, CT USA

1.2 What Does Dymax Sell?

Light-Curable Materials* (LCMs) and light-curing equipment make up the majority of Dymax's sales. Dymax is the only major manufacturer of both light-curable materials and light-curing equipment. This focus on light-curing technology coupled with the synergy produced by designing both the materials and equipment, uniquely positions Dymax as the technical leader in light-curing technology. The primary uses of Dymax products are:

Light-Curable Materials

- Adhesives – primarily for glass, plastic, metal, and ceramic
- Coatings – primarily conformal (for electronics) and thick decorative coatings
- Encapsulants – for electronics, especially on flexible circuits
- Shallow Potting Compounds – primarily less than 3/8″ deep
- Masking Materials – primarily for protection during coating, plating, and blasting processes
- Gaskets – primarily for sealing against moisture and reducing noise

Light-Curing Equipment

- Spot Lamps – for small areas
- Flood Lamps – for larger areas
- Conveyors – for large-scale production
- Radiometers – for measuring light intensity

In addition to its light-curable materials, Dymax also produces a line of two-part, no-mix structural acrylic adhesives. Contact Dymax Applications Engineering to

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learn more about the uses, properties, and advantages of these fast-setting, high-strength magnet and metal bonding adhesive systems.

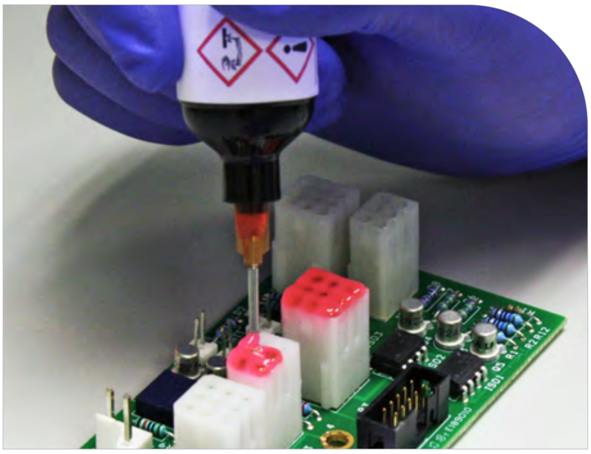
Dymax has developed over 3,000 light-curing products. The products are sold primarily through a worldwide network of distributors and manufacturer's representatives.

1.3 Who Uses Dymax?

Manufacturers from many industries use Dymax products to increase productivity (i.e. lower total assembly costs). The majority of Dymax customers are manufacturers from the following markets:

- Medical
- Electronics
- Automotive
- Aerospace
- Telecommunications
- Optical
- Packaging
- Industrial

Over 50% of Fortune 500 manufacturers in these markets are direct or indirect Dymax customers and about half of Dymax's sales are to countries outside the United States.



1.4 Advantages of Dymax Light-Curable Materials (LCMs)

Each Dymax customer will perceive and realize a unique set of benefits from Dymax products, but there are a few features/benefits that Dymax customers consistently cite:

Feature	Benefit
Fast Light Cures "On Demand"	• Reduces overall assembly costs • Reduces labor costs • Easier automation • Easier alignment of parts before cure • Improves in-line inspection • Reduces work-in-progress • Shorter cycle times • Shorter lead times to customers • Fewer assembly stations required • Eliminates racking • Eliminates ovens/heat curing
One-Component	• Reduces overall assembly costs • Eliminates mixing • Eliminates pot life issues, less waste • Less expensive dispensing equipment • No hazardous waste due to purging/poor mixing • No static mixers • Easier to operate/maintain dispensing systems
Environmentally and Worker Friendly	• Better worker acceptance • No explosion-proof equipment • Reduces health issues • Reduces regulatory costs • Reduces disposal costs
Wide Range of LCMs	• Wide range of viscosities available • Wide range of hardnesses available • Adhesion to a wide range of substrates • Clear, fluorescing, and colored formulas • Multiple curing options • Over 3,000 formulations available

Limitations of Light-Curable Materials (LCMs)

As with all products, there are limitations associated with LCMs. The most obvious limitation of LCMs is that they are only appropriate in applications where, after assembly, the LCM can be exposed to light*. Where light-curing technology is not feasible, consider using two-part, no-mix structural acrylics (ideal for bonding magnets and metal substrates). Contact Dymax Applications Engineering for more information on these fast-setting, high-strength magnet and metal bonding adhesive systems.

Generally, LCMs are limited to cure depths of ¼" -½". There are upper and lower limits for each of the physical properties associated with Dymax products, like hardness, viscosity, temperature resistance, etc. For more information on the properties of Dymax LCMs, see *Section 2.2 Typical Properties of Dymax Materials (LCMs).*

*Through the use of patented adhesive and curing processes, Dymax can now cure through most UV-blocked substrates, provided they transmit visible light.

1.5 Specific Advantages of Dymax LCMs Over Other Chemistries

Adhesives, sealants, coatings, gaskets, masks, etc., can vary in many ways. Here are just a few:

- Curing process
- Bond strength to specific substrates
- Viscosity, hardness, flexibility
- Speed of cure, depth of cure
- Minimum or maximum gap required/allowed
- Shrinkage, CTE, Tg
- Moisture, heat, cold, UV, and thermal cycling resistance
- Environmental impact
- Worker safety
- Dispensing and curing equipment/process required
- Pot life, shelf life, and stability
- Color, clarity, odor
- Pricing and packaging
- Blooming, stress cracking

Each potential adhesive/coating application and customer will have a unique set of requirements, and for each application there are chemistries that fit well and those that don't fit as well. The following section highlights the advantages of Dymax LCMs versus competing chemistries. Be aware that an advantage shared by both chemistries will not be listed, i.e. "no mixing" is not listed as an advantage in the section comparing Dymax LCMs to hot melts since neither technology requires mixing.

1.5.1 Versus One-Part Silicones

✓ Indicates Superiority		Feature
Dymax LCM	Silicone	
✓		**Faster Cures** –100% cure in 1-30 seconds upon exposure to light versus silicones that require exposure to humidity for 30 minutes to several days to properly cure.
✓		**Stronger Bonds** – Typically 500-4,000 psi versus 100-500 psi for silicones.
✓		**No Silicone Contamination** – Silicones can migrate across an entire plant affecting the wetting and adhesion of surfaces that require coating or bonding.
✓		**Unaffected by Humidity** – Moisture-cured silicones often require humidity chambers because humidity greatly affects their cure speed. The Dymax light-curing process is essentially unaffected by humidity.
✓		**Longer Shelf Life** – Moisture-cured silicones can be "spoiled" prior to use if exposed to humidity and usually have a 3-6 month shelf life. Dymax LCMs are unaffected by exposure to ambient humidity and typically have a 1-year shelf life.
	✓	**Bonds Opaque Substrates**
	✓	**Light-Curing Equipment Not Required**
	✓	**Higher Temperature Resistance** – Upwards of 200°C for silicones versus a maximum of 150-175°C for most Dymax LCMs.

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1.5.2 Versus Cyanoacrylates (CAs)

✓ Indicates Superiority		Feature
Dymax LCM	Cyanoacrylate	
✓		**Faster Cures** – 100% cure in 1-30 seconds versus CAs which merely fixture in 10-60 seconds.
✓		**Unlimited "Open Time"** – Dymax LCMs do not begin curing until exposed to high-intensity light providing an unlimited "open time". CAs have a short "open time" of 10-30 seconds.
✓		**Better Temperature Resistance** – Cyanoacrylates are not recommended for high-temperature (225ºF or greater) applications. Many Dymax LCMs can withstand temperatures of -65ºF or 300ºF long term.
✓		**Better Moisture Resistance** – Cyanoacrylates are not designed for high humidity or long term moisture exposure, whereas Dymax LCMs can be formulated to exhibit excellent moisture resistance.
✓		**Better Impact Resistance** – Cyanoacrylates are typically very brittle and have little impact resistance versus Dymax light-curable formulations that can range from flexible to rigid.
✓		**Better Gap Cures** – Dymax LCMs typically cure through gaps of ¼" or more versus cyanoacrylates which require intimate contact.
✓		**No "Blooming"** – Cyanoacrylates can produce a white haze around the bond-line after cure.
✓		**No Stress Cracking** – Cyanoacrylates can impart tiny cracks in plastic prior to cure.
✓		**Won't Bond Skin on Contact**
✓		**Less Odor**
	✓	**Light-Curing Equipment Not Required**
	✓	**Bonds Opaque Substrates**
	✓	**Bonds Rubber**

