Light-Curable Adhesives

Dispensing a soft gasket into the groove of an appliance device creates a water-tight seal that also reduces vibration.

Optimizing the assembly process can lower overall costs.

by virginia p. read

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Manufacturers have recently faced the most challenging economic conditions in decades and have aggressively sought means to reduce costs without sacrificing product quality. Optimizing assembly process efficiency and minimizing material consumption are viable pathways to significant reductions in assembly manufacturing expense. Many assembly operations are ideal for using adhesives for bonding and joining. In these applications, light-curable materials (LCMs) offer several avenues to increase productivity and reduce waste over traditional two-part slow-cure adhesives, thermally-cured adhesives, or solvent-based adhesive systems.

Selecting the right adhesive to meet the performance, production, and environmental demands of an appliance assembly application can be a daunting decision process. Many factors must be considered before choosing a method to bond and seal plastic, metal, glass, or other substrates. Yet, despite a multitude of available options, the decision-making process can be simplified by knowing the right questions to ask.

Establishing the application requirements for the adhesive or sealant and identifying the ideal performance criteria provide the foundation for the selection process. The major requirements and ideal performance criteria for adhesives and sealants used in the bonding of plastic, glass, metal, or other substrates to similar or dissimilar materials are listed in ***Table 1.***

Vigorous global competition, coupled with environmental mandates, compel manufacturers to consider far more than just the lowest price-per-gram in selecting an adhesive. Light-curable systems frequently provide the highest product quality and the most cost-efficient process with the least environmental impact, in comparison to slow-cure adhesives, and sonic and solvent-welding processes. ***Table 2*** shows a comparison of the benefits and limitations of various plastic joining technologies.

Light-curable adhesive systems can

Adhesives with red or blue fluorescing technology are used to bond polycarbonate substrates for easy in-line inspection.

enable numerous assembly process improvements in the areas of throughput, quality, durability, labor costs, and improved work safety.

Material cost savings can also be achieved with light-curable adhesives. Consider a two-component, urethane adhesive which has a dollar per lb. material price less than that of a one-component, light-curable acrylic. The expected material cost benefit of the lower-priced, two-part system vanishes in a side-by-side study which reveals higher two-part material usage due to purging, improper mixing, and general waste in the mixing system.

Selection considerations

Selecting the best adhesive for a specific appliance assembly operation should consider several important factors.

Chemistry

When bonding engineered plastics such as polycarbonate, acrylic, urethane, ABS, nylon, or other resin systems to other plastics, metal, or glass, there are several adhesive chemistry options. These include light-curable acrylated urethanes, cyanoacrylates, one-part or two-part urethanes, and even a few hybrid combination adhesives such as thermally-curable and light-curable adhesives or light-curable silicone hybrid systems. Bonding to silicones is often best accomplished with silicone adhesives, but under the right conditions bonding to silicone elastomers can be done with urethanes.

Viscosity and thixotropy

Viscosity is the measure of a fluid's resistance to flow. The lower a fluid's viscosity, the greater the fluid's ability or tendency to flow or spread over a surface or bond joint. As a point of reference in evaluating viscosity of an adhesive, water has a viscosity of 1 cP and honey has a viscosity of 10,000 cP. Potting or filling a groove molded into plastic would likely require a low-to-medium viscosity fluid, as a low viscosity material will self-level and fill the groove without voids or air bubbles.

An additional property for consideration is thixotropy. Materials which are thixotropic flow easily when placed under shear (e.g., during dispensing), but exhibit a higher viscosity when the shear force is removed (dispensing stops). For example, ketchup, which has viscosity around 10,000 cP and is thixotropic, flows easily when dispensed, but stays in-place on top of the hot dog. The thixotropic index (recovery) of a material is a helpful value. Typically materials with values of 2.0 to 3.5 are very thick or gel-like and materials with values of 1.5 to 2.0 tend to slump. A thixotropic material would be an ideal candidate to create a gasket bead profile on an unrestricted, open surface. This bead (which will act as a moisture, sound, or chemical barrier) must be easily dispensed and maintain its profile prior to cure without the assistance of the assembly structure.

Adhesion

Once the adhesive chemistry is selected, an individual product within that adhesive class should be chosen based upon its adhesion to various substrates. The test criteria are defined by the specific performance expectations of the adhesive, based on the design of the components. Lap-shear testing or peel-force testing is common, as well as pressurization to burst or leak testing. Accelerated aging tests criteria will depend on the expected storage and in-use conditions expected over the life of the device. Attempting to "accelerate the accelerated aging test" by employing even more aggressive conditions should be avoided. Conducting the test at too high a temperature may inaccurately characterize the adhesive by creating additional cross-linking within the adhesive, which in turn will cause a reduction in elongation properties.

