
PLEXUSTM

*Guide to Bonding
Plastics*

ITWPLEXUS

PREFACE

New structural materials create challenging assembly problems

Today's designer has an exciting variety of advanced composites and materials available for product design. High-performance plastics and corrosion-resistant metals offer choices that were unheard of only a few years ago.

New plastic alloys and metal finishing advances bring with them a new generation of adhesive bonding challenges. With experience and demonstrated ability to solve difficult bonding problems, *ITW* Plexus has the answer!

PlexusTM Adhesives: A cost-effective solution to bonding advanced plastics and dissimilar materials

Plexus Adhesives is a product line of *ITW* Plexus, an Illinois Tool Works Company. *ITW* specializes in engineered products and systems for improved production and quality.

Plexus Adhesives offer proven solutions to the structural bonding of today's most advanced and exotic materials. They are designed to bond high-performance plastics and combinations of dissimilar materials. Simple to mix and rapid curing, they provide a cost effective assembly method for today's automated manufacturing operations.

General Terms

Adhesion

Adhesion is the process by which two surfaces are held together by interfacial forces (surface attraction) or mechanical interlocking.

Adhesive

An *adhesive* is a substance which is capable of holding materials together in a useful fashion by means of surface attraction. Surface attraction results from placing a thin layer of adhesive between two objects.

While many substances are capable of holding materials together, not all are useful. Molasses, for example, can be used to hold two pieces of wood together, but the joint can hardly be considered useful.

Bond Line

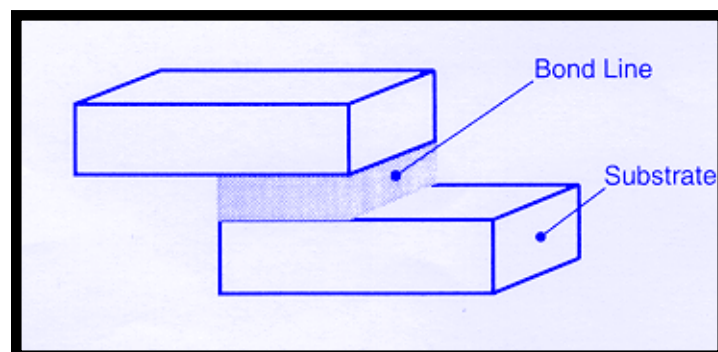
The *bond line* is the space or gap between two substrates which contains the adhesive.

Substrate

A *substrate* is a material which is held by an adhesive. Substrate is a generic term for the objects which are being bonded.

Surface

The *surface* of an object is that face of the object which is coated with an adhesive. Surfaces are usually not what they seem. A steel surface, for example, has layers of metal atoms beneath additional substances which include metal oxides, an oxygen-hydrogen (OH) layer and water. An adhesive is actually applied to this water layer.



Types of Adhesives

- Heat-Cured Adhesives** Any adhesives which must be heated to promote curing.
- Holding Adhesives** *Holding adhesives* are used to hold surfaces together, but not permanently. They do not have to withstand a great deal of force. Adhesive tape is an example of a holding adhesive.
- Hot Melt Adhesives** *Hot melt adhesives* are applied in the molten state and then harden. The adhesive substance is melted, applied to the surface, and then the parts are joined. Once the adhesive cools and solidifies, the joint is complete.
- Instant Adhesives** Any adhesives which cure within seconds to minutes.
- Locking Adhesives** *Locking adhesives* or sealants are used to prevent the loosening of threaded parts. Locking adhesives are placed on the threads of a bolt to prevent it from becoming loose from vibration.
- Pressure Sensitive Adhesives** *Pressure sensitive adhesives* form bonds easily when pressure is applied. Pressure sensitive adhesives are used on self-sealing envelopes and double-sided tape. The joint is made with very little pressure.
- Retaining Adhesives** *Retaining adhesives* are used to prevent the twisting or sliding of non-threaded parts. Retaining adhesives are very similar to locking adhesives except that they are used on nonthreaded parts.
- Sealing Adhesives** *Sealing adhesives* are used to prevent the passage of air, water, oil, etc. between two surfaces. The caulking used around windows is an example of a sealing adhesive.
- Structural Adhesives** *Structural adhesives* are capable of withstanding a significant load. The term “significant load” has never been defined, but the implication is that the adhesive must be able to withstand a great deal of stress-enough stress, in fact, that, in the absence of unnaturally high forces, the substrates could be considered to be permanently joined. Examples of structural adhesives are those used to bond airplane assemblies and automobile plastic bumpers.
- Ultraviolet Adhesives** Any adhesives which cure when exposed to ultraviolet light.

Adhesive Composition

The following terms relate to the composition of an adhesive.

