



Thermoplastic olefins offer durability, flexibility, and resistance to heat, moisture, and solvents.

Bonding Low Surface Energy Plastics

New Adhesive Systems Provide Alternative Fastening Methods For Low Surface Energy Plastics

The use of polypropylene (PP), polyethylene (PE), and other thermoplastic olefins is growing because of their low cost and excellent physical properties – durability, flexibility, and resistance to heat, moisture, and solvents. Unfortunately, some of the same properties that make these plastics attractive to designers also make them difficult to bond with adhesives, a preferred method of attachment. PP and PE belong to a group of low surface energy (LSE) plastics, which includes Teflon, that are not easily bonded with conventional adhesives.

As a result, mechanical fasteners and ultrasonic welding are used to assemble LSE plastic structural components in transportation, general industrial, medical, and electronic applications. These approaches create problems that affect the service life and aesthetics of products. Mechanical fasteners constrain components and increase the risk of cracking and failure at attachment points due to material expansion/contraction, flexing, and vibration. Ultrasonic welding is time-consuming and often produces unacceptable surface dimpling.

As designers and production engineers specify more LSE plastics they are seeking better, more efficient and lower cost ways to attach LSE plastics to themselves as well as other substrates.

Adhesives offer several advantages over other joining methods. Adhesives distribute loads evenly, reducing stress on a joint. They resist stresses caused by flexing, vibration, and impact and form a bond as well as a seal to minimize joint corrosion. Adhesives easily gap fill surfaces that would be difficult using mechanical fasteners or ultrasonic methods. Since they are applied inside a joint, they are invisible within an assembly. In addition, roughly shaped surfaces are more easily joined with adhesives, there is minimal increase to weight, and there is no change in dimensions.

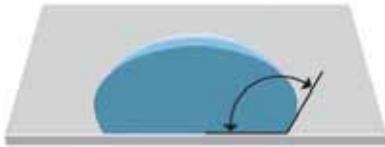
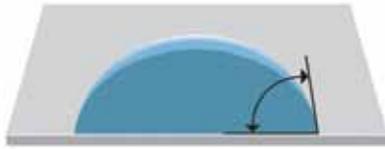


Illustration 1: The water drop (top) has a contact angle less than 90 degrees indicating a substrate material with a higher surface energy. The drop (below) has a contact angle greater than 90 degrees indicating that the substrate material has a low surface energy.

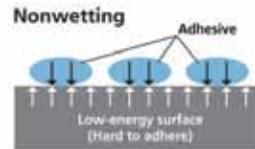
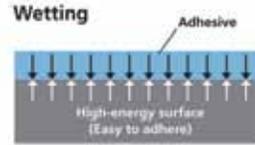


Illustration 2: A high surface energy substrate (top) promotes wetting by the adhesive, which creates a stronger adhesive/substrate bond. The low surface energy substrate (bottom) impedes wetting and creates a weaker adhesive/substrate bond.

However, until recently, practical and economical adhesives for joining LSE plastics were not available. Now, new advanced liquid and viscoelastic adhesives are changing the outlook for adhesive-based assembly of LSE plastics.

Surface Dynamics of LSE Plastics

The problem is that LSE plastics have low surface energy, rendering them “non-stick” (like Teflon). The adsorption theory of adhesions states that adhesion results from molecular contact between two materials and the resulting surface forces that develop. The process of establishing contact between an adhesive and a material is known as “wetting.” After wetting, it’s believed that adhesion results primarily through forces of molecular attraction such as van der Waals forces.

Surface energy is important because it influences the ability of adhesives to adequately wet plastic surfaces and create strong bonds.

The surface energy or wettability of a material is measured in dynes/cm (See Table 1). For example, PP and PE have low surface energy of 30 dynes/cm. Polytetrafluoroethylene (PTFE), the original coating for non-stick cookware, is the LSE champ at 19 dynes/cm. Plastics with relatively high surface energy, acrylonitrile butadiene styrene (ABS) and polycarbonate for example, bond readily because they are easily wet by conventional adhesives. Properly prepared aluminum – with a surface energy of 840 dynes/cm – strongly bonds with adhesives, which explains why modern aluminum-skinned aircraft rely more on adhesives than rivets for structural assembly.

Surface energy is determined by measuring the contact angle of a water droplet on the surface of a material (See Illustration 1). Contact angles greater than 90 degrees indicate lower surface energy – and a surface that is more difficult to wet, for example, epoxy adhesive on fluoroethylene polypropylene substrate). Contact angles

less than 90 degrees indicate higher surface energy – a surface that is easier to wet, for example, epoxy adhesive on metal substrate. A surface producing a contact angle near 180 degrees would be very difficult to wet: the water in effect “beads up,” like water on your waxed car. A surface producing a contact angle approaching zero degrees is easily wet: the water forms a sheet.