1.5.3 Versus Two-Part Epoxies

✓ Indicates Superiority		Feature
Dymax LCM	Two-Part Epoxy	
✓		**Faster Cures** – 100% cure in 1-30 seconds versus epoxies that require several hours at room temperature or minutes with high-temperature cure.
✓		**Meter Mix Equipment Not Required**
✓		**Unlimited Pot Life**
✓		**Do Not Require Purge Cycles that Result in Hazardous Waste**
✓		**Better Impact Resistance**
✓		**Both Flexible and Rigid Formulations Available**
	✓	**Can be Better for Applications Requiring Extreme Chemical Resistance**
	✓	**Less Expensive Per Pound**
	✓	**Light-Curing Equipment is Not Required**
	✓	**Bonds Opaque Substrates**

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1.5.4 Versus One-Part Epoxies

✓ Indicates Superiority		Feature
Dymax LCM	One-Part Epoxy	
✓		**Faster Cures** – 100% cure in 1-30 seconds versus epoxies that require 5-60 minutes with heat curing ovens.
✓		**Longer Shelf Life** – Most one-part epoxies exhibit a shelf life of 6 months or less versus Dymax LCMs which typically offer a 12-month shelf life. Some one-part epoxies require refrigerated or frozen storage whereas Dymax recommends room temperature storage for almost all of its LCMs.
✓		**Heat Curing Not Required** – One-part epoxies typically require a heat cure of 220°F or more for 20 minutes or more.
✓		**Better Impact Resistance**
✓		**Both Flexible and Rigid Formulations Available**
	✓	**Light-Curing Equipment Not Required**
	✓	**Bonds Opaque Substrates**
	✓	**Can be Better for Applications Requiring Extreme Chemical Resistance**

1.5.5 Versus Two-Part Urethanes

✓ Indicates Superiority		Feature
Dymax LCM	Two-Part Urethanes	
✓		**Faster Cures** – 100% cure in 1-30 seconds versus two-part urethanes that require five minutes to several hours, with or without heat-curing ovens.
✓		**Expensive Meter Mix Equipment Not Required**
✓		**Does Not Require Purge Cycles that Result in Hazardous Waste**
✓		**Unaffected by Humidity**
✓		**No Free Isocyanates** – Isocyanates can be a worker hazard and can lead to hazardous waste.
	✓	**Light-Curing Equipment Not Required**
	✓	**Bonds Opaque Substrates**
	✓	Less Expensive Per Pound

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1.5.6 Versus Hot Melts

✓ Indicates Superiority		Feature
Dymax LCM	Hot Melts	
✓		**"Cure on Demand"** – Dymax LCMs have an unlimited "open time" unlike hot melts that begin curing immediately upon dispensing.
✓		**Stronger Bonds**
✓		**Hot Melt Guns and Heated Pots / Lines Not Required**
✓		**Less Likely to Damage Heat Sensitive Substrates**
✓		**No Risk of Burning Workers**
✓		**Higher Temperature Resistance**
✓		**Optically Clear Formulations Available**
✓		**Less Prone to Environmental Degradation**
✓		**Wide Range of Viscosities Available**
✓		**Not Stringy** – Unlike hot melts which can be stringy during dispensing.
	✓	**Light-Curing Equipment Not Required**
	✓	**Bonds Opaque Substrates**
	✓	**Less Expensive Per Pound**

1.5.7 Versus Solvent-Based Adhesives

✓ Indicates Superiority		Feature
Dymax LCM	Solvent-Based Adhesives	
✓		**Faster Cures** – in as little as 0.5 seconds.
✓		**"Cure on Demand"** – Ensures properly aligned parts prior to cure, unlike solvent-based materials that begin curing immediately upon assembly.
✓		**No Stress Cracking** – Solvents can impart tiny cracks in plastic surfaces.
✓		**Bonds Dissimilar Plastics, Thermoset Plastics, Metals, Glass, Rubber, and Ceramics**
✓		Fills Gaps – Dymax LCMs are more forgiving of part fit.
✓		**Less Odor**
✓		**Non-Flammable Liquid**
✓		**Special Ventilation Not Typically Required**
✓		**More Worker Friendly**
✓		**More Environmentally Compliant**
	✓	**Light-Curing Equipment Not Required**
	✓	**Bonds Opaque Substrates**
	✓	**Less Expensive per Pound**

Section 2: Dymax Light-Curable Materials (LCMs)

2.1 The Chemistry Behind Dymax Light-Curable Materials (LCMs)

Dymax LCMs contain ingredients known as photoinitiators. Photoinitiators begin the curing reaction upon exposure to certain wavelengths of light. Dymax LCMs are usually one-component mixtures of oligomers, monomers, photoinitiators, and modifiers (hardness modifiers, colorants, fluorescing agents, thickeners, wetting agents, etc.). Over 95% of Dymax LCMs are acrylates (a urethane backbone with an acrylic functional group). The balances are cationic epoxies. Be aware that acrylates and cationic epoxies are, aside from being light curable, significantly different from traditional acrylics and epoxies. The two chemistries also vary in many ways from each other.

UV-Curable Acrylates Generally Offer:

- Faster and deeper cures
- Wider range of properties
- Adhesion to a wider range of substrates
- Complimentary cure mechanisms, including visible light and heat

UV-Curable Cationic Epoxies Generally Offer:

- Superior adhesion to certain substrates (i.e. PP, PE, silicone)
- Superior resistance to some solvents
- Moderate speed and depth of cure (UV-curable acrylates cure faster and deeper)
- Tack-free surface cures, even at very low intensity (some UV-curable acrylates exhibit a tacky surface due to oxygen inhibition)

2.2 Typical Properties of Dymax Light-Curable Materials (LCMs)

Since its inception, Dymax has developed over 3,000 light-curable formulations and continues to create new products, typically at the request of customers. The following section describes the “typical” properties of these 3,000+ formulations when considered in aggregate. Be aware that Dymax products exist with properties beyond these “typical” properties.

2.2.1 Cure Speed

Dymax LCMs typically cure in 1-30 seconds, depending upon the following:

- **Formula** – Cure speed can vary significantly between formulas.
- **Light Source** – Higher intensity light source will typically result in a faster cure.
- **Thickness, Substrates, and Oxygen Exposure** – Significantly thicker films of Dymax LCMs may require a longer cure time (differences of 0.010" or less generally do not affect cure speed). When curing through a substrate, better light transmission provides faster cures. Surfaces exposed to oxygen during cure may require longer cure times, see *Section 3.5 Eliminating Tacky Surfaces*.

For more information on light curing, see *Section 3.2 Basic Concepts of Light Curing*.

2.2.2 Depth of Cure

Light-curable materials vary greatly in their “ultimate” depth of cure. Dymax LCMs typically feature superior depth of cure versus competitive light-curable materials. Some materials (especially older technology) can only be light cured to a millimeter or less. Most Dymax formulations, those that cure with both UV and visible light, typically cure to a depth of ¼" to ½" (0.6 to 1.3 cm). Some formulas are even capable of quickly curing over 1" (2.5 cm) deep. For more information on light curing, see *Section 3.2 Basic Concepts of Light Curing*.

2.2.3 Adhesion

Each Dymax LCM offers some adhesion to every substrate, it’s just a question of bond strength. In practical terms, Dymax provides materials capable of structurally bonding glass, metals, plastics, rubbers, and ceramics. When discussing the adhesion of Dymax materials, it is important to consider the following:

- **Substrate(s)** – The adhesion of a Dymax material is dependent upon the formulation and the substrate(s). For example, Ultra Light-Weld® 4-20418 offers terrific bond strength to polycarbonate and moderate adhesion to metal, whereas Multi-Cure® 6-621 offers terrific adhesion to glass and metal and moderate adhesion to polycarbonate.

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- **Coatings** – When considering adhesion, it is important to consider surface cleanliness and whether or not the surface is treated, painted, or plated. For example, Dymax's best aluminum adhesive might not be the best candidate for bonding a coated-aluminum surface. Furthermore, if the coating's adhesion to the underlying substrate is weak, the overall bond strength of the assembly will also be weak since "a chain is only as strong as its weakest link".
- **Stresses** – When choosing a Dymax product for a given application, it is important to consider the stresses that might be encountered in use, including tensile, shear, peel, cleavage, torque, and impact. More flexible products generally perform better than rigid products in cleavage, peel, and impact.
- **Cohesive Strength** – Normally, "adhesion" refers to the ability of an adhesive to "stick" to a substrate, but in a practical sense, the cohesive strength of the adhesive is also important, i.e., the ability of an adhesive to resist tearing and fracture. Compared to CAs (which can be very brittle) and silicones (which can easily tear), light-cured systems are very tough and compare favorably with epoxy and urethane systems.

Due to the complexities associated with adhesion, it is important to consult with Dymax selector guides and Dymax Applications Engineering when selecting candidate Dymax materials. Candidate materials should then be thoroughly tested to determine their suitability for a given application.