Activators	Activators are chemicals which can be applied directly to a surface or substrate or mixed with an adhesive to speed up the solidification of the adhesive. Activators are similar to both the curing agents and catalysts.
Catalysts/ Accelerators	Catalysts, also called accelerators, are chemicals which, when added in small amounts, cause adhesives to solidify.
Curing Agents	A curing agent is a chemical which reacts with an adhesive polymer to cause it to solidify. Approximately equal amounts of adhesive resin and curing agent are mixed together to form a solid adhesive.
Miscellaneous Components	Some additional components that may be found in an adhesive include pigments, flame retardants, antifoam agents, and tougheners.
Plasticizers	A plasticizer is a chemical added to an adhesive to prevent it from becoming brittle. Many adhesive polymers are very strong, yet brittle enough to crack under impact. Plasticizers are added to soften the adhesive to keep it from becoming too brittle.
Polymers	Polymers are large chemicals composed of repetitive units. Polymers make up the largest portion of an adhesive.
Solvents	Solvents are liquids used to dissolve or suspend adhesives. Solvents are added to an adhesive formulation to make them fluid, allowing the adhesive to be spread or sprayed on a surface more easily. After the adhesive has been applied, the solvent evaporates during cure. Solvents are also used as thinners for some types of adhesives.
Tackifiers	A tackifier is a chemical which is added to an adhesive to make it “stickier”. The tackifier holds the substrates together while curing is taking place. Not all adhesives contain tackifiers.

Adhesive Characteristics

The following terms deal with the application and usable life of adhesives.

Cure	When an adhesive <i>cures</i> , it is converted from a liquid to a solid state. The curing process may be accomplished by cooling, loss of solvents, or internal chemical reaction. Curing generally implies some type of physical or chemical change in the adhesive, while hardening or melting is reversible.
Green Strength	The <i>green strength</i> is a measure of the ability of the adhesive to support a load during the green time.
Green Time (Open Time)	<i>Green time</i> is the time between application and solidification of the adhesive. During the green time, it is still possible to position parts. Fixturing time (the amount of time before bonded parts can be handled) is often somewhat longer than green time.
Kickover	<i>Kickover</i> is the sudden increase in viscosity which accompanies the curing of an adhesive. Once an adhesive “kicks over”, it is almost in its solid state and can no longer be easily spread.
Pot Life	The <i>pot life</i> of an adhesive is the length of time it remains usable for mixing. Pot life is usually an important factor only with adhesives which are mixed together and begin curing almost immediately.
Rheology	<i>Rheology</i> is the ability of a material to flow and deform. Adhesives with good rheology flow easily and break cleanly at the end of a bead.
Shelf Life	<i>Shelf life</i> is the usable storage time of a material. Most adhesives have a shelf life of 6 to 12 months. The shelf life of an adhesive may be increased by refrigeration, and is usually shortened by exposure to heat.
Viscosity	<i>Viscosity</i> is the resistance to flow or degree of thickening of a fluid. Some adhesives flow very easily, whereas other types of adhesives are so thick they hardly flow at all. Water and thick putties represent the extremes of viscosity.
Wetting	<i>Wetting</i> is intimate contact of a liquid and a surface. Good wetting is only possible if there is good attraction between the surface and the liquid. Proper wetting of a mating surface is essential for good bonding.

Structural Adhesives

Structural or Performance Adhesives are load-bearing adhesives. That is, they add strength to the products being bonded. Structural adhesives are used to build products as varied as office furniture, boats, and automobiles. There are approximately ten adhesive families commonly referred to as structural adhesives: Acrylic, Anaerobic, Cyanoacrylate, Epoxy, Hot Melt, Methacrylate, Phenolic, Polyurethane, Solvent Cement, and Tapes. The seven most commonly used are:

- **Acrylic**
- **Anaerobic**
- **Cyanoacrylate**
- **Epoxy**
- **Hot Melt**
- **Methacrylate**
- **Polyurethane**

Acrylic Adhesives have formulations that tolerate dirtier and less prepared surfaces generally associated with metals. They challenge epoxies in shear strength, and offer flexible bonds with good peel and impact resistance. Acrylics are two-part adhesives, the resin is applied to one surface and an accelerator or primer to the other. The two parts can be pre-applied and later mated. Once mated, handling strength is typically achieved in a few minutes. Curing can be completed at room temperature. Newer formulations of acrylics are now available in mix-in formulations.

Anaerobic Adhesives are one of the most easily applied structural adhesives. Because the curing mechanism is triggered by deprivation of oxygen (hence the name “anaerobic”, or “without air”), anaerobic adhesives will not cure prematurely. These adhesives are based on acrylic polyester resins and are produced in viscosities ranging from thin liquids to viscous thixotropic pastes. Although they have high cohesive strength, they have low adhesive strength and are not suited to permeable materials. Anaerobics do not fill gaps well and may require primers. They are generally used as thread fasteners (i.e. Henkel Omnifit).

