SABIC
Innovative
Plastics™

Adhesive bonding

Adhesive bonding in SABIC Innovative Plastics' applications

Adhesive bonding is a convenient method of assembling a plastic part to either a similar or dissimilar (including non-plastic) material. Adhesives distribute stresses over the entire bond area, and can provide a hermetic seal if needed. Flexible adhesives allow some movement between mating parts, and thus can compensate for differences between the materials, such as coefficient of thermal expansion. Adhesives are relatively inexpensive, and often require little or no special equipment for application.

Adhesive selection

When selecting an adhesive system for bonding a thermoplastic resin to itself or to a dissimilar material, one should first consider the factors common to all adhesive bonding applications. The expected end use environment is probably the most important of these considerations. Among the environmental concerns are expected temperature ranges, chemical and UV exposure and possible UL electrical requirements.

Other important considerations are the anticipated bond loading and strength requirements of the final application. In most cases, more than one type of adhesive could fulfill the necessary requirements. Each system exhibits characteristic properties that fit particular application needs. There are five common families of adhesives used for bonding SABIC Innovative Plastics resins as shown below

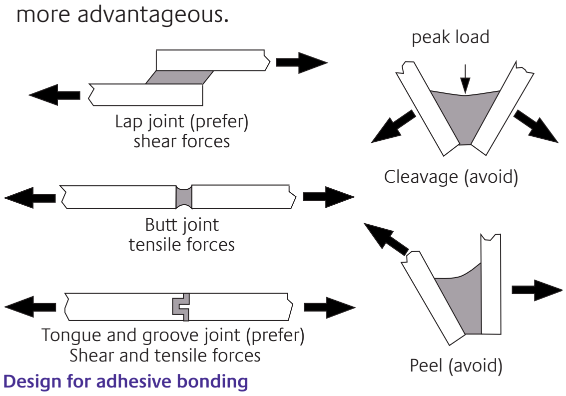
Adhesive joint design

Adhesive bonding is a complex phenomenon involving chemical reaction, electrical attraction at the molecular level and various mechanical factors. The adhesive introduced at the interface of two parts must be compatible chemically, electrically and mechanically with BOTH substrates AND with the end-use environment. In addition, the adhesive medium should have a similar coefficient of thermal expansion to the substrates, or, if they are dissimilar, it must be flexible.

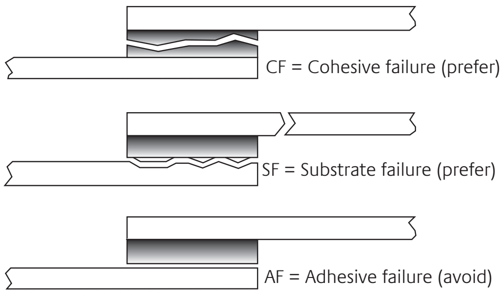
Joint design is critical to the optimum performance of a bond. Factors to be considered in choosing a joint design include

Translation and guidelines

- Joint orientation will define the type of loading applied to the bond - shear, peel, tensile, etc.
- Optimize the area of the bond to match the adhesive strength and the expected loadings.
- Aesthetics in the bond area may restrict the choice of joint design.
- Moldability and mold design can be compromised by some joint designs.
- Ability to maintain tolerances on the mating parts is critical to some joint designs, such as the tongue and groove
- Part design and mold design must anticipate the tolerances required at the joint interface.
- Gap filling ability of the adhesive must be considered in the dimensions of the joint
- Set time for the adhesive and the need for handling of the parts after assembly may make some joints more advantageous.



Design for adhesive bonding



Adhesive failure modes

Characteristic	**Epoxy 2K**	**PUR 1K**	**PUR 2K**	**PUR reactive hot melt**	**MS polymer**	**Silicone 1K**	**Silicone 2K**	**Acrylic 2K**	**Cyano-acrylate**
Gap filling	Yes < 1mm	Yes	Yes 3 - 4mm	Yes	Yes	Yes	Yes	Medium < 1mm	No
Stiffness	High	Low	Med/Low	Medium	Med/Low	Very Low	Low	Yes	No
Toughness	No/Yes for specials	Yes	Yes	Medium	Yes	Yes	Yes	Yes	No
Curing handling	Reaction 15-120 min †T stronger	Moisture 0.58 hrs. →CO_2gas	Reaction 10-40 min. †T faster	Moisture ΔT 10 min. cure 2 hrs.	Reaction 10-40 †T faster	Moisture 2-3 hrs. smell	Reaction 5-30 min.	Fast	Moisture 1-10s Acid →base
Strength shear	High 8-20 MPa	Peel < 5 MPa	Peel 3-10 MPa	Medium 3-10 MPa	Peel 2-3 MPa	Peel < 3 MPa	Peel < 3 MPa	High	High > 30 MPa
Temperature resistance	High> 80°C Adh. ↓	Medium -40-80°C Low T flex.	Meduim 130°C	Medium 130°C	Medium 130°C	High200°C low T tough	High200°C low T tough	High, but strengh ↓at †T	Low < 80°C
Moisture resistance	Very good	Moderate	Moderate	Moderate	Moderate	Good	Good	Good	Poor
Chemical resistance	Very good	Good	Very Good	Good	Good	Very Good	Very Good	Moderate	Moderate
UV resistance	good	Poor	Moderate	Moderate	Good	Very Good	Very good	Good	Good
Surface preparation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not critical oil tolerant	Yes Basic surface
Contents	Acids	Isocyanate residue	Isocyanate curing	Isocyanate residue	Silane	Acetic acid Methanol	Acetic acid Methanol	Methyl-Methacrylate	Cyano-acrylate
Applications	Car body	Sealing, B&C, porous	General	Laminates, constr.	Expensive, difficult materials	Glazing B&C	Auto-EMS electronics	Structural	Electronics