2.2.4 Viscosity

Viscosity is the degree to which a fluid resists flow under an applied force (like gravity, pressure, or mixing). Water, by definition, has a viscosity of 1 centipoise (cP). Dymax LCMs range in viscosity from 40 cP (similar to olive oil) to over 1,000,000 cP (like peanut butter), and anywhere in between. In many cases, the viscosity of a formula can be modified up or down without altering any of the other properties such as cure speed, adhesion, hardness, and moisture resistance. Many Dymax formulations can be purchased in multiple viscosities, like the 3069 family shown in the table at the bottom of this page.

Notice the part numbers are identical except for the descriptive suffix. The product data sheet for each product family lists the specific viscosity options available for that product family. *Table 5.1 Viscosity* on page 25 shows the viscosity of common fluids for comparison.

It should be noted that viscosity alone does not provide a complete description of the flow characteristics of a fluid. Most Dymax resins can be classified as either Newtonian or thixotropic. The viscosity of a Newtonian fluid is unaffected by agitation or shear. A thixotropic material (most Dymax gels, for example) will "thin" (have a lower viscosity) upon shear (dispensing/mixing) and will, upon sitting, return to its original viscosity. Dymax typically uses a viscometer to measure viscosity. When comparing viscometer measurements of different materials, be sure that the viscosities were measured using the same spindle at the same shear rate (rpm) and temperature.

Product Name	Viscosity Description	Viscosity @ 20 rpm	Measurement Method	Fluid Type
3069	Standard	450 cP (mPa • s) nominal	Rotational Viscometer	Newtonian
3069-T	Thick	5,700 cP (mPa • s) nominal	Rotational Viscometer	Thixotropic
3069-VT	Very Thick	14,000 cP (mPa • s) nominal	Rotational Viscometer	Thixotropic
3069-Gel	Gel	25,000 cP (mPa • s) nominal	Rotational Viscometer	Thixotropic

2.2.5 Hardness and Flexibility

The hardness of a Dymax material is generally measured on one of three hardness scales, Shore –OO (softest), Shore A (soft), and Shore D (hard). Dymax LCMs can be formulated to be as soft as gelatin (shore OO-0), as hard as laminated composite material (shore D 90), and anywhere in between. In general, softer materials provide better impact resistance and peel strength, but lower tensile strength and tear resistance. Selection of a given hardness (a rough indication of flexibility) should be based on the anticipated stresses. *Table 5.2 Hardness* on page 25 shows the hardness of common materials for comparison.

2.2.6 Temperature Resistance

Dymax LCMs provide excellent temperature resistance, both hot and cold. It is important, however to understand the effects of temperature upon performance. Temperature affects the performance of all adhesives, coatings, and sealants in two ways:

Performance at Temperature – Some cured performance characteristics (such as adhesion, hardness, and more) vary with temperature. In other words, an adhesive may have bond strength of 2,000 psi at 70°F, but only 1,000 psi at 200°F. In general, adhesion and hardness decrease with increasing temperature. Performance testing should be conducted over the temperatures anticipated during use.

Performance After Temperature Exposure – Some cured performance characteristics (such as hardness) can be altered permanently after exposure to extreme temperatures. For example, high-temperature exposure can result in embrittlement and low-temperature exposure can result in cracking. In the case of embrittlement or cracking, the resin will perform differently after extreme temperature exposure. In general, LCMs have an upper thermal limit of 300°F (150°C) with some Dymax products capable of withstanding higher temperatures. Most Dymax LCMs have a lower temperature limit of -65°F (-54°C). Many Dymax products can withstand more extreme temperatures for a short period of time. For example, many Dymax products can withstand a solder reflow process that can reach temperatures over 230°C, but only for a few minutes. The recommended temperature limits listed on each product data sheet are determined by evaluating the stress/strain curves of a virgin specimen with one that has been exposed to an extreme temperature for 30 minutes, both at room temperature. When the stress/strain curve demonstrates a significant change, the material is said to have exceeded its thermal limit. The operating temperature limits for each product are located on each product data sheet.

2.2.7 Thermal Cycling

Thermal cycling testing is frequently used to simulate thermal cycling that might be encountered in use, especially in electronic and automotive applications. Predicting the performance of a Dymax material in a specific thermal cycling test is very difficult as it depends upon many factors:

- Adhesion to the substrates
- Coefficient of Thermal Expansion (CTE) and modulus of the substrates, and the Dymax material
- Part geometry (including mass)
- High and low test temperatures
- Cycle and transition times

Thermal cycling and temperature-resistance testing on actual customer parts is recommended to confirm the suitability of a specific Dymax material for a specific application.

2.2.8 Chemical and Moisture Resistance

In general, cured Dymax materials (chemically cross-linked systems) are relatively resistant to both moisture and chemicals. Chemical resistance in a particular application is, however, difficult to quantify since it depends upon the formula, the chemical (and its concentration), the temperature, the time frame, and part geometry. To expand upon part geometry, for example, a Dymax material which may be suitable for one application with little exposed resin, may be unsuitable for another application where more resin is exposed. Dymax recommends that chemical resistance testing relevant to the customer's application be performed during validation.

Moisture resistance in a particular application, like chemical resistance, is also difficult to quantify without specific testing since there are so many variables that affect it. Moisture resistance, however, is such a common inquiry that Dymax conducts moisture absorption testing on most of its LCMs. About 90% of Dymax materials absorb less than 10% of their weight in water when soaked in either boiling water for 2 hours or room temperature water for 24 hours. Some Dymax materials absorb as little as 0.01% of their weight under these conditions. Dymax water absorption testing is conducted on 2.25" diameter x ¼" thick "pucks" that are 100% exposed to water (versus testing only as an adhesive or coating).

2.2.9 Clarity, Color, Fluorescing, and Refractive Index

Dymax materials are available with any of several different appearances.

- **Optically Clear** – Some grades are so clear that they are even used to laminate sunglass lenses!
- **Translucent** – Some grades are translucent with a hazy, yellow, or white appearance. Thinner layers of these materials usually appear clear.
- **Fluorescing** – Some formulas are colorless, but contain a UV fluorescing agent that, when exposed to a "blacklight", fluoresce brightly.
- **Colored** – Several colored materials are available, including blue, red, yellow, white, and even black! It should be noted that colorants may negatively affect cure speed and depth of cure.

Refractive index is the ratio of the speed of light in a vacuum to that through a transparent material. Soda lime glass, for example, has a refractive index of 1.510. In general, the refractive index of Dymax materials ranges from 1.419-1.585. Most plastics and glass materials fall into a similar range. Therefore Dymax adhesives rarely distort light visibly and provide clear, sharp bond lines.

2.2.10 Shrinkage and Coefficient of Thermal Expansion (CTE)

Dymax materials typically shrink 2-3% linearly during cure. A low-shrinkage series of Dymax adhesives, the OP-LS series, shrink < 0.1% linearly upon cure, a property which has been very well received by the precision optical market.

The Coefficient of Thermal Expansion (CTE) is the rate at which a material expands with increasing temperature and contracts with decreasing temperature. Dymax materials typically exhibit a CTE in the range of 40-250 PPM/°C. Some of the low-shrinkage products described above exhibit even lower CTEs. The topic of CTE can become quite involved in situations where parts are cycled through large temperature ranges. Specific questions should be directed to a Dymax technical expert.

2.2.11 Outgassing

Dymax LCMs typically outgas slightly during the light-curing process (typically <1% as an adhesive and <3% as a coating, by weight). Cured Dymax LCMs (like most polymers) will also outgas slightly at high temperatures and/or low pressures.

Dymax has developed a line of lower outgassing, light-curable materials. For more specific information on low-outgassing products, contact Dymax Applications Engineering.

2.2.12 Odor

Dymax LCMs, like most adhesives and coatings, have a characteristic odor. It is typically slight and easily eliminated with positive fresh-air exhaust.

2.2.13 Flammability

Uncured Dymax light-curable materials have a flashpoint above 200°F and are therefore classified as non-flammable. Cured Dymax light-cure coatings have UL-94 V0 or V1 ratings when tested per United Laboratories.

2.3 Chemical Safety

Please refer to *TB094 Chemical Safety Technical Bulletin* for information on the use of Dymax light-curable materials.

2.4 Environmental Impact

Dymax LCMs are generally considered environmentally preferable to other chemical assembly methods.

The typical environmental profile of Dymax LCMs is:

- No solvents
- No Ozone Depleting Compounds (ODCs)
- Compliant with European RoHS regulations
- Meet Montreal Protocol and Clean Air Act
- Cured material is typically not considered hazardous waste
- All products comply with TSCA regulations

Section 2: Dymax Light-Curable Materials (LCMs)

2.5 Specifications

Many Dymax LCMs have been approved or classified by third party organizations like Mil Spec, UL, ISO, USP, IPC, GM, Ford, Telcordia, etc. Contact Dymax Applications Engineering for the specific products that have been classified or approved by these organizations.