Cyanoacrylate Adhesives (Crazy Glue’ or Super Glue’) are also easily applied and offer extremely fast cure rates. Cyanoacrylates are relatively low viscosity fluids based on acrylic monomers and, when placed between closely fitting surfaces, some will cure to a strong joint in two to three seconds. Cyanoacrylates’ ability to bond plastics and rubbers to themselves or to other substrates are their biggest advantage. On the other hand, cyanoacrylate adhesives exhibit poor impact resistance, are vulnerable to moisture and solvents, and are suitable only for bonding small areas. In addition, they do not fill gaps well, require precise mating of bonded surfaces, and are relatively expensive. They also have poor solvent and water resistance.

Epoxy Adhesives have been available longer than any other engineering adhesive and are the most widely used structural adhesive. Epoxy adhesives are thermosetting resins which solidify by polymerization and, once set, will soften but not melt on heating. Two-part resin/hardener systems will solidify on mixing (sometimes accelerated by heat), while one-part materials require heat to initiate the reaction of a latent catalyst. Epoxies offer very high shear strengths, and can be modified to meet a wide variety of bonding needs. Generally, epoxy bonds are rigid; they fill gaps well with little shrinkage.

Hot Melt Adhesives have moved out of their traditional applications into areas of low-stress product assemblies. They form flexible and rigid bonds, achieve 80% of their bond strength within seconds, bond permeable and impermeable materials, and usually require no elaborate surface preparation. Hot melts are insensitive to moisture and many solvents, but they soften at high temperatures.

Methacrylate Adhesives provide a unique balance of high tensile, shear, and peel strengths with the maximum resistance to shock, stress, and impact across a wide temperature range. Methacrylates can generally be used without surface preparation when joining plastics or metals. They are two-component reactive materials based on methyl methacrylate monomer that, when mixed together, have a controlled cure speed based on the appropriate application process. Methacrylates are tolerant to off-ratio mixing and remain strong and durable under severe environmental conditions. They resist water and solvents to form an impenetrable bond.

Polyurethane Adhesives are named after the polymer type formed on completion of the reaction. The adhesives are usually two-component, one side is always isocyanate based, the other formulated from one of several coreactants often amines or glycols. They are known for toughness and flexibility even at low temperatures. They have fairly good shear strength and excellent water and humidity resistance.

Adhesives Comparison Chart

Type	Advantages	Limitations
Solvent Cements	<ul style="list-style-type: none"> Low price per gallon Excellent wetting and penetration Many types available for substrates Easily applied to large surfaces Easily sprayed Moderate clamp pressure needed Long shelf life No special equipment required 	<ul style="list-style-type: none"> Usually low strength Poor gap cure Poor creep resistance Shrinkage up to 70% Slow drying time (evaporation) Many must be applied to both surfaces Poor temperature, moisture, and solvent resistance Attack many plastics Flammable Difficult to automate Environmentally unfriendly Expensive on a dried solids basis
Hot Melts	<ul style="list-style-type: none"> Moderately priced Good gap-filling capabilities Rigid to flexible bonds available Versatile formulations Fast setting 	<ul style="list-style-type: none"> Usually low strength Poor wetting Poor creep resistance Usually low solvent resistance Low heat resistance - degrade as heat rises Stringy Parts must be mated before adhesive cools Short part life Messy, can burn workers Requires special dispensing equipment Difficult to automate
Silicones	<ul style="list-style-type: none"> Moderately priced Good gap-filling capabilities Good for bonding glass to most other substrates Excellent sealant for low stress applications Flexible Good water resistance Range of viscosities Good selection of colors Excellent temperature resistance - 	<ul style="list-style-type: none"> Low strength Limited solvent resistance Too flexible for structural loads Slow curing Most need moisture to cure Corrosive One component, short shelf life Give off odors when curing Hard to clean Expensive to automate 400 - 500F

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Adhesives Comparison Chart (continued)

Type	Advantages	Limitations
Urethanes	<ul style="list-style-type: none"> Moderately priced Excellent toughness and flexibility Good flexibility at low temperatures Excellent adhesives for a wide range of materials One- or two-component, room- or heat-cure available Varying cure times 	<ul style="list-style-type: none"> Poor temperature resistance Sensitive to moisture both in cured and uncured state May undergo reversal with heat and moisture Two component mixing or single component toxicity Short pot life Require special equipment to mix and dispense
Epoxies	<ul style="list-style-type: none"> Usually low priced Good gap-filling capabilities High strength; can be filled with metals Wide range of formulations Versatile Good temperature and solvent resistance 	<ul style="list-style-type: none"> Adhesives thin during curing cycles Two component mixing and measuring required Exact proportions needed for optimal strength Single component usually requires refrigeration and heat cure Slow fixturing Short pot life creates waste Special equipment needed to weigh, mix, and dispense
Anaerobics	<ul style="list-style-type: none"> Moderately priced High strength on some substrates Flexible for form-tough bonds Rapid cure at room temperature Good solvent and temperature resistance Versatile Range of viscosities Nontoxic No mixing required Dispenses easily from package 	<ul style="list-style-type: none"> Not recommended for many plastic or rubber substrates Won't cure where air contacts adhesive - wet fillets Primers required for many materials 300 - 400F temperature limitations Generally brittle. Limited gap cure.