For an adhesive to wet a surface, the adhesive should have a lower surface tension than the solid. The better a liquid adhesive wets a material surface the more area it can cover (See Illustration 2). This has two beneficial results. Better wetting increases the attraction and interaction of reactive groups in the adhesive and the substrate, making a stronger chemical bond. Better wetting also promotes surface penetration, which fills in microscopic irregularities producing adhesive interlocks that make a stronger mechanical bond.

without olefin primers and include accelerators to assure rapid cure rates in low-humidity environments.

Light-cure acrylics are on-part solvent-free liquids with typical cure times of 2 to 60 seconds and cure depths exceeding 0.5 inches. They provide good environmental resistance, superior gap filling, clear bond lines to improve aesthetics, and availability in a wide range of viscosities.

Light-cure cyanoacrylate adhesive is a hybrid technology that offers increased cure depth, high bond strength, and compatibility with primers for LSE plastics. Rapid cure rates allow parts to be processed in seconds rather than minutes in high-volume applications involving relatively small plastic parts. If necessary, even greater levels of bond strength can be achieved through the use of primers, plasma, or corona treatments. They offer minimal blooming/frosting, increased cure depth, rapid dry-surface cure, high-bond strength, and compatibility with primers for difficult-to-bond plastics.

Advantages of New LSE Plastics Adhesives

This new generation of liquid adhesives, adhesive tapes, and thin-film/foam bonding systems create strong bonds with LSE plastics that are more impact-, shock-, and fatigue-resistant than conventional mechanical and ultrasonic fastening. New LSE series adhesives are being developed that offer even greater levels of adhesions without requiring surface treatment or

primers. The availability of reliable adhesive bonding alternatives for LSE plastics promises faster production and assembly using less-skilled labor. Adhesives add little additional weight to assemblies, cause no change in part dimensions or geometry, and readily bond dissimilar substrates and heat-sensitive materials. And because the limitations of conventional fastening techniques are not an issue, designers have more latitude in specifying component plastic thickness and shape. Generally, a thin bonding product offers as good or a superior bond as a liquid adhesive if one of the substrates is thin or lightweight, or if one or both of the adhesives are flexible.

Designers are already using these new liquid adhesive thin film/foam bonding systems as alternatives to mechanical fasteners and ultrasonic welding to attach polypropylene fenders, bumpers, body trim, body panels, and other items on vehicles and recreational trailers. They are used to attach name plates, protective windows, and warning labels to industrial equipment and are finding specialized niches in diagnostic medical products.

Applications for Hard to Bond Surfaces

Transportation

In transportation there has been a big push to adopt LSE plastics because of their excellent performance characteristics and significant cost savings over older technologies. Designers already are using new liquid adhesives and thin film bonding systems as alternatives to mechanical

fasteners and welding to attach polypropylene fenders, bumpers, body trim, body panels and other items in vehicles and recreational trailers.

In automobiles, most interior trim pieces are now LSE plastics. Thin bonding systems can handle the extreme temperatures encountered in auto interiors and hold these parts in place for the life of the vehicle without the need for unsightly mechanical fasteners.

Flexible LSE rubber gaskets are increasingly used in transportation. Die-cut thin bonding films are readily laminated to these gaskets, providing a peel-and-stick solution for assemblers attaching the gaskets to areas that need protection. Advanced LSE paint systems are impervious to conventional adhesives, but gaskets incorporating the new thin formulations make permanent bonds with these extremely durable paints.

Many all-terrain recreational and work vehicles have hoods and other body panels made from LSE plastics or blends containing LSE plastics. Using die-cut thin bonding films, manufacturers are able to quickly adhere heat shielding materials and sound dampening foams under the hood and inside the engine bay with a peel-and-stick approach that replaces a time consuming, labor intensive, and environmentally hazardous process that used liquid contact adhesives.



New pressure-sensitive adhesive technologies produce excellent structural bonding with many LSE plastics without the use of priming or other pretreatment steps.

Achieving Better Adhesive Bonds

Surface energy, in terms of the performance of an adhesive, is a relative phenomenon. Ideally, the surface energy of a plastic should be 7 to 10 dynes/cm higher than the surface energy of an adhesive. Therefore, there are two ways to improve bonding with LSE plastics:

1. **Raise the surface energy of the LSE plastic** – This is usually accomplished by pre-treating LSE plastics with primers, flame, plasma, or corona discharge processes that change the surface chemistry of the plastic, rendering it wettable by conventional adhesives.
2. **Lower the surface energy of the adhesive** – A liquid or pressure-sensitive adhesive with a surface energy of 20 dynes/cm will spontaneously wet out LSE plastics with surface energies of 30 dynes/cm or more. With double-coated or transfer tapes, tackifiers are added to the adhesive formulation to produce an aggressive bond.