Testing all of our products to all of the specifications invoked across all markets is cost prohibitive. The testing that has been accomplished to date has typically been driven by customer requests or market demands. Often, our untested products can also meet the above specifications (as well as other specifications not mentioned). Where third party specifications or testing is required for a single customer application, testing costs are usually shared.

2.6 Shelf Life and Storage

Dymax offers a 12-month shelf life from the date of shipment from Dymax, when properly stored in the original, unopened container. A handful of Dymax products have a shorter shelf life (3 or 6 months). For most Dymax products, storage temperatures between 40°-90°F (4°-32°C) are recommended (although a handful requires refrigeration). Specific shelf life and storage information is available on each product data sheet. For a charge, Dymax may be able to extend the shelf life (up to 3 months) of expired LCMs that pass re-certification testing.

2.7 Cleaning and Rework

Workers should avoid skin contact through the use of impervious (like nitrile rubber) gloves and other protective equipment as described in *TB094 Chemical Safety Technical Bulletin*. In the event that there is skin contact, users should immediately wash with soap and water. Isopropyl alcohol (IPA) is typically recommended for flushing dispensing fluid lines (if needed) and removing uncured adhesive from assembly equipment. Do not use acetone, MEK, or other ketones as they may leave an incompatible residue.

Rework, or removing cured material, is typically a challenge due to the bond strength and chemical resistance of Dymax materials. Some solvents (like methyl alcohol, methylene chloride, etc.) or heat can soften cured materials making them easier to remove. Contact Dymax Applications Engineering for more guidance on reworking and removing cured Dymax materials.

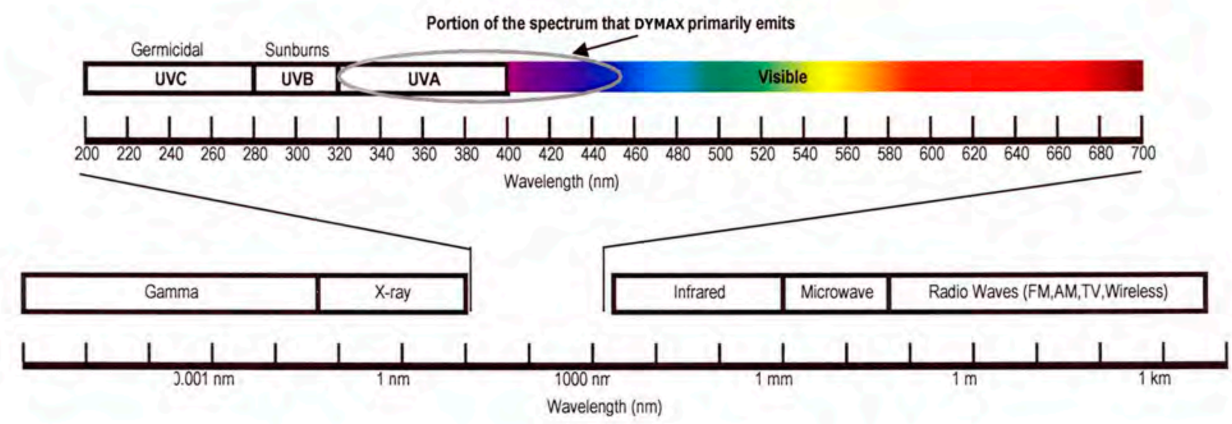
2.8 Disposal

Dymax materials are used in many different cities, states, and countries, each with varying environmental regulations. It is therefore difficult to provide strict guidance regarding disposal. In the United States, cured Dymax materials are generally considered plastic industrial waste and can be disposed of similarly. Small quantities of unused light-cured material may be cured prior to disposing using either sunlight or a light-curing lamp. Dymax recommends that customers comply with state, local, and federal regulations when disposing of Dymax LCMs.

Section 3: Dymax Light-Curing Equipment / Process

3.1 UV and Visible Light

The electromagnetic spectrum is divided into different regions based on wavelength. UV light is the range of shorter wavelengths adjacent to the visible-light spectrum. Visible light is the only portion of the electromagnetic spectrum that the eye can see. Wavelengths in these regions are commonly measured in nanometers (nm). A nanometer is a billionth of a meter or a thousandth of a micron. Dymax formulations typically require UVA light (320-400 nm) and/or the shorter wave (blue) visible light (400-450 nm) for curing. The UVA range is generally considered the safest of the three UV ranges (UVA, UVB, and UVC). UV- cured inks often require the UVB portion of the UV spectrum for curing. A chart depicting the electromagnetic spectrum is shown below.



3.2 Basic Concepts of Light Curing

Developing a successful light-curing process requires knowledge of several key concepts. This section will provide an overview of these concepts.

- **How it Works** – Curing with light is a relatively simple process. Dymax LCMs contain ingredients known as photoinitiators that initiate the curing reaction upon exposure to certain wavelengths of light. Except for cationic epoxies, all Dymax LCMs reach full cured properties immediately after exposure to light of appropriate wavelength, intensity, and duration. Cationic epoxies reach full cured properties within 24 hours after light exposure. Product data sheets for cationic epoxies will state that full properties require an additional 24 hours.

- **Higher Intensity = Faster Cures** – Intensity is the light energy reaching a surface per time and it is often measured in mW/cm^2. When using the term intensity, it is important to define which wavelength(s). Higher intensity light (of the proper wavelengths) will generally provide a faster cure.

- **Distance and Substrates Affect Intensity** – Distance from a light-curing lamp, always affects intensity. Intensity decreases with increasing distance from both spot lamps and flood lamps, especially spot lamps. Intensity decreases with increasing distance from the focal point for focused-beam systems. When curing through a substrate, light-transmission rates below 100% will reduce the intensity that reaches the LCM. See *Section 3.7 Light Curing Through Transparent, UV-Blocked Substrates*.

- **Limited Depth of Cure** – LCMs themselves absorb light and so each Dymax material has a maximum cure depth. For most products, this depth is between ¼" (6 mm) and ½ (12.7 mm). Also, it may take 3-4 times longer to cure a product ½" (12.7 mm) deep than it does to cure that same product ¼" (6 mm) deep.

- **Determining Complete Cure** – The simple answer is that a Dymax LCM is cured when it changes from a liquid to a solid. A more complete answer is that a Dymax LCM is fully cured when acceptable physical properties are achieved and further light exposure no longer improves product properties. See *Section 3.8 Confirming Complete Cure* for more information on this subject.

- **Shadows** – Only material that has been exposed to light of appropriate wavelength, intensity, and duration will reach full cure properties. Material in "shadowed areas" will not cure unless the material has a secondary curing option. For more information on curing in shadowed areas, see *Section 3.6 Shadow Curing.*

3.3 Light-Curing Equipment

Dymax provides light-curing spot lamps, flood lamps, conveyors, and radiometers. This section contains a brief description of each type of equipment. Contact your Dymax representative or visit dymax.com for more information on Dymax light-curing equipment.

3.3.1 Power Supply Options

The power supply is an important consideration when selecting a light-curing lamp. Dymax manufactures spot, flood, and focused-beam lamps with either a transformer-based or auto-switching power supply. When ordering a transformer-based system, the source voltage must be specified (reference the current Dymax Equipment Price List for voltage options). If the source voltage is different from the factory specified voltage, the lamp may not operate properly (low voltage may produce lower intensity or not ignite at all and high voltage may result in higher intensity and shorter bulb life). Transformer-based power supplies are typically heavier and cost less than auto-switching power supplies. Auto-switching power supplies are not voltage sensitive and will operate properly on 90V-136V and 180V-264V, at both 50 Hz and 60 Hz. Dymax offers spot, flood, and focused-beam lamps with auto-switching power supplies.

3.3.2 Spot Lamps (for small areas up to ½" (12.7 mm) diameter)

Dymax spot lamps, like the BlueWave® 200 (below), provide very high intensity (1,000-20,000 mW/cm^2) over a small area (typically <1/2" (12.7 mm) diameter). These intensities typically result in a 1-to-10 second cure. Dymax spot lamps utilize an integral timed/manual shutter mechanism and usually require little external shielding. It should be noted that, because light exiting the lightguide is diverging, intensity at the part is very sensitive to the distance between the lightguide and the part.