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Adhesives Comparison Chart *(concluded)*

Type	Advantages	Limitations
Cyanoacrylates	<ul style="list-style-type: none">Rapid cure at room temperatureSingle component adhesiveExcellent adhesion to rubberGood adhesion to metalHigh tensile strengthNo mixing requiredIndefinite pot lifeDispense easily from package	<ul style="list-style-type: none">Higher pricedLimited gap cureLow solvent resistanceLow temperature resistanceBond skinPoor impact and peel resistance
Methacrylates	<ul style="list-style-type: none">Moderately pricedGood gap cureExcellent impact resistance and flexibilityExcellent peel and shear strengthsSubstrate versatility	<ul style="list-style-type: none">Some odor problemsFlammable

WHY BOND PLASTICS WITH PLEXUS[™] ADHESIVES?

Plexus Adhesives offer significant advantages over other assembly methods.

Plexus Adhesives

vs.

Mechanical Fasteners

Mechanical fasteners are quick and easy to use, but have a number of significant drawbacks.

- (1) They create stresses in the plastic which lead to distortion or cracking. Plexus Adhesives do not.
- (2) Mechanical fasteners are additional components which must be purchased and inventoried. Plexus Adhesives let you avoid additional components.
- (3) Mechanical fasteners require altering the design of the product to include bosses and holes. Bosses can cause sink marks on molded plastic parts; holes can create weak spots and stress risers. Plexus Adhesives require no special features.
- (4) Mechanical fasteners often interfere with the appearance of the product. Plexus Adhesives are invisible inside a bonded joint.
- (5) Mechanical fasteners concentrate all of the holding power at the fastener location, causing the applied load to be carried by a small area. Plexus Adhesives distribute the load evenly over the entire joint area.

Plexus Adhesives

vs.

Ultrasonic Welding

Ultrasonic welding can be an excellent method for certain types of assemblies. There are, however, a number of factors which limit its usefulness.

- (1) Ultrasonic welding is not viable for thermosets. Plexus Adhesives are viable.
- (2) Joining plastics to metal, glass, or other materials by ultrasonic welding is not feasible in most cases. Plexus Adhesives do this easily.

(3) The design of joints is restricted to geometrics which are favorable to the ultrasonic welding process. Ideally, joints should have a small uniform contact area in which the ultrasonic energy can be concentrated. Plexus Adhesives can accommodate irregular bond lines.

(4) With ultrasonic welding, the capability of joining different thermoplastics in the same assembly is limited to those that are chemically compatible and have similar melting points. Plexus Adhesives can be used without such limitations.

(5) Ultrasonic welding requires a significant investment in machinery, as well as special tooling for each part. It can also cause read-through on surfaces that show. Plexus Adhesives require no such machinery or tooling.

Plexus Adhesives
vs.
Solvent Welding

Solvent welding can be a useful, low-cost method of assembling plastics. However, its usefulness is limited by a number of disadvantages.

- (1) Many solvents are flammable or toxic.
- (2) Solvent welding cannot be used with dissimilar materials such as metal or glass. Plexus Adhesives can.
- (3) Solvents will not work with thermoset plastics. Plexus Adhesives will.
- (4) Solvents are more likely to cause stress cracking than Plexus Adhesives.
- (5) The time between the application of the solvent and the joining of parts is critical. Joints are weakened if too much solvent remains in the bond area, or if too much solvent has flashed off prior to assembly. Plexus Adhesives have a much less critical open time.

Plexus Adhesives offer significant advantages over other adhesives.

Plexus Methacrylate Adhesives offer an unmatched combination of speed, ease of use, and overall convenience. They adapt easily to high-speed production lines without special curing ovens.

When total costs of the finished product are considered, Plexus Adhesives are often the most economical means of assembly.

Plexus Adhesives are also faster, easier to use, and more convenient than hot melts, epoxies, urethanes, or solvent cements.

Plexus Adhesives
vs.
Standard Epoxies

When first introduced, epoxies were a major breakthrough in adhesive technology. Their ability to cure at room temperature without excessive shrinkage, combined with versatility of formulation, made them extremely popular. However, they are not the easiest materials to use for several reasons:

- (1) Epoxies are very often rigid and brittle, which limits their effectiveness on plastics.
- (2) The time from mixing to use is often critical to success but is difficult to control, particularly when the production rate is irregular.
- (3) Short pot life often causes material waste.
- (4) Epoxies that require heat curing cannot be used on heat-sensitive plastics.
- (5) Cure times without heating are too long for automated assembly.

Plexus Adhesives
vs.
Hot Melts

Hot melts are low-cost, single-component, fast-setting adhesives. They are often used in bonding packaging components, furniture, or toys. Their limitations are significant, however.

