Optimizing the Assembly Process with Cure-On-Demand UV/Visible Light-Curable Adhesives

Virginia P. Read
Industrial Market Segment Manager
DYMAX Corporation
Torrington, CT
www.dymax.com

Introduction

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.

Determining the Ideal Performance Criteria

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 the table below:

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

Components of portable electronic devices can be sealed, bonded, laminated, coated, and otherwise protected through the use of light-curable materials.

Dispensing a soft gasket into the groove of an appliance device to reduce vibration and create a water-tight seal.

Advantages of Light-Curable Materials

Light-curable adhesive systems can enable numerous assembly process improvements in the areas of throughput, quality, durability, labor costs, and improved work safety.

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

Material cost savings can also be achieved with light-curable adhesives. Consider a two-component, urethane adhesive which has a $ per lb. material price less than that of a one-component, light-curable acrylic. The expected material cost benefit of the lower-priced, 2-part system vanishes in a side-by-side study which reveals higher 2-part material usage due to purging, improper mixing, and general waste in the mixing system.

Adhesive 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, 1-part or 2-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. 1-part adhesives require a simple dispensing system versus a metered mix system for 2-part adhesives. Additionally, 1-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 1-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 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% cost savings in process efficiencies.

Process Savings Opportunities with Light-Curable Materials

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

Material Costs

High-performance adhesives often cost more than commodity materials such as 2-part epoxies, thermally-cured adhesives, solvent-based adhesives, or 1-part moisture-cure silicones. Since light-curable materials are 1-part formulations, there is less material waste than 2-part systems. With 1-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 Costs

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-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%*** over 2-part epoxy systems, 2-part silicone systems, or 1-part silicone systems. Consider parts on racks awaiting their turn in a cure oven, cooling after the cure oven, or drying on racks for 3 to 7 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 your adhesive chemistry system.

QA Testing Costs

On-demand cure enables QA check of the bond-line immediately following the cure, 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 determine completeness of adhesive cure. Light-curable materials can reduce QA testing costs ***up to 50%*** over traditional adhesive chemistries.

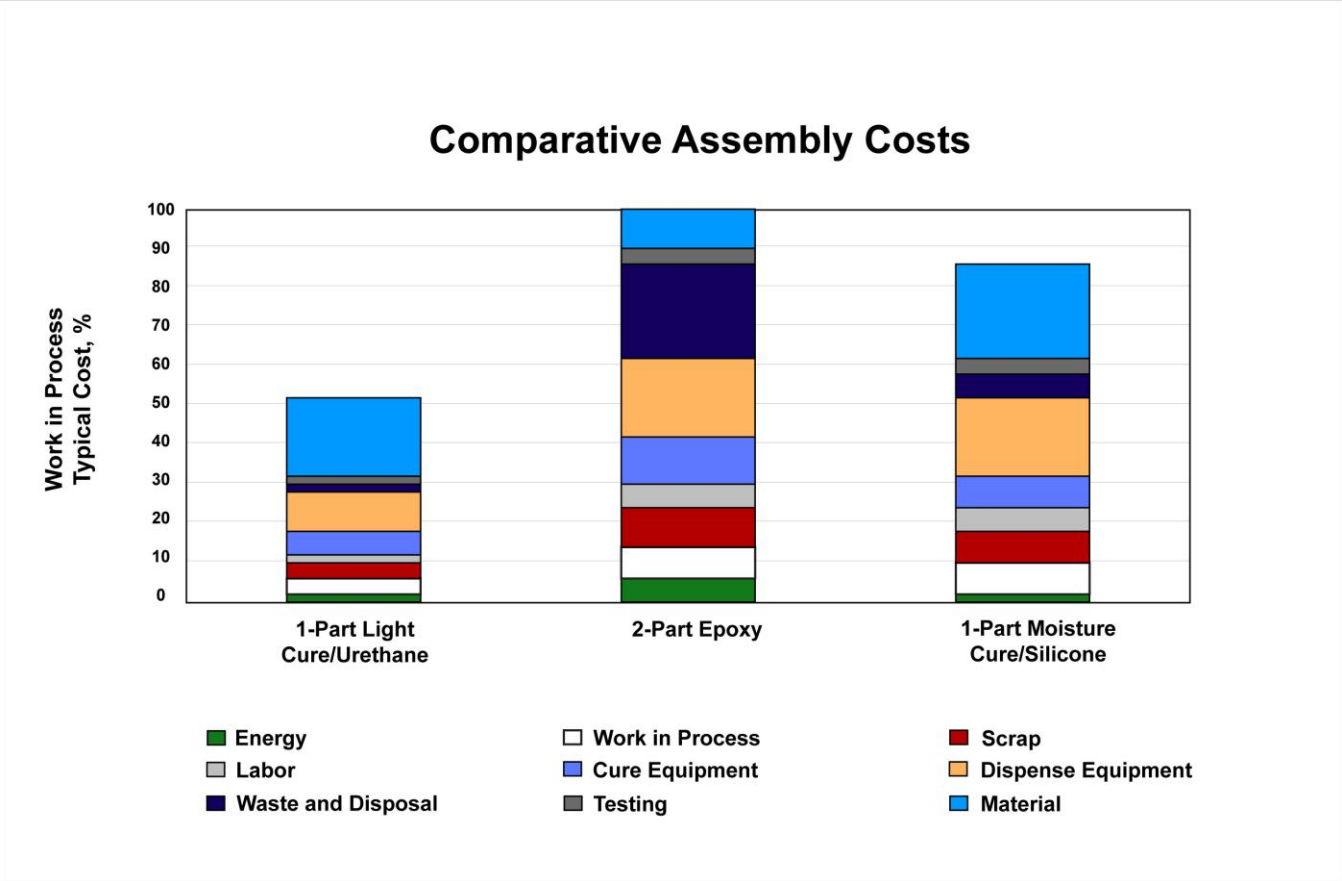
Inventory Costs

The inventory costs associated with assembly processes utilizing light-curable materials can be reduced by ***up to 50%*** 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 Costs

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 the chart below, and can result in at least a *30% savings* in overall process costs.



A Case History

A leading manufacturer of premium, portable, ruggedized safety flashlights used by firefighters, police officers, and military troops in the field, experienced the benefits of a light-curable adhesive. During development of their high-intensity series flashlights the company was searching for a way to ruggedize the lens and reflector housings by applying a sealant to bond the sub-assembly. The company's engineers needed the flashlights to withstand rough handling, extreme conditions in the field, and work in a wide range of environments, such as search and rescue or life-threatening situations. DYMAX recommended Multi-Cure® 621-T adhesive to bond the glass lens to the reflector housing because of this adhesive's ability to adhere dissimilar materials, its fast cure, and excellent adhesion properties. The rapid cure allowed the bonded parts to immediately move onto the next step in the manufacturing process. The lighting company experienced improved quality *and* process savings with the incorporation of the light-curable adhesive system.

Conclusion

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.