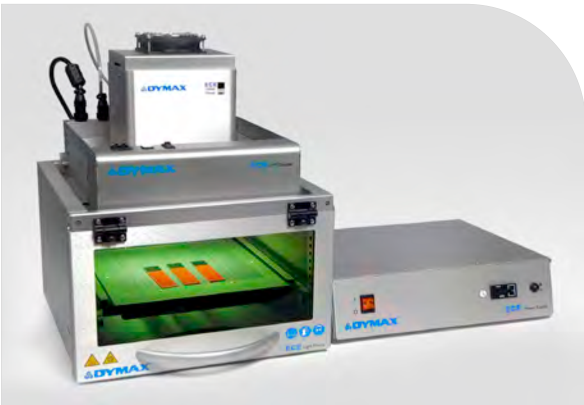
Spot lamps are ideal for curing small areas quickly and can be easily integrated into an automated assembly process or used as turnkey bench top systems.

3.3.3 Focused-Beam Lamps (high-intensity lamps for conveyors)

Dymax provides focused-beam lamps. Due to their high intensity and smaller curing area, focused-beam lamps are typically incorporated into either conveyors or automated assembly equipment (with proper shielding).

3.3.4 Flood Lamps (for curing larger areas or many small areas simultaneously)

Dymax flood lamps offer moderate intensity (50-225 mW/cm^2) over a large area 5" x 5" or 8" x 8" (127 mm x 127 mm or 200 mm x 200 mm). These lamps, like the 5000-EC, are ideal for curing areas larger than ½" (12.7 mm) in diameter. Dymax flood lamps can also be used to cure many small parts simultaneously. For example, a spot lamp might cure one small part in 3-5 seconds whereas a flood lamp might cure many small parts at one time but slower (say in 10-20 seconds). Light emitted from flood lamps diverges, but much less dramatically than light emitted from a spot system. Therefore, flood lamps vary in intensity with distance, but to a much lesser degree than spot lamps. Unlike a spot lamp, flood lamps do not necessarily utilize an integral shutter so care must be taken to ensure a consistent cure time (optional shutter assemblies are available for flood lamps). Flood lamps, like spot systems, are often incorporated into turnkey bench top and automated assembly systems.



3.3.5 Conveyors (for continuous automation)

Dymax conveyors incorporate flood-curing systems. The benefits of light-curing conveyors include consistent cure times and the ability to cure larger parts. Another benefit of conveyors is that they completely shield operators from UV light. Dymax conveyors have 12 cm (UVC-5) or 20 cm (UVC-8) wide belts. Conveyor speed is tightly controlled and typically ranges between 1.4-11 m/min (UVC-5) or 1-15 m/min (UVC-8) (although faster conveyors are available). Dymax light-curing conveyors can be outfitted with different types of lamps.

3.3.6 Radiometers (for process control)

A radiometer is a device that measures the intensity and/or energy associated with light of specified wavelengths. UV light is, by definition, not visible and so a radiometer is the only way to determine UV intensity.

Dymax offers the ACCU-CAL™ 50 radiometer which measures UVA (320-395 nm) light for spot lamps, floods, and conveyors. The ability to measure light intensity is useful for three reasons:

- **Maintaining a Light-Curing Process** – A radiometer can measure whether a light-curing system is providing intensity above the minimum or "bulb change" intensity. A radiometer is to a light-curing process what a thermometer is to an oven-curing process. For more information on this subject, see *Section 3.10 Setting Up and Monitoring a Light-Curing Process* on page 20.
- **Insuring a Worker-Friendly Light-Curing Process** – A radiometer can be used to determine if any UV light is reaching operators or bystanders.
- **Measuring Transmission Rates Through Substrates** – A radiometer can be used to measure the transmission rates of various wavelengths through substrates that absorb UV and/or visible light. This can be very useful in setting up and maintaining a consistent light-curing process.

Dymax's ACCU-CAL™ 50 is capable of measuring light intensity from spot lamps, flood lamps, focused-beam lamps, and conveyors.

3.3.7 Selecting a Curing System

There are several things to consider when determining whether to utilize a spot lamp, flood lamp, or conveyor. The table on page 18 lists some of the equipment currently available from Dymax and some key features of each. Dymax provides CE marked equipment for Europe.

3.3.8 Equipment Try-and-Buy Program

Customers can use a Dymax Try-and-Buy Program to evaluate lamps at a very low cost. The highlights of the program are:

- Rental fees are deducted from the cost at purchase
- Customer pays shipping
- Customer completes Rental Agreement
- Dymax requires a purchase order for the equipment in case it is not returned or is damaged

Contact Dymax Customer Service to initiate the Dymax Try-and-Buy Program.

3.4 UV Lamp Safety

Please refer to *UV Lamp Safety Technical Bulletin* for information on the safe operation of Dymax light-curing equipment.

3.5 Eliminating Tacky Surfaces

In some cases, air-exposed surfaces of Dymax adhesives may remain tacky after cure. This is caused by oxygen inhibition. Oxygen in the air actually slows the cure at the top-most layer of air-exposed surfaces. This tackiness does not necessarily indicate incomplete cure as this tackiness is observed with some materials, even after complete cure. In general, there are four options available to help minimize or eliminate the tackiness associated with oxygen inhibition:

- **Longer and/or Higher Intensity Cure** – In most cases, curing longer or with higher intensity will minimize or eliminate a tacky surface. In general, higher intensity cures overcome oxygen inhibition more efficiently. For example, Multi-Cure® 984-LVUF conformal coating requires approximately 30 seconds of exposure to 200 mW/cm^2 (or 6 Joules/cm^2 of energy) to cure "tack-free". This same coating cures "tack-free" in approximately 1 second upon exposure to 4,000 mW/cm^2 (or 4.0 Joules/cm^2 of energy).
- **Use of a "Shortwave" Bulb** – Use of a UVB shortwave) bulb instead of a UVA (longwave) bulb may also help to eliminate surface tack. Both longwave and shortwave bulbs are available from Dymax. UVA (longwave) bulbs come standard in Dymax lamps because they typically provide faster, deeper curing of Dymax materials.
- **Choose an Alternative Dymax Material** – Each formula is affected by oxygen inhibition to a different degree. Some formulas cure "tack-free instantly" while others remain tacky even after long, high-intensity cures. Contact Dymax Applications Engineering to determine if a tack-free alternative is available.
- **Blanket with Inert Gas** – Although rarely used, blanketing with inert gas (like nitrogen or argon) during cure can often eliminate the problem of oxygen inhibition completely. Argon is heavier than oxygen (versus nitrogen which is lighter) and is ideally suited for blanketing.

Contact Dymax Applications Engineering for further formation on oxygen inhibition.

3.6 Shadow Curing

There are many adhesive applications where, due to geometry of the assembly, some portion of the LCM is "shadowed" from the curing light. In these areas, the material will not cure unless it has been formulated to cure by some additional curing mechanism.

Dymax has developed three types of secondary cure mechanisms: heat, oxygen, and catalyzed two-part mix. Heat is the most commonly used secondary cure mechanism.

The typical heat cure schedule is as follows:

- 1 hour at 225°F (107°C)
- 30 minutes at 250°F (121°C)
- 15 minutes at 300°F (149°C)

Section 3: Dymax Light-Curing Equipment / Process

	BlueWave® 200	ECE 2000	ECE 5000
Type of Lamp	Spot	Flood	Flood
Maximum Curing Area	½" (13 mm) Diameter	8" x 8" (20 cm x 20 cm)	5" x 5" (13 cm x 13 cm)
Maximum Intensity (mW/cm²)	20,000	105	225
Typical Cure Speeds	1-10 seconds	10-30 seconds	5-15 seconds
Timer / Shutter	Yes (Digital)	Optional	Optional
Typical Bulb Life (Hours)	2,000	2,000	2,000
Typical Bulb Degradation* (Typical % loss at end of bulb life)	<50%	<20%	<20%
Footprint	11.5" x 11.5" (29 cm x 29 cm)	16" x 12" (41 cm x 30.5 cm)	16" x 12" (41 cm x 30.5 cm)
Voltage	100-260V**	90-240V**	90-240V**

* Bulb degradation is significantly dependent upon lamp use. See *Section 3.11 Maximizing Lamp Performance* for more information on bulb degradation and proper lamp operation.

** Auto switching power supply. Lower cost, transformer based versions are available.

It should be noted that heat curing alone will rarely cure oxygen-exposed surfaces to a tack-free condition. Initial exposure to light is required before heat curing to obtain a tack-free surface cure. Contact Dymax Applications Engineering for more information on the other secondary cure mechanisms.