Table of adhesive characteristics

SABIC Innovative Plastics material	**Epoxy 2K**	**PUR 1X**	**PUR 2K**	**PUR** reactive hot melt	**MS Polymer**	**Silicone 1K**	**Silicone 2K**	**Acrylic 2K**	**Cyano-acrylate**
Cycolac*	OK	Sometimes primer	OK	OK	-	OK	OK	Agressive solvent	Aggressive solvent, cure fast
Cycoloy*	OK	Sometimes primer	OK	OK	OK	OK	OK	Aggressive solvent	Aggressive solvent, cure fast
Lexan*	OK	Sometimes primer	OK	OK	OK	OK	OK	Aggressive solvent	Aggresive solvent, cure fast
Noryl*	OK	Pimer	Primer	Primer	test	OK	OK	OK	OK
Noryl GTX*	-	Primer	Primer	Primer	OK		OK	Corona + primer	OK for non-auto
Ultem*	OK	Primer	OK	OK	OK	OK	OK	Aggressive solvent	Aggressive solvent, cure fast
Valox* Enduran*	Cure at 80°C		Primer		Test		OK	Test	OK
Xenoy*	OK	Primer	OK	Test	OK	OK	OK	OK	OK but aggresttive to PC

Table of adhesive compatibility

Adhesive families

The five common families of adhesives that have been used for bonding SABIC Innovative Plastics resins are listed in table 1.

	Impact resistance	**Moisture resistance**	**NO. of components**	**Temperature limits**	**Set time**
Urethane	VG	F	2	110°C	5 min +
Anaerobics	G	G	1	200°C	10 sec
Cyanoacrylate	F	F	1	80°C	10 sec
Acrylic	G	G	2	100°C	2 min +
Epoxy	G	E	1 or 2	200°C +	5 min +
(Based on information from adhesive manufacturers.)					

Table 1 - Common adhesive families

Epoxies
Epoxies are known for their versatility. Their bond strength, electrical conductivity and temperature resistance can be modified to fit almost any specific application needs. Epoxies are made in either one- or two-part formulations. The two-part systems consist of a resin and a hardener, which must be mixed together in strict proportions for maximum bond strength. They can be cured at room or elevated temperatures. One-part epoxies require no mixing; however, they must be cured by heat, usually around 300º F for one hour or more. Heat cured epoxies tend to exhibit greater strength than their mixed counterparts. The two-component systems are more widely used because they can be stored for long periods of time and do not activate until mixed. Unlike other adhesives, epoxies are not solvent based, but cure as the result of a chemical reaction.

Forms	Liquid, paste, film
Shear strength	5,000 to 10,000 psi
Operating temperature	-70° to 450°F
Advantages	Disadvantages
• good adhesion	• poor peel strength
• high tensile and shear strength	• brittle
• creep resistance	• low impact strength
• good rigidity	• high cost
•high heat tolerance	
• easy to cure	

Urethanes
This adhesive family, also called polyurethanes, forms strong bonds on a variety of substrates. Urethanes are found primarily in applications that require high strength with flexibility.

Urethanes are available in both one- and two-part systems. One-part formulations require heat curing while two-part systems may be room temperature cured.

Forms	Liquid, paste solvent-based
Shear strenght	Up to 8,000 psi
Operating temperature	-300° to 300° F
Advantages	Disadvantages
• toughness	• volatility
• flexibility	• excessive creep
• impact strength	• poor strength at high temperature
• abrasion resistance	• chemical sensitivity
• high peel strength	• lack of long term durability
	• usually needs primers
	• moisture sensitivity in uncured state

Acrylics
The acrylics used today are second generation or modified acrylic systems. These "improved" acrylics provide many of the same attributes as epoxies and urethanes as well as having the advantage of rarely needing primers. These are one- or two-part systems consisting of a catalyst primer and the adhesive. Usually, the two-part systems do not need mixing or weighing, greatly simplifying their application.