Raising the surface energy of LSE plastics as outlined in (1) above adds cost and time to assembly or production processes.

Flame, plasma, and corona discharge treatments produce surface changes that may improve bonding, but often only for a limited time measured in minutes, days, or weeks depending on the plastic. These techniques, including primers, also pose environmental issues that must be considered.

Finding better adhesives that adequately wet a LSE plastic surface has designers focused on advanced liquid adhesives and thin film/foam bonding systems that were thought to be impractical and expensive only a few years ago.

New Bonding Techniques for LSE Plastics

The most promising approaches employ specific acrylic and cyanoacrylate adhesives that strongly adhere to LSE plastics and to other higher surface energy plastics as well as metal, glass, and other substrates.

New acrylic liquid adhesive and pressure-sensitive adhesive tape technologies produce excellent structural bonding with many LSE plastics without the use of priming or other pretreatment steps. One approach is based on a two-part, solvent-free, room temperature curing acrylic

adhesive. The new system cuts costs, saves time, and avoids the need for curing ovens, UV lamps, and heaters. The resulting structural bonds are in excess of 1,000 psi in overlap shear, often exceeding the strength of the substrates joined. They effectively resist chemical attack, water, humidity, and corrosion.

For applications where there is either a thin, lightweight, or flexible substrate, consider a pressure-sensitive, double-coated tape or transfer tape. There are thin adhesive products designed to bond LSE materials and if one of the above criterion is met they will perform at the same level as their structural counterparts in regards to temperature resistance, solvent resistance, and peel strength.

Cyanoacrylates are high-strength, one-part adhesives that cure at room temperature. They form thermoplastic resins when confined between two substrates that contain trace amounts of surface moisture. They have a limited cure-through gap of approximately 0.010 inches. Cyanoacrylates are available with a wide range of viscosities, cure times, strengths, and temperature resistance. Newer formulations produce good bond strength on LSE plastics

Table 1:**Relative Surface Energy of Materials**

Material	Abbreviation	Surface Energy (dynes/cm ²)	Contact Angle (degrees)
Polyethersulfone	PES	46	90
Polyphenylene oxide	PPO	47	75
Polycarbonate	PC	46	75
Polyethylene terephthalate	PET	42	76
Polymethylmethacrylate	PMMA	41	82
Styrene acrylonitrile	SAN	40	74
Polyimide	--	40	83
Polyvinyl chloride, rigid	PVCR	39	90
Polyester	PE	41	70
Acetal	--	36	85
Acrylonitrile butadiene styrene	ABS	35	82
Polyphenylene sulfide	PPS	38	87
Polyvinyl chloride, plasticized	PVCP	35	89
Polystyrene	PS	34	72
Surlyn ionomer	--	33	80
Polybutylene terephthalate	PBT	32	88
Polypropylene	PP	30	88
Polyurethane	PU	38	85
Polyethylene	PE	30	88
Polydimethyl siloxane	PDMS	23	98
Polytetrafluoroethylene	PTFE	19	120



Liquid adhesives, adhesive tapes, and thin film/foam bonding systems create strong bonds with LSE plastics that are more resistant to impact, shock, and fatigue than conventional mechanical and ultrasonic fastening.

Appliances

In appliance manufacturing, powder coating provides a lasting, durable, LSE finish. Such cured paints have been difficult to adhere to, until now. With new thin bonding film formulations, manufacturers are able to securely attach sound-deadening insulation, metal identification and serial labels, and internal LSE plastic components that operate at elevated temperatures. This eliminates conventional fasteners that detract from modern design aesthetics and may promote corrosion and stress cracking.

Electronic and Medical

In many electric and electronic applications, polypropylene film is used as insulation because of its dielectric properties. This LSE plastic is difficult to hold with conventional adhesives, but thin bonding systems are supplying a durable, dependable, and cost-effective solution. In the competitive medical disposables market, an LSE plastic is often used as part of a diagnostic strip because of its low cost. Thin bonding film now is used to laminate test strip components together to produce the final product.

About Fabrico

Fabrico is a recognized leader in cost-effective product design and engineering, as well as converting and custom fabrication services for flexible materials. The company designs and manufactures components and sub-assemblies using flexible materials for industries as diverse as transportation, medical device, general industrial, solar, and military.