3.7 Light Curing Through Transparent, UV-Blocked Substrates

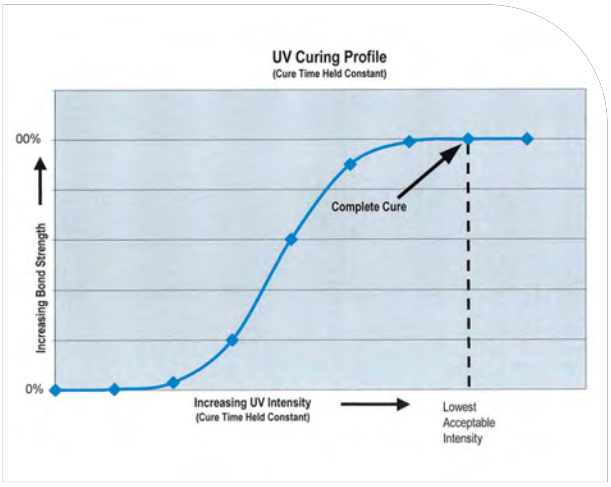
In 1995, Dymax introduced the first adhesives that not only cure with UV light, but also with visible light (400-450 nm). This resulted in faster, deeper cures and the ability to cure through visibly translucent, but UV-blocking substrates. Products capable of curing with both UV and visible light typically bear the Dymax trade name Ultra Light-Weld®.

3.8 Confirming Complete Cure

"How do I know when a Dymax material is fully cured?" is a frequently asked question. The simplest answer is that the Dymax material is cured when the material changes from a liquid to a solid. Oftentimes, this explanation is satisfactory.

A more complete answer, however, is that a Dymax LCM is fully cured when further curing does not improve its physical properties. Quantitative testing of specimens cured for various cure times can be used to determine complete cure. The graph in the next column shows how this method could be used in a bonding application.

Each Dymax material's product data sheet provides light-curing guidelines for a limited number of lamps and configurations. Actual cure times will almost certainly differ for each specific application. Dymax always recommends confirming the suitability of a given light-curing process through "lifetime testing" of parts manufactured using this process.



3.9 Overexposure of Assemblies to UV

The effect of underexposure is obvious; incomplete cure. The effects of overexposure are more complex. Cure time is typically three to five times fixture time. Higher intensities or longer cures (up to 5x) generally have no measurable adverse effect on Dymax products. However, significant overexposure to UV light can degrade any UV-cured material and some substrates (especially plastics). This degradation may appear as cracking, physical distortion, changes in color, chalking, and/or a change in some physical property such as an increase in hardness or decrease in elongation. The degree of degradation will depend upon several factors including intensity of the lamp, the wavelengths transmitted to the adhesive, temperature in curing area, exposure time, substrates, and formulation. This degradation is caused by both the UV light itself and excessive heat absorption. A cooling fan in the curing area can help minimize the effect of excessive heat absorption.

Significant overexposure of the LCM to UV is unlikely to occur in a properly controlled curing process. End-users should test and validate their assembled devices at the lower and upper operating limits of their light curing process.

3.10 Setting Up and Monitoring a Light-Curing Process

There are two parameters that must be considered to ensure a successful light-curing process, 1) intensity at the curing location and 2) cure time. Dymax recommends setting up and monitoring a UV light-curing process as follows:

1. **Choose a Light-Curable Material (LCM)** – Select an LCM that satisfies the performance of the application.

2. **Determine Available Cure Time** – Determine the cure time available so that the UV-curing process is not a "bottleneck" in the manufacturing process. For example, if dispensing and assembly requires 12 seconds per part in a one-piece flow process, the maximum available cure time is 12 seconds. For UV-curing conveyor, determine the minimum line speed required.

3. **Choose a Light-Curing System** – Choose the appropriate light curing system that will fully cure the LCM within the cure time available. Dymax Applications Engineering can help you identify the best light curing system for a specific application.

4. **Determine the Lowest Acceptable Intensity** – The lowest acceptable intensity is that which fully cures the material in the available cure time (determined above). The lowest acceptable intensity can be determined through quantitative testing of parts cured at various intensities as shown in the diagram to the top left. In the case of a focused-beam lamp on a conveyor, determine the lowest acceptable energy, not intensity.

   The following techniques may be used to artificially modify intensity to facilitate determining the lowest acceptable intensity.

   Increase Distance – Since light emitting from light curing lamps diverges, the intensity decreases as the distance from the lamp increases.

   Utilize an Old Bulb – When increasing intensity is not practical, older bulbs can be used. As with any manufacturing process, it is advisable to operate with a safety factor. Dymax recommends a "bulb change" intensity above the "lowest acceptable intensity".

5. **Monitor and Maintain Intensity** – Using a radiometer, monitor the UV-light intensity at the bond line. If the intensity reaches the "bulb change" intensity, install a new bulb or conduct appropriate maintenance (see *Section 3.11 Maximizing Lamp Performance*). In the case of a conveyor, curing energy (not intensity) should be monitored.

If the resulting cure process is causing heat damage, a cooling fan or shorter cure time is recommended. If the resulting bulb life is too short, a longer cure time or higher intensity lamp is recommended.

3.11 Maximizing Lamp Performance

There are three ways to maximize lamp performance:

- **Proper Set-Up** – The first key to maximizing lamp performance is proper set-up. Reference the operation manual provided with each Dymax lamp for instructions on proper set-up. After ignition, wait 3-5 minutes before use to allow the lamp to reach full intensity. Then, use the following techniques to maximize intensity at the curing location.

  Spot-Cure Systems – Maximize curing intensity by minimizing distance from the end of the lightguide to the light-curable material, while still covering the curing area. Positive airflow can prevent those vapors commonly emitted during cure from condensing on the end of a lightguide. Be aware that excessive bending, clamping, or set-screw tightening can damage lightguides. The minimum bend radii for standard lightguide diameters are as follows:

  - 3 mm lightguides – 40 mm bend radius
  - 5 mm lightguides – 60 mm bend radius
  - 8 mm lightguides – 100 mm bend radius

  Flood Lamps – Minimize distance from the bottom of the flood housing to the light-curable material. Note that distances 3" or more from the lamp housing provide the most uniform intensity across the curing area.

  Focused-Beam Lamps – Place light-curable material at the focal point of the focused beam lamp for maximum intensity.

- **Optimizing Bulb Life** – The intensity of light being emitted from UV bulbs gradually decreases with usage. This degradation cannot be avoided, but it can be minimized through proper operation.

  The longest bulb life is obtained by simply using the lamp continuously (not turning it off). The more often the lamp is cycled on and off, the more quickly the bulbs degrade. The general rule of thumb is to leave the lamp on if it will be used again within four hours.

  Once ignited do not turn the lamp off for at least five minutes. Turning the lamp off before it has reached its operating temperature can damage the bulb.

- **Proper Maintenance** – As with all production equipment, routine maintenance will optimize performance. In the case of a spot lamp, keep the end of the lightguide clean and replace if it no longer transmits enough light (a lightguide simulator is available from Dymax to help determine lightguide transmission). See *PB075 Lightguide Simulator Product Bulletin* for more information on lightguide and bulb maintenance. In the case of a flood lamp, the reflector and lamp base (sockets that the bulb fit into) should be cleaned and/or replaced as necessary. Please refer to the operation manual for each lamp for further guidance on proper maintenance.

Section 4: Surface Preparation and Dispensing

4.1 Surface Preparation

Appropriate surface preparation can help maximize the wetting and adhesion of a Dymax LCM to a given substrate. In most cases, no surface preparation provides adequate results. Where improved performance is required, Dymax recommends testing the effectiveness of these surface preparation options.

4.1.1 Cleaning

Cleaner surfaces produce stronger, longer lasting bonds. If sufficiently strong bonds are provided without cleaning, cleaning may not be required.

Both the contaminant and the substrate(s) should be considered when developing a cleaning process. Particulates can be removed with high-pressure air or brushing while chemical contaminants require aqueous (water) or solvent-based cleaners. The aqueous or solvent-based cleaner should be selected such that it removes the contaminant without harming the substrate.

4.1.2 Abrasion

In general, abrasion creates more surface area for bonding which typically improves bond strength. Abrasion can also be used to remove a coating or surface layer.

4.1.3 Corona or Plasma Treatment

These surface treatment operations can be useful for improving bond strength to hard-to-bond to plastic substrates. Both treatments can be incorporated into a batch or automated assembly process.

4.1.4 Plastic Molding

The plastic molding process can dramatically affect adhesion to the molded part. An adhesive may have terrific adhesion to a part from one molder and no adhesion to the same part produced by another molder. In these cases, excess internal or external mold release may be present on the surface of the molded part. Internal mold release can be removed from the surface, but it may migrate back to the surface over the life of the part. Lifetime tests that involve heated storage or thermal cycling may help determine whether this migration will occur. External mold release may be removed through cleaning, abrasion, or seeking an alternate plastic source (either finished or raw).

In the case of molding filled plastic parts, molding pressures and temperatures may affect the concentration of filler present on the surface. In many cases, a Dymax adhesive adheres significantly better to either the resin or the filler. In these cases, variations in the surface concentration of the filler can cause significant variations (up to 5X in magnitude) in the overall adhesion. Please contact Dymax Applications Engineering for more guidance on improving wetting and bond strength through surface preparation.