- (1) Hot melts have poor temperature resistance.
- (2) Hot melts require special equipment to melt and dispense.
- (3) Hot melts are messy.
- (4) Control of joint open time is critical to hot melt performance.
- (5) Hot melts may degrade if held in the melted form for extended periods of time.

Plexus Adhesives
vs.
Solvent Cements

Solvent cements are low-cost materials which have traditionally been used to join plastics. Their primary advantage is their low cost. Their limitations are numerous and significant.

- (1) Solvent cements have poor resistance to heat and solvents.
- (2) Solvent cements produce fumes which may be toxic or flammable.
- (3) Open time of the solvent cement bonded joints is critical.
- (4) Solvent cements require long drying times.
- (5) Solvents trapped inside the joint may lead to porosity or weakness.
- (6) Solvent cementing cannot be used to join parts with significant gaps between them. Plexus Adhesives accommodate much larger gaps.

Plexus Adhesives
vs.
Polyurethanes

In recent years, polyurethanes have been the best choice for most plastic bonding applications. Their primary advantages have been user familiarity and flexibility. Their limitations, however, are significant:

- (1) Polyurethanes are toxic, and their use is governed by Federal laws.
- (2) Polyurethanes generally require primers when used on plastics.
- (3) Polyurethanes are very sensitive to mixing.
- (4) Polyurethanes are slow curing.
- (5) Polyurethanes are sensitive to moisture, both in cured and uncured state.

Plexus Methacrylate Adhesives can be reground for plastic recycling.

Concern

Many plastic manufacturers and their customers are now demonstrating a commitment to plastic recovery and reuse programs. However, a serious gap exists between resin manufacturers and the manufacturers of adhesives that are currently used to structurally bond recyclable plastics. While plastics can and are being reground and remanufactured, the intrinsic nature of epoxies, urethanes, and other structural adhesives poses a serious regrind problem. These adhesives and a good portion of the surrounding plastic must be cut out *before* the plastic can be reground. This procedure is labor intensive and generates nonusable waste.

A leading manufacturer of thermoplastics estimates that by the year 2000 global environmental concern will mandate that all products, including adhesives, be designed for recyclability.

Response

As an innovative manufacturer of cost-effective structural adhesives, ITW Adhesives is presently committed to the future of resource recovery. Unlike other adhesives, the unique methacrylate adhesive technology of Plexus Adhesives is more akin to the chemistry of recyclable plastics. As a result, Plexus Adhesives can be reground and remolded with the recycled plastic.

Recycling Benefits

- No need to cut adhesive out of the bonded part.
- Compatibility with many types of thermoplastic regrind reduces concern when separating plastic types.
- Minimal influence on injection and molding parameters of the plastic.
- Minimal or no loss of properties.

THERMOPLASTIC		VIRGIN	REGRIND	REGRIND + ADHESIVES
Tensile Shear Strength (Psi)	PC*/Polyester	7,500	7,300	7,300
	ABS	8,800	8,700	8,300
	TPU**	7,000	6,800	6,600
Melt Index (g/10 min)	PC*/Polyester	15	18	13
	ABS	3.7	4.0	3.7
	TPU**	111	106	110

*PC - Polycarbonate

**TPU - Thermoplastic Polyurethane

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Plexus Adhesive	Mix Ratio	Feature
MA200	10:1	Expanding Adhesive. Nontoxic self-expanding adhesive. Excellent gap filling qualities. Structural bond strength performance. Expands to twice original volume.
MA300	1:1	General-Purpose Adhesive, semi-flexible. Bonds most unprepared common plastics (ABS, PVC, Acrylic), fiber reinforced composites and metals.
MA310	1:1	Chemical-Resistant Adhesive. Bonds nylon, nylon alloys, modified polyesters, standard plastics, and composites. Semi-flexible. Excellent harsh environment durability.
MA320	10:1	High-Performance Plastic Adhesive. Flexible, high impact, high peel, low temperature resistance. Bonds most plastics, FRPs, and gelcoats.
MA330	1:1	Special Plastic Adhesive. Rigid, pigmented version of MA310, excellent sanding and painting characteristics. High chemical and fuel resistance.
MA340	1:1	Flexible Gap-Filling Adhesive. Increased gap-filling capabilities. Bonds nylons, common plastics RIM Ureas and urethanes. Sandable and paintable.
MA440	10:1	Corrosion-Resistant Composite Adhesive. Highly moisture and chemical resistant, low viscosity self-leveling adhesive.
MA550	10:1	Marine Adhesive. Bright white, UV-stable, nonyellowing adhesive with extended open time. Excellent adhesion to unprepared marine gelcoats, FRPs, and plastics. Forms a tough, flexible waterproof bond.
MA1020	10:1	A two-part methacrylate adhesive designed for structural bonding of thermo plastic, metal and composite assemblies. This product is the standard for structural bonding because it requires no surface preparation and exhibits low cure shrinkage. In addition, it provides a unique combination of excellent fatigue endurance, outstanding impact resistance and superior toughness. Recommended for ABS, Acrylic, FRP, Gelcoats, Polyesters, PVC, Urethanes, Styrenics and Viny Esters. Low Odor. Low Shrinkage.
MA1025	10:1	A two-part methacrylate adhesive designed for structural bonding of thermo-plastic, metal and composite assemblies. Designed Recommended for ABS, Acrylic, FRP, Gelcoats, Polyesters, PVC, Urethanes, Styrenics and Viny Esters. Low Odor. Low Shrinkage. This product is the standard for structural bonding in the marine industry because it requires no surface preparation and exhibits low cure shrinkage. It is used for bonding stringers and liners into fiberglass boats with bond lines up to one inch thick.