Acrylics boast rapid cure at room temperature with a setting time of approximately 60 to 90 seconds and full cure within 30 minutes or less. Application of heat may reduce cure times.

Forms	Liquid, paste
Shear strength	Up to 6,000 psi
Operating temperature	-240° to 350°F
Advantages	Disadvantages
• bonds to dirty surfaces	• strong odor
• high strength	• flammability problems
• superior toughness	• minimal gap filling
• fast curing	

Anaerobics

Anaerobics are one-part thermosetting adhesives whose curing mechanism is triggered by the absence of oxygen. This eliminates the problem of premature curing. Curing occurs at room temperature, and can be speeded by addition of heat or ultraviolet radiation. The cure cycle may be as short as 15 seconds set time and 2–24 hours for full cure. Anaerobics also exhibit the useful property of being easily cleaned from unbonded surfaces after the bondline has set up.

Anaerobics are excellent for critical sealing and bonding applications where strength is not critical. Their use is also expanding into the sealing of welds and soldered joints.

Forms	Liquid
Shear strength	Up to 5,000 psi
Operating temperature	-65° to 400°F
Advantages	Disadvantages
• good solvent resistance	• sensitivity to surface cleanliness
• bond flexibility	• poor gap filling properties
• high peel strenght	
• good impact strength	

Cyanoacrylates

Cyanoacrylates are single-part, fast curing "convenience adhesives." With a normal setting time of 2 or 3 seconds and a full cure time of 24 hours at room temperature, these systems are popular in tacking and quick contact assembly operations. The presence of surface moisture, even in limited quantities such as humidity in the air, initiates curing. Cyanoacrylates are highly application specific.

Forms	Liquid
Shear strength	Up to 5,000 psi
Operating temperature	-65° to 180°F
Advantages	Disadvantages
• high tensile strength	• brittleness
• no shelf life limitations	• not usually recommended for dissimilar materials
	• poor gap filling
	• limited impact and peel strength
	• not recommended for constant water exposure

UV Curable Adhesives

Ultraviolet (UV) curing technology was first developed in the mid 1960s as a method for curing packaging inks. Since then, the technology has advanced and spread into other areas. Adhesives, potting compounds and sealants, as well as inks, are now available with UV curing systems. The rapid cure and other advantages of these systems have made UV curables one of the fastest growing families of adhesives in use today.

UV curing is a process that uses ultraviolet light energy to initiate polymerization. Adhesives that rely on this cure mechanism generally consist of a base monomer, a photoinitiator and additives to promote adhesion, lower viscosity and add color. When these systems are exposed to the appropriate wavelength of UV light (usually around 365 nm), the photoinitiators decompose to form free radicals. These active molecules then migrate to the crosslinking sites of the base monomer to effect a cure. When this process is complete, the adhesive has been converted from a liquid containing many loose polymer chains to a fully crosslinked solid. The entire process is extremely fast. A typical cure cycle ranges from 5 to 60 seconds depending on the intensity of the UV source, the thickness of the bond line and the formulation of the adhesive.

It is important that the entire bond line "see" the UV radiation, for free radical formation and cure will not occur in those areas not exposed. To account for the possibility of opaque substrates or shadowed areas, many suppliers include a secondary cure method. Aerobic, anaerobic and moisture cures are often added to insure complete cure of the adhesives.

With opaque substrates a method known as trigger curing can sometimes be used. The adhesive is applied to one side of the assembly and activated. The other half is then fixtured to the first until the cure is complete. This method is somewhat slower than the typical UV cure cycle but still offers a faster cycle time than many conventional cure methods.

The intensity of the UV source is very important to the speed and quality of the cure, as each adhesive or coating requires a certain amount of energy to cure completely. The amount of energy delivered is a function of time and intensity of light, so that higher intensity light requires less time to produce a complete cure. Intensity of light is controlled by the wattage rating of the source, the condition of the source and the distance of the source from the bondline.

UV radiation can be provided by a number of means. The sun, sun lamps, xenon arc lamps, and medium pressure mercury vapor lamps can all be used to cure UV adhesives and coatings. Medium pressure mercury vapor lamps are the main source of UV in industry. The lamps consist of a quartz envelope containing argon gas and liquid mercury. When high voltage electricity or microwave energy is passed through the envelope, it excites the mercury vapor causing it to emit light of the desired wavelength. These bulbs are usually rated to last 2000 hours, but they begin to deteriorate at about 200 hours. As the bulb deteriorates, the intensity of the light produced decreases, and the time necessary for proper curing increases. For this reason many manufacturers choose to monitor the UV intensity to insure consistent cure quality.

UV curable adhesives offer many advantages	**But, as with all assembly techniques, there are disadvantages**
• 100% reactive liquids - no solvents	• high cost
• low shrinkages	• high equipment cost
• low energy cost - lights take much less energy than ovens	• light systems produce hazardous ozone
• fast cycle times - usually in the order of seconds	• UV radiation can cause severe burns and retinal damage

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