4.2 How are Dymax Light-Curable Materials (LCMs) Typically Applied?

Since Dymax LCMs are typically one component and available in a wide range of viscosities, many different dispensing methods can be used including needle dispensing, spraying, brushing, stenciling, screen-printing, and coating.

The most common dispensing method involves a dispensing needle, which is either applied to a dispensing valve or a syringe. The pictures below represent the two most common needle dispensing systems.

Roll coating, stenciling, and screen printing are effective methods of applying a thin layer of adhesive or coating to large, flat areas quickly. Contact your Dymax representative for more information on recommended dispensing methods.

4.3 Packaging Options

Dymax materials are typically available in many different package sizes. The following is a list of some package sizes available in the North America:

- Syringes (3 mL, 10 mL, and 30 mL)
- Cartridges (170 mL, 300 mL, and 550 mL)
- Bottles (10 mL, 30 mL , 250 mL, and 1 liter)
- Pails (15 liters)
- Drums (~200 kilograms, depending upon density of formula)

Additional packaging options may be available where grams are substituted for mL and kilograms are substituted for liters.

Be aware that medium-to-gel viscosity materials can trap air during shipping when packaged in bottles, pails, and drums due to the open head space. Syringes and cartridges have no head space and remain essentially air-free. Lower viscosity materials (<500 cP = mPas) release air bubbles naturally and are bubble-free in all packages. Some higher viscosity products (whose viscosity is measured using ASTM D-1084) will also release air. Products whose viscosity is measured by ASTM D-2556 will not release air naturally.

It should be noted that not all products are available in all package sizes. Contact your Dymax representative for more guidance on packaging.

4.4 Common Dispensing Pitfalls

There are several mistakes that customers can make when implementing dispensing systems for Dymax materials. Understanding these common pitfalls and taking the suggested precautions will allow trouble-free dispensing:

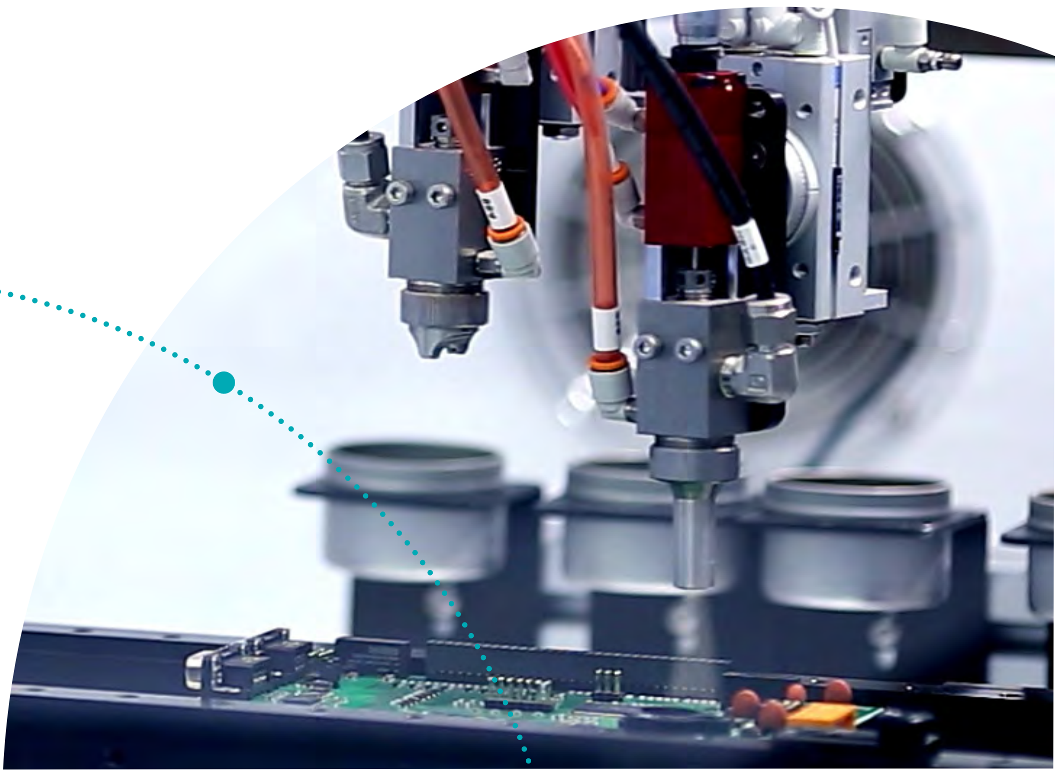
- **Incompatible Materials** – Dispensing system materials of construction should be compatible with Dymax LCMs. Metal parts and fittings should only be 300 Series stainless steel. Other metals can cause the adhesive to polymerize. Plastic materials that are compatible with Dymax LCMs include polyethylene, polypropylene, PTFE, Nylon, and acetals. Other plastics may be attacked by the resin.
- **Transparent Fluid Lines** – Black or opaque plastic fluid lines should be used to ensure that the adhesive is not exposed to ambient light, which may cause the adhesive to polymerize.
- **Air Bubbles** – Air bubbles may become trapped in fluid lines when an empty adhesive container is removed for replacement in a dispensing system. To avoid this possibility it is recommended that the fluid line be purged after refilling or replacing the empty container. Maintaining only the line length necessary to transport the fluid from the reservoir to dispense point will facilitate the purging process.
- **Pour-In Pressure Pot versus Drop-in Pressure Pot** – For lower viscosity fluids (<500 cP = mPas) that naturally release air bubbles, (see Section 4.3 Packaging Options) either pour-in or drop-in pressure pots can be used. For fluids that do not release air bubbles naturally, drop-in pressure pots are recommended. (Drop-in pressure pots are large containers into which bottles or pails of adhesive are placed). Dymax recommends the use of a 10 gallon drop-in pressure pot for adhesives with viscosities up to 25,000 cP. For resins with viscosity >25,000, or where pressure exceeding 30 psi (0.2 MPa) is required for dispensing, "ram-style pail pumps" are recommended.
- **Excessive Air Pressure** – The application of excessive air pressure >30 psi (0.2 MPa) to pressure pots may cause air to dissolve into the adhesive. When this pressure is alleviated (either when the pressure pot is opened or the fluid is dispensed) this dissolved air may come out of the solution in the form of air bubbles that become trapped in the adhesive.

  To maintain appropriate pressure and prevent the formation of air bubbles in the adhesive, use larger ID fittings and tubing, minimize tubing length, fully open the dispense valve, and use a shorter and larger ID dispensing needle. If none of this is effective and pressure of 30 psi (0.2 MPa) or greater is still needed, a "ram-style pail pump" is recommended. This involves force being applied directly to the adhesive in the pail via a follower plate allowing for very high pressures without air. "Ram-style pail pumps" are recommended for resins with a viscosity of 25,000 cP or greater.
- **Narrow and Long Fluid Lines** – Generally, the shorter and wider the fluid line, the better. A fluid line diameter of 3/8" (10 mm) is desirable. The longer and narrower the line, the more air pressure is required to transfer the fluid to the dispense valve. This can result in a slow flow rate, and the need for high pressure to move the material with the unfortunate result of air-bubble formation as mentioned under "Excessive Air Pressure".
- **High-Shear Pumps and Valves** – The use of pumps that produce shear, such as gear pumps, is not recommended with Dymax LCMs. Shear

Section 4: Surface Preparation and Dispensing

occurs when the adhesive is caught between two tightly fitting, moving metal parts, which can cause the adhesive to polymerize and clog the system. Simple pressure pots with pneumatic and "ram-style pail pump" systems are recommend.

- **Positive Displacement Valves** – Positive displacement valves should be tested for compatibility with Dymax CMs prior to their incorporation into a dispense system. Contact Dymax for further guidance in selecting an appropriate valve for dispensing a particular adhesive.
- **Using Vacuum to Remove Air Bubbles** – A vacuum should not be used to remove air bubbles from Dymax LCMs. This may remove constituents from the adhesive, altering performance and/or reducing its shelf life.
- **Excessive Vacuum Suck-Back on Syringe Dispensers** – Caution should be taken to apply only he amount of suck-back or vacuum pressure needed to prevent adhesive drip following dispensing. Excessive vacuum pressure may pull the plunger out of the syringe barrel or suck air into the syringe, creating bubbles.
- **Incorrect Cartridge Fitting** – One quarter inch (¼") PT fittings are not recommended for use with Dymax LCMs supplied in cartridges. Although the fitting in the nozzle appears to be a standard ¼" (6 mm) NPT, it is tapered and requires a modified fitting.



