Adhesive Technologies for the Assembly of Hard-to-Bond Plastics

Defined by their economical, flexible and high performance characteristics, common difficult-to-bond plastics including acetals, polyethylenes, fluoropolymers, polypropylene and TPVs are an industry essential. A wide range of assembly methods, including mechanical and chemical, can be used for bonding both similar and dissimilar plastics, although adhesive assembly methods offer a unique ability to bond and seal for equal stress distribution, fast cure times, gap filling capability and simplified automation.

Defining Hard-to-Bond Substrates

Once polymerized, thermoset plastic resins are not modifiable. This group includes polyester, phenolic and epoxy resins. Contrarily, thermoplastics can be reflowed and include acrylonitrile butadiene styrene (ABS), polyamide (nylon), polycarbonate, and polyolefins. Such difficult-to-bond substrates are differentiated by linear or branched carbon chain polymers with low surface energies, low porosity, and non-polar or non-functional surfaces to which an adhesive cannot bind.

A semi-crystalline thermoplastic created through free-radical polymerization, low density polyethylene (LDPE) generally features lower strength and hardness. However, LDPE provides advantages such as enhanced flexibility, clarity, and impact resistance. Like LDPE, high density polyethylene (HDPE) is the product of a polymerization reaction but is characterized by increased strength, hardness and chemical and abrasion resistance. Both substances are commonly used for packaging, medical device, electrical component and various other applications.

With its excellent thermal and chemical resistance, high moisture resistance and good mechanical properties, polypropylene (PP) is a crystalline thermoplastic commonly found in packaging, appliance, medical, electrical and fiber applications. The primary downside is low-temperature impact resistance related to crystallinity.

Teflon® and other fluoropolymers are created through free radical polymerization. These highly crystalline thermoplastics feature excellent thermal resistance, chemical resistance and weatherability as well as low flammability. Fluoropolymers are characterized by low coefficients of friction with average service temperatures of about 500°F, making them ideal for high temperature applications as found in the electrical or mechanical industries. However, a higher pound cost of certain grades can be a downside of using fluoropolymers.

Acetal homopolymer (acetal) resins are defined by impact strength, low permeability, temperature resistance, and good dielectric properties. Produced through a polymerization reaction involving formaldehyde, primary disadvantages of acetals are poor UV resistance and poor resistance to strong acids. Due to their wear resistance, acetals are common to automotive, industrial, electronics and consumer applications.

Thermoplastic vulcanizates (TPVs) are classified as thermoplastic elastomers and may be difficult to join. A combination of polypropylene and vulcanized rubber, TPVs are inherently flexible with excellent thermal, weathering and chemical resistance as well as flexural resistance, abrasion resistance and tensile strength. TPVs are commonly found in a range of industries such as automotive, electrical, medical and construction.

Adhesives for Hard-to-Bond Plastics

The most common assembly method for hard-to-bond plastics is adhesives due to both versatility and the ability to join thirty-six types of plastic. However, few adhesives provide consistently high bond strength on difficult-to-bond plastics. These include cyanoacrylates and light curing cyanoacrylates available in a range of viscosities with varying cure times, temperature resistance and strengths.

Standard unfilled ethyl monomer based cyanoacrylates cure as thermoplastic resins, which generally display low impact and peel strengths with mid-level resistance to solvents. With a maximum operating temperature of 160-180°F, these cyanoacrylates fixture in as quickly as three seconds. Engineered for improved peel and impact strength, rubber modified cyanoacrylates have a slightly increased fixture time of about 30 seconds to two minutes.

Certain cyanoacrylate adhesives offer monomers to minimize “blooming” or “frosting” – the presence of a white, milky haze around a bondline. However, this change in monomer can impact physical properties of the adhesive as well as operating temperatures and cure times. Available in both black and clear options, thermally resistant ethyl cyanoacrylates are modified for enhanced temperature resistance up to 250°F, but with increased fixture time.

While light curing acrylics lack the performance strength of cyanoacrylates when used with hard-to-bond substrates, they provide moderate performance for certain plastics. With appropriate light exposure, light curing cyanoacrylates form thermoset resins and are available in a range of viscosities and final cured forms. To achieve a full cure, light must reach the entire bondline, as shadowed adhesive will remain in liquid form. With the ability to cure in as little as five seconds, light curing acrylics form thermoset plastic resins once cured to provide improved thermal, chemical environmental resistance.

Classified as ethyl-based photoinitiators, light curing cyanoacrylates can quickly fixture with low intensity light in shadowed areas. With characteristics similar to those of traditional cyanoacrylates, light cure cyanoacrylates also minimize blooming and frosting and are compatible with primers for difficult-to-bond plastics.

Developed for moisture resistance as well as resistance to acids, bases, alcohols and polar solvents, polyolefin hot melts provide excellent adhesion to polypropylene. Designed for performance on hard-to-bond plastics, reactive urethane hot melts form thermoset plastics with full cure to offer increased performance.

A two part-acrylic-based adhesive has been developed to provide enhanced performance with tenacious bond strength on materials such as polyethylene and polypropylene. This unique acrylic adhesive offers in excess of 1000 PSI on common metals and plastics and creates a chemical attachment to mated surfaces.

Surface Preparation Methods

Hard-to-bond materials require special surface preparation to improve adhesion. Both chemical and physical methods are used to enhance surface reactivity and roughness, including plasma, corona and flame treatments as well as surface priming or chemical etching.

Used on a range of substrates like polyolefins and polyester, plasma treatment is often used with cyanoacrylate, light curing acrylic, and light curing cyanoacrylates. Designed to enhance surface reactivity and wettability, the major drawback of plasma treatment is a potentially brief shelf life.

Like plasma exposure, corona discharge has a limited shelf life and thus parts must be assembled within a specified time window. Commonly used on polyolefin substrates bonded with cyanoacrylate or light curing acrylic adhesives, corona treatment delivers significant bond strength.

Typically used with polyolefins and acetals, chemical treatments such as chromic acid etching are often used on a limited basis to treat substrates prior to bonding, as handling and storage of chemical treatment materials is often hazardous.

Flame treatments are developed to lower surface energy of the substrate to enable better wetting. Commonly used with polyolefins and polyacetals, flame treatments are most often used in conjunction with cyanoacrylates.

Surface roughening methods provide enhanced bond strength of most adhesive technologies and are used widely with both difficult-to-bond and traditional substrates.

Applied with a brush or as a spray, primers are solvent-based systems. As the solvent evaporates, a reactive species remains on the substrate, acting as a bridge between substrate and adhesive. Often used to provide enhanced bond strength for a range of substrates, primers are part of a two-step bonding process that can be applied with little cost and remain active on substrates in excess of eight hours.

This article is based on an original publication by Henkel.