BONDING TECHNOLOGY

There are more than 4,500 different plastics in use today, with new formulations being developed daily. Different plastics are designed for different processing and application methods, and not all plastics respond to bonding in the same fashion. Difficulties in bonding plastics may arise from either poor compatibility, poor surface wetting, or inactive or inert surfaces. Steps can be taken to overcome any of these problems.

Compatibility

When bonding plastics, care must be taken to prevent stress cracking. Most susceptible are the transparent plastics such as acrylic, polycarbonate, polystyrene, SAN, and polysulfone. Other susceptible plastics include ABS, PPO, and high-impact (non transparent) polystyrene. Plastics resistant to stress cracking include thermosets, acetals, nylons, thermoplastic polyester rigid PVC, polyolefins, polyamide, and PPS.

Stress cracking occurs when adhesives are applied to the surface of stressed plastic parts. Softened and weakened, the plastic's surface cracks, allowing penetration of the liquid adhesive into the part.

Crazing, a mild form of stress cracking, occurs when the cracks stop near the surface of the part. In severe cases, cracks may propagate throughout the entire part, causing failure. Glass fiber-filled plastics are more resistant to damage.

Poor Surface Wetting

Adhesives usually exhibit excellent wetting on clean metal surfaces, because their surface tension is lower than that of the metal. In the case of some plastics, however, the surface tension of the surface may be so low that the adhesive will not wet or spread. These plastics may cause the adhesive to "bead up" like rain on a new wax job. Poor bonds which result from this condition may be improved by one of the following surface treatments:

Solvent Cleaning

Wiping the surface with a solvent will often remove dirt, oil, leftover mold release agents, or other contaminants. 1. 1. 1. Trichloroethane can be used for thermosets, nylon, acetals, and other chemically resistant plastics. Isopropyl alcohol or other mild solvents should be used on acrylics, styrene, polycarbonate, and similar plastics. A suggested cleaning solvent for each plastic is listed in the Bonding Recommendations Section.

Abrasion *Abrading* the surface of plastic parts can remove weak surface layers and, at the same time, increase surface roughness - in many cases improving bond quality. The most effective form of abrasion is gritblasting to a fine matte surface. Sandpaper and emery cloth are also effective to a lesser degree.

Flame Treating *Flame treating* is useful for improving adhesion to polyethylene, polypropylene, acetals, and thermoplastic polyesters. Flame treating is accomplished by holding the surface of the part in the outer portion of a gas flame for a few seconds. The surface will change from glossy to dull, indicating it is ready for bonding.

JOINT DESIGN

INTRODUCTION This section discusses terms and concepts related to joint design. It is divided into four topics: Types of Joints, Types of Stresses, Joint Stress Distribution, and Design Guidelines.

An understanding of the following terms will be helpful in our discussion of different types of joints.

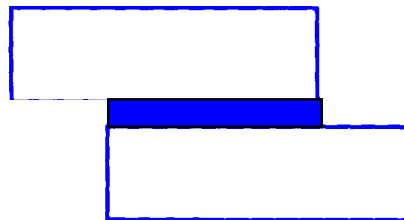
Joint A joint is the location where an adhesive joins two substrates.

Joint Geometry Joint geometry refers to the general shape of an adhesive bond. Joint geometries are described in general terms such as long and narrow, short and wide, thick or thin.

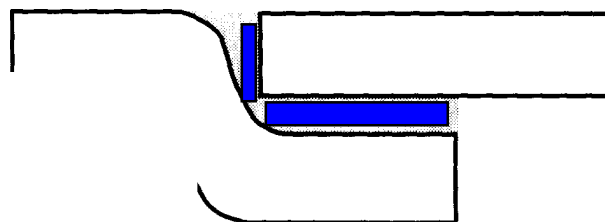
Types of Joints

Joint design often affects bond strength. Aesthetics are also a consideration. Typical joint designs include:

Lap/Overlap Joint A lap joint, also called an overlap joint, is formed by placing

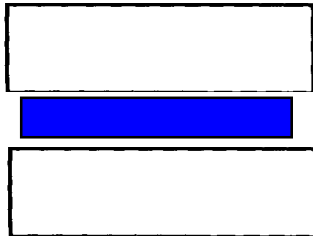


Joggle Lap Joint A joggle lap joint is an offset joint very similar to the lap joint.