Section 5: Tables

5.1 Viscosity

Approximate Viscosity (cP and MPa) at Room Temperature	Fluid
1	Water
80	Olive Oil
200	Motor Oil (SAE 30)
3,000	Honey
8,000	Molasses
65,000	Vaseline
100,000	Sour Cream
150,000-250,000	Peanut Butter

5.2 Hardness

Durometer Hardness Scales*			
00	**A**	**D**	**Feels Like:**
		90	
		80	Polycarbonate
	-	70	
-	-	58	
-	-	46	
-	90	39	
-	85	33	
-	80	29	
-	75	25	Auto Tire Treads
-	70	22	
-	65	19	Pencil Eraser
-	60	16	
-	55	14	
90	50	12	Pink Eraser
88	45	10	
86	40	-	
83	35	-	
80	30	-	Rubber Band
76	25	-	Gummy Bear candy
70	20	-	
62	15	-	
55	10	-	
45		-	

*This chart is for comparison purposes only. This is NOT a conversion chart.

5.3 Temperature Conversion

To Fahrenheit F° = (9/5 x C°) + 32 To Centigrade C° = (5/9) x (F°-32)							
°F	°C	°F	°C	°F	°C	°F	°C
-65	-54	40	4	145	63	250	121
-60	-51	45	7	150	66	255	124
-55	-48	50	10	155	68	260	127
-50	-46	55	13	160	71	265	129
-45	-43	60	16	165	74	270	132
-40	-40	65	18	170	77	275	135
-35	-37	70	21	175	79	280	138
-30	-34	75	24	180	82	285	141
-25	-32	80	27	185	85	290	143
-20	-29	85	29	190	88	295	146
-15	-26	90	32	195	91	300	149
-10	-23	95	35	200	93	305	152
-5	-21	100	38	205	96	310	154
0	-18	105	41	210	99	315	157
5	-15	110	43	215	102	320	160
10	-12	115	46	220	104	325	163
15	-9	120	49	225	107	330	166
20	-7	125	52	230	110	335	168
25	-4	130	54	235	113	340	171
30	-1	135	57	240	116	345	174
35	2	140	60	245	118	350	177

Section 5: Tables

5.4 Units Conversion*

Length	1 meter = 100 centimeter = 1,000 millimeter = 106 microns = 1.094 yards = 3.281 feet = 39.37 inches
Area	1 m2 = 10,000 cm^2 = 10.76 ft^2 = 1550 in^2
Volume	1 liter = 1,000 mL = 1,000 cm^3 = 0.001 m^3 = 0.2642 gal = 1.0567 qt = 2.113 pt = 33.81 fluid oz = 0.3531 ft^3 = 61.02 in^3 1 gallon = 3.785 liters
Weight	1 kilogram = 1,000 grams = 1,000,000 milligrams = 35.27 ounces = 2.205 pounds
Speed	1 meters/min = 0.01667 meters/sec = 3.281 feet/min = 0.05467 feet/sec = 38.62 inches/min = 0.6560 inches/sec
Heat Transfer and Thermal Conductivity	1 Watt = 3.412 BTU/hr 1 W/m2°K = 0.5778 BTU/(Hr•Ft•°F)
Force	1 lb. force = 4.448 Newtons
Pressure	1,000 PSI = 6.895 MPa = 70.307 kg/cm^2

*For a more complete list of unit conversions, visit www.onlineconversion.com

5.5 Estimating Usage

Bond-Line Gap or Coating Thickness	Theoretical Area Covered by 1 Liter of Adhesive or Coating
0.002" (51 µm)	30,500 in^2 (212 ft^2) (19.7 m^2)
0.005" (127 µm)	12,200 in^2 (84.7 ft^2) (7.88 m^2)
0.010" (254 µm)	6,100 in^2 (42.4 ft^2) (3.94 m^2)
0.015" (381 µm)	4,070 in^2 (28.3 ft^2) (2.63 m^2)

Bead Size	Theoretical Usage (Length per Liter)
1/32" (.79 mm)	66,300 in (1,684 m)
1/16" (1.6 mm)	16,600 in (422 m)
3/32" (2.4 mm)	7,400 in (188 m)
1/8" (3.2 mm)	4,100 in (104 m)
3/16" (4.8 mm)	1,900 in (48 m)
1/4" (6.4 mm)	1,000 in (25.4 m)

Common Calculations		
Circumference	Circle	= diameter x π*
Area	Rectangle	= length x width
	Circle	= radius² x π*
	Cylindrical Surface	= diameter x length x π*
Volume	Rectangular Solid	= length x width x height
	Sphere	= 4/3 x radius³ x π*
	Cylinder	= radius2 x π* x length

*π is approximately 3.14159

Section 5: Tables

5.6 Dymax Trade Names

Trade Name	Description
ACCU-CAL™	Radiometers
BlueWave®	Light-Curing Equipment
Crosslink®	Epoxies
Encompass®	Light-Curable Adhesives Formulated with Both See-Cure & Ultra-Red®
LIGHT-CAP®	LED/LCD Encapsulants
Light Weld®	UV-Curable Materials
MD®	Medical Device Adhesives
Multi-Cure®	Light-Curable Adhesives with Secondary Cure
PrimeCure®	Equipment - 385 nm Cure Intensity
QX4®	4 Wand Spot Lamp
RediCure®	Equipment - 365 nm Cure Intensity
SpeedMask®	Light-Curable Masking Resins
Ultra Light-Weld®	UV- and Visible-Cure Materials
Ultra-Red®	Red Fluorescing
VisiCure®	Equipment - 405 nm Cure Intensity

5.7 Intensity Conversion Table

Energy(mJ/cm^2) = Intensity(mW/cm^2) x Time(seconds)
Intensity(mW/cm^2) = Energy(mJ/cm^2) / Time(seconds)
Intensity (uW/cm^2) = Energy (uJ/cm^2) / Time (seconds)
1000 mJ/cm2 = 1 Joule/cm^2
1000 mW/cm2 = 1 Watt/cm^2

Section 5: Tables

5.8 Dymax Part Numbers and Suffixes

Part Number	Description
1xx-M	Medical-Grade Materials
1xx-MSK	
1xxx-M	
1-2xxxx	
2xx	
2xxx-MW	
2xxxx	Activator-Cure Materials and LCMs (variety of applications)
3xx	Fiber Optic LCMs (old system)
3xxx	Plastic Bonding LCMs
3-xxxx	
3-2xxxx	
4xx	Glass Bonding LCMs
4-xxx	
4-2xxxx	Glass/Plastic Bonding LCMs and Light-Curable Dome Coatings
5xx	Activators, Primers, Accelerators
5-2xxxx	Activators
6xx	Metal/Glass/Plastic Bonding LCMs
6-xxx	
6-2xxxx	
7xx	SpeedMask® and Medical LCMs
7xxx	
8xx	Activator-Cure Magnet/Metal Bonding Adhesives
8-2xxxx	
9xx	Electronic Materials
9xxx	
9-xxx	
9-xxxx	
9-2xxxx	
CAxxx	Cyanoacrylates
GA-xxx	Light-Curable Gaskets
MB-2xxx	Activator-Cure Magnet Bonding Adhesives
OP-xx	Optical LCMs
OP-4-2xxxx	

Suffix	Description
-B	Black/Blue
-F	Fluorescing
-Gel	Gel
-LV	Low Viscosity
-LVF	Low Viscosity Fluorescing
-LVUF	Low Viscosity, Ultra-Fluorescing
-PF	Pink Fluorescing
-RF	Red Fluorescing
-REV-A	Revision A
-REV-B	Revision B
-SC	See-Cure Technology
-SC-UR	Encompass® Technology
-SP01	Special Product 01
-SV01	Special Viscosity 01
-T	Thick
-UF	Ultra Fluorescing
-ULF	Ultra Light-Weld® Fluorescing
-UR	Ultra-Red® Fluorescing
-v	Version
-VLV	Very Low Viscosity
-VT	Very Thick
-VTS	Very Thick Special

Section 5: Tables

5.9 Common Plastics

Abbreviation	Chemical Name
ABS	Acrylonitrile-butadiene-styrene
EVA	Ethylene vinyl acetate
FR-4	Fiber reinforced epoxy
LDPE	Low-density polyethylene
LCP	Liquid crystal polymer
HDPE	High-density polyethylene
PA	Polyamide
PBT	Polybutylene terephthalate
PC	Polycarbonate
PE	Polyethylene
PEI	Polyetherimide
PEEK	Polyetheretherketone
PES	Polyether sulfone
PET	Polyethylene terephthalate
PETG	Glycol-modified PET
PI	Polyimide
PMMA	Polymethyl methacrylate
PP	Polypropylene
PPO	Polyphenylene oxide
PPS	Polyphenylene sulfide
PS	Polystyrene
PSO	Polysulfone
PUR	Polyurethane rubber
PVC	Polyvinyl chloride
PTFE	Polytetrafluoroethylene
SAN	Styrene-acrylonitrile

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