New Adhesive Systems For Low Surface Energy Plastics

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

The use of polypropylene (PP), polyethylene (PE), and other thermoplastic olefins is growing because of their low cost and excellent 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.

The problem is that LSE plastics have low surface energy rendering them "non-stick" (like Teflon). Surface energy is important because it influences the ability of adhesives to adequately wet plastic surfaces and create strong bonds.

The surface energy or wetability of a material is measured in dynes/cm (See Table 1).

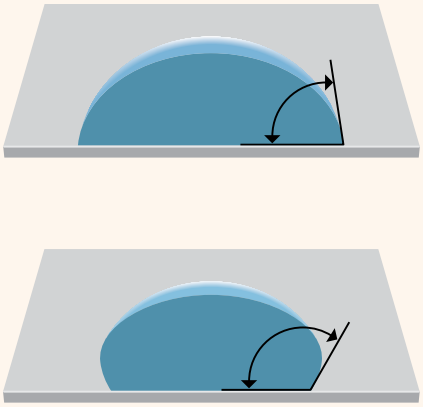
Table 1: Relative Surface Energy of Materials

MATERIAL	SURFACE ENERGY (dynes/cm)	CONTACT ANGLE (degrees)
Copper	1,103	
Aluminum	840	
Glass	250 - 500	
Polycarbonate (PC)	46	75
Acrylonitrile Butadiene Styrene (ABS)	35	82
Polypropylene (PP)	30	88
Polyethylene (PE)	30	88
Polytetrafluoroethylene (PTFE)	19	120

Bonding, Joining & Sealing

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 and Adhesive Wetting



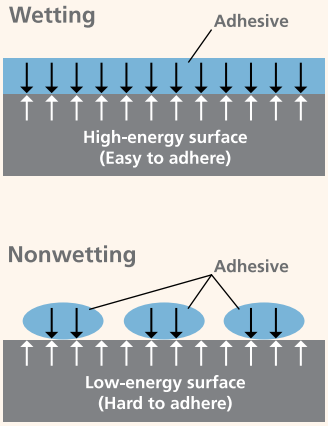


Illustration 1: The water drop (top) has a contact angle less than 90 degrees indicating a substrate material with a higher surface energy. The drop (below) has a contact angle greater than 90 degrees indicating that the substrate material has a low surface energy.

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.

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. Contact angles less than 90 degrees indicate higher surface energy — a surface that is easier to wet. 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.

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 surface irregularities producing adhesive interlocks that make a stronger mechanical bond.

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 wetable 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 transfer tapes, tackifiers are added to the adhesive formulation to produce an aggressive bond.

Raising the surface energy of LSE plastics (See Illusration 1) 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.

New pressure-sensitive adhesive technologies produce excellent structural bonding with many LSE plastics without priming or pretreatment.

This new generation of liquid adhesives, adhesive tapes, and thin film/foam bonding systems create strong bonds with LSE plastics.

New Bonding Techniques for LSE Plastics

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. Newer formulations produce good bond strength on LSE plastics without olefin primers and include accelerators to assure rapid cure rates in low-humidity environments. 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.

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 adhesion without requiring surface treatments 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 thickness and shape.

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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.

Material Partners

Fabrico has strategic relationships with world-class materials suppliers, such as 3M and Loctite®, to assist its customers in selecting the best material for the intended use and to expedite materials sourcing. Whether adhesive films or liquids, all critical material properties are considered in any Fabrico project, including chemical, thermal, and moisture resistance.

With more than 30 years of materials experience, Fabrico engineers also understand the impact of a material selection on the overall manufacturing process, and design material systems that optimize production efficiency and improve overall cost-effectiveness.

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