Ease of processing

If multiple adhesive choices still remain, evaluate the adhesive based on its ease of processing. One-part adhesives require a simple dispensing system versus a metered mix system for two-part adhesives. Additionally, one-part systems usually do not require dispensing system purging or have issues with pot life. The ability to dispense and cure where and when needed make one-part acrylated urethanes ideal for many appliance assembly applications, requiring only that light (UV or visible) reach some portion of the bond line. A careful consideration of the level of automation required for the assembly operation (manual, semi-automated, or fully automated) is also important. Can the system be stopped or shut off easily, or is there a shut down that needs to be followed? Can the process be adjusted or qualified to handle lot-to-lot variation in viscosity or cure time?

Quality enhancement

Since the quality and reliability of the appliance product is of the utmost importance, the ability to assure a high-quality

Requirements	Ideal Performance Criteria
Bond-line integrity	Exceeds strength of substrates
Integrity of seals	Gap fill for range of part tolerances
Environmentally friendly	Solvent Free
Lowest assembly costs	Increase production rates and productivity
Workplace safety	No OSHA or EPA impact
High assembly yields	100% in-line bond or seal QC inspection

Table 1.

adhesive bond is critical. Some appliance assembly adhesives are formulated to fluoresce under a black light. This enables quality technicians to confirm that the adhesive covers the prescribed bond or seal area, and also to detect any leaks, air bubbles, or voids. Fluorescing adhesive formulations are available in both blue and red fluorescing color versions. Red is particularly useful in providing the proper contrast in situations where the surrounding plastics also fluoresce blue. An innovative, recent advancement that even further assures joint quality is the introduction of See-Cure technology. This technology offers a blue color in the uncured adhesive which changes to clear/colorless once cure has been completed. A simple, post-cure visual inspection can thus determine completeness of adhesive cure.

Cost

The true in-use cost of an adhesive considers all aspects of the process including waste, downtime, start-up time, scheduled maintenance, tight quality specifications to minimize variability within the process, the number of workers required for a specific process, and scrap rate. Two adhesives may differ only slightly in their price per gram, yet one of these materials may deliver at least a 30 percent cost savings in process efficiencies.

Savings opportunities

Cost savings in the assembly operation drop directly to the company's bottom line. These can be achieved in several areas.

Materials

High-performance adhesives often cost more than commodity materials such as two-part epoxies, thermally-cured adhesives, solvent-based adhesives, or one-part moisture cure silicones. Since light-curable materials are one-part formulations, there is less material waste than two-part systems. With one-part chemistry adhesives, it is not necessary to purge the dispense system and dispose of the dispense tips or static mixing tips because of an incorrect mix ratio.

Assembly labor

Light-curable materials reduce labor costs by eliminating the costs associated with stacking and racking parts of slow-curing adhesives. Light-curable materials cure on-

Fastening Method	Advantage	Limitations/Considerations
Light-Curable Adhesives	• Solvent free • Instant cure; bonds on-demand • No parts racking • Joins dissimilar substrates • Conforms to simple and complex configurations • Suitable for both high-volume automated and low- volume manual processes • Low energy use	• Modest capital investment • Can be substrate specific • Light must reach the adhesive/gasket/coating to enable cure
Solvent-Based Adhesives	• Low material cost per Unit of Measure (UOM)	• Potentially toxic residues absorbed into plastics • Can be difficult or impossible to remove • May contain Materials of Concern to OSHA, EPA • Poor gap filling • Requires close part tolerances • Can craze plastics
Heat Sealing (various methodologies)	• Fast, inexpensive • Solvent free	• Only useful on certain plastics and certain geometrics • Not for dissimilar substrates
Sonic Welding	• Fast, moderately inexpensive • Solvent free	• Large capital investment • Only useful for certain plastics and certain geometrics • Generally not for dissimilar materials • Requires good part fit
Hot Melt Adhesives	• Moderate cost • Solvent free	• Difficult to apply • Cure times (open time) can be inconveniently too short or too long • Do not form structural bonds
Two-Part Urethanes	• Solvent free • Bonds most surfaces	• Toxic residues likely • Slow cure
Epoxies	• Solvent free • Bonds most surfaces	• Difficult to apply • Slow to cure • Reports of toxic tissue reactions for amine and polyamide hardeners
Cyanoacrylates	• Solvent free • Very fast cure	• Brittle bonds, limited to certain plastics • Possible toxic residues • Bonds skin • Generally lower moisture resistance • Difficult disposal • May craze plastics
1-Part silicones	• Very flexible over a wide temperature range	• Long cure times • Leaving group during cure, potentially corrosive • Variable cure rate based on humidity levels.
2-Part silicones	• Very flexible over a wide temperature range	• Moderate cure times • May be susceptible to poisons on the substrate surface