Butt Joint

A butt joint is formed by bonding two objects end to end

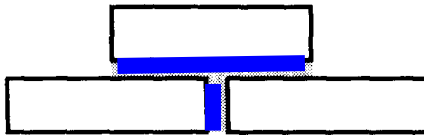
**Scarf Joint**

A scarf joint is an angular butt joint. Cutting the joint at an angle increases the surface area.

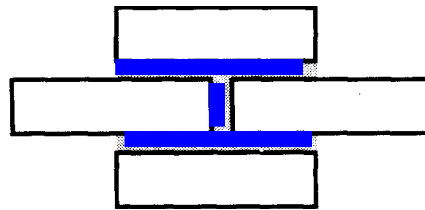
**Strap Joint**

(Single or Double)

A strap joint is a combination overlap joint with a butt joint.



Single Strap Joint



Double Strap Joint

Cylindrical Joint

A cylindrical joint uses a butt joint to join two cylindrical objects.



Types of Stresses

Stress

Stress is a force applied to a bond, usually expressed in Newton's per square meter, or Pascals. Stress, in the English system, is expressed in pounds per square inch (psi).

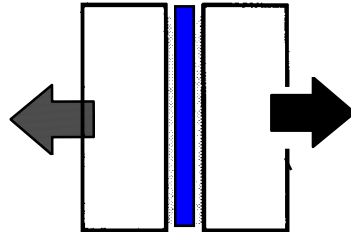
Several types of stresses commonly found in adhesive bonds include:

Impact Stress

Impact stress occurs when a sudden force or shock is applied to a joint.

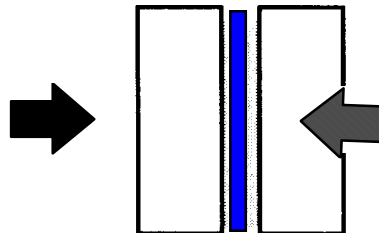
Tensile Stress

Tensile stress tends to pull an object apart. It also tends to elongate an object

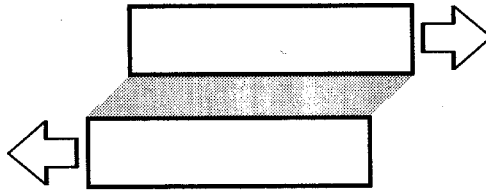


Compressive Stress

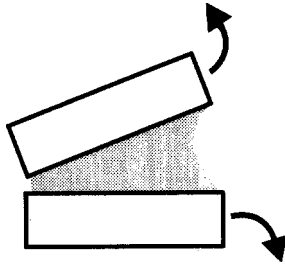
The opposite of tensile stress, compressive stress tends to squeeze an object together.



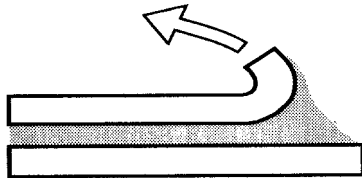
Shear Stress Shear stress is created by two surfaces sliding over one another.



Cleavage Stress Cleavage stress occurs when a joint is being opened at one end.



Peel Stress Peel stress occurs when a flexible substrate is being lifted or peeled from the other substrate.

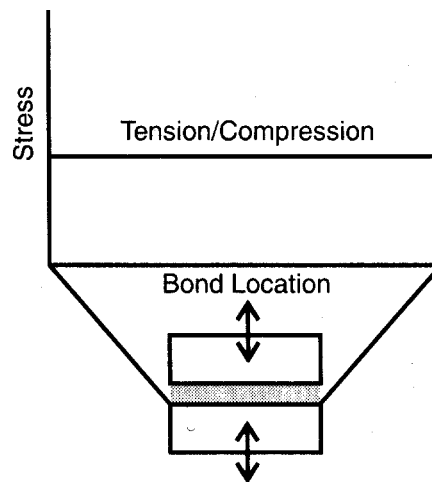


Joint Stress Distribution

Joint stress distribution is the location of stresses within a bond.

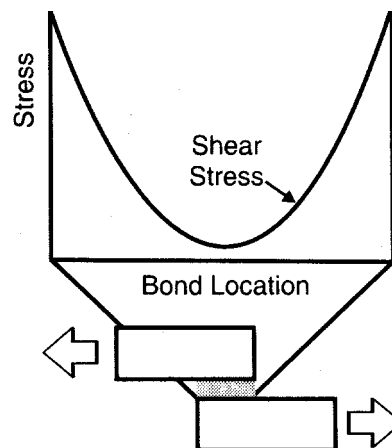
Tension and Stress Distribution Compression

When a bond experiences either tensile or compressive stress, the joint stress distribution is illustrated as a straight line. The stress is evenly distributed across the entire bond.