Table 2. Comparison of plastic joining technologies. *Source: Dymax.*

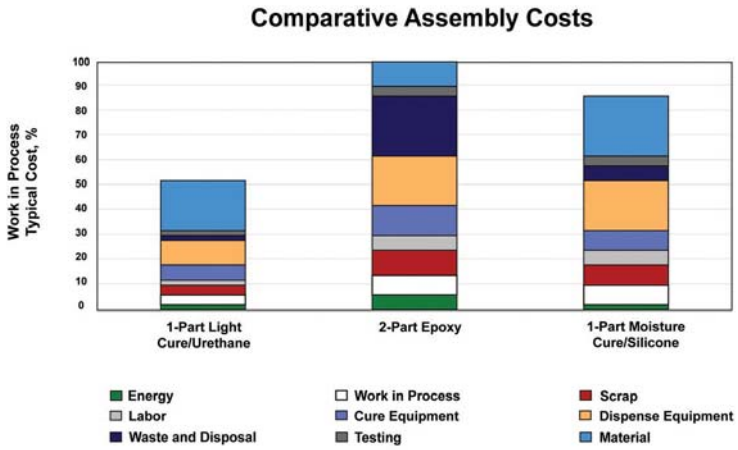

Fig. 1.

demand, ensuring that the bonded appliance assembly is immediately ready for the next step in the process. Assembly labor costs can be reduced by up to 70 percent over two-part epoxy systems, two-part silicone systems, or one-part silicone systems. Consider parts on racks awaiting their turn in a cure oven, cooling after the cure oven, or drying on racks for three to seven days. The labor associated with racking, and loading into cure ovens is eliminated with the use of light-curable materials. Unlike other adhesive products, there is no need to be concerned with environmental conditions such as high humidity adversely impacting the adhesive chemistry system.

QA testing

On-demand cure enables QA check of the bond-line immediately following the cure, thus eliminating the retrieval of defective parts. This immediate check minimizes scrap and work-in-process. The fluorescing of some adhesives allows for void or bubble detection. Manufacturers can then fix and repair, or scrap these parts before adding additional value to the part through down-stream operations. On a high-speed assembly production line, for instance, a high-speed camera can detect and confirm the post-cure presence of adhesive on the bond-line via the fluorescing of the adhesive under black light. Red fluorescing is particularly useful in providing the proper contrast in situations where the surrounding plastics also fluoresce blue. An innovative, recent advancement that even further assures joint quality is the introduction of See-Cure technology. A simple, post-cure visual inspection can thus determine completeness of adhesive cure. Light-curable materials can reduce QA testing costs up to 50 percent over traditional adhesive chemistries.

LCM Process Improvement	Achieved by:
Enhancing Productivity	• Fast curing and the ability to automate
Enhancing Quality	• Toughness, durability and structural integrity of bonds, pottings, sealants, and protective coatings • Joints which are filled, strengthened, and reinforced • Immediate, in-line inspection • Formulations matched to specific performance needs
Bondline Durability	• Aerobic adhesive resistance to thermal and mechanical shock and excellent moisture resistance
Customized Curing	• "Instant cure" property, but only "on-demand" when exposed to light
Profitability	• Lower per unit labor content • Smaller footprint of light-cured process • Compatible with J.I.T. and production flexibility requirements • Improved quality that reduces opportunity for returns for defects • 1-part formulations that reduce waste and disposal costs
Worker Safety & Regulatory Compliance	• 100% reactive formulations • Absence of solvents, volatiles, Materials of Concern

Table 3.

Inventory

The inventory costs associated with assembly processes utilizing light-curable materials can be reduced by up to 50 percent over traditional adhesive chemistries. These reductions in inventory costs result from on-demand cure and instant QC testing which eliminates excess inventory of slow-curing commodity adhesives. Light-curable adhesive systems avoid costly waste due to improper mixing of two-component systems and can minimize adhesive waste by eliminating the need to purge during start up, shut down, and line-down scenarios.

Floor space

Light-curable material assembly processes have a smaller footprint since racking, batch process ovens, and cooling racks are unnecessary. The light-curable material assembly process offers compatibility with JIT manufacturing or Kanban production lines. Floor space savings enables the opportunity to expand the production operation and increases the value of dollars of product produced per square foot of floor space.

Potential accumulated cost reductions in the aforementioned opportunity areas are illustrated in ***Fig. 1*** and can result in at least a 30 percent savings in overall process costs.

Light-curable materials offer numerous opportunities to increase productivity and reduce waste in assembly operations. Instant on-demand cure, automated in-line inspection, solvent-free formulations, and the smaller footprint of the light-cure process are just some of the benefits of LCMs that provide significant, positive impacts to the bottom line. ■

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