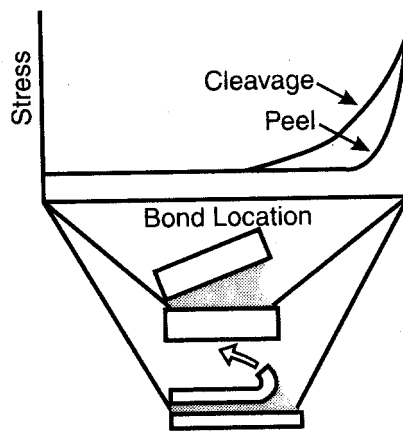
Shear Stress Distribution

Shear stresses are distributed across the bond in an entirely different way. The ends of the bond resist a greater amount of stress than the middle of the bond does.



Cleavage and Peel Stress Distribution

When cleavage or peel stress is applied to a joint, most of the stress is concentrated at one end.



Design Guidelines

Engineers must have a good understanding of how stress is distributed across a joint when force is applied to it. Several design guidelines should be considered when designing an adhesive joint.

(1) Maximize Shear/Minimize Peel and Cleavage

Note, from the Cleavage and Peel Stress Distribution Curve, that bonds do not resist stress very well. The stress is located at one end of the bond line, whereas, in the case of shear, both ends of the bond resist the stress.

(2) Maximize Compression/Minimize Tensile

Note, from the Tension and Compression Stress Distribution Curve, that stress is uniformly distributed across the bond. In most adhesive films, the compressive strength is greater than the tensile strength. An adhesive joint is less likely to fail under a compressive force than under tension.

(3) Joint Width Is More Important than Overlap Length

Note, from the Shear Stress Distribution Curve, that the ends of the bond resist a greater amount of stress than the middle of the bond does. If the width of the bond is increased, the bond area at each end also increases, producing a stronger joint.

In this same overlap joint, if the overlapping length is greatly increased, there is little, if any, change in the bond strength because the contribution of the ends is not increased. The geometry of the ends has not changed, thus their contribution to the bond strength has not changed.

As a general rule, increase the joint width rather than the overlap length.

SURFACE PREPARATION

INTRODUCTION

Surfaces can be prepared for bonding by one of three general methods:

- Abrasion
- Cleaning
- Conversion

Abrasion

Abrasive methods of preparing a surface require that the surface be rubbed or struck with a hard, coarse material. The two most common types of abrasion preparation are *brushing* and *blasting*.

Brushing

In a *brushing* operation, a coarse, stiff brush is used to rub the surface of a material.

Blasting

Blasting or *shot blasting* is used when cleaning a large surface area, or when considerable material must be cut away as the small, sharp pieces of the blast medium impact the surface.

Cleaning

The two most common general types of cleaning are *solvent cleaning* and *chemical cleaning*.

Solvent Cleaning

In *solvent cleaning*, a solvent is applied to a surface to dissolve the contaminate material. This can be accomplished by any of the following methods:

- Solvent Dip
- Solvent Wipe
- Vapor Degreasing
- Ultrasonic Cleaning

Solvent cleaning methods tend to be more mild than the chemical cleaning methods.

Solvent Dip

In a *solvent dipping* operation, the object to be cleaned is immersed in a container of solvent which dissolves and carries away the surface contaminants.

This method is commonly used for oil- and grease-coated parts. A drawback of this method is that the solvent becomes contaminated.

Solvent Wipe

Solvent wiping consists of using a solvent-soaked material to wipe the surface of a part until it is clean and contaminants are removed.

This method is very simple, economical, and widely used. One drawback of using this method is the contamination of the wipe rag.

Vapor Degreasing

The *vapor degreasing* method of cleaning is usually used for parts which have crevices or intricate surface details which may be difficult to clean with a rag.

In vapor degreasing, a solvent is heated so the vapor comes in contact with the part to be cleaned. The vapor condenses on the part and the liquid which forms runs over the part, carrying the oil and grease back to a basin. The oil and grease settle to the bottom of the degreaser and the solvent is revaporized to repeat the process.

Proper ventilation is essential when using a vapor degreaser.

Ultrasonic Cleaning

In *ultrasonic cleaning*, high-frequency sound waves are used to vibrate dirt away.

The part is immersed in a solvent which is vibrated by high frequency sound waves.

Chemical Cleaning

More severe than solvent cleaning, chemical cleaning removes contaminants from a surface by means of harsh chemicals. Chemical methods include:

- Hot Alkaline Cleaning
- Pickling
- Etching

Hot Alkaline Cleaning

Hot alkaline cleaning is the washing of a part in a hot soap or detergent solution. Strong detergent is required to remove oil and grease from a part. In most cases, a part which has been cleaned by the hot alkaline method must be rinsed and dried before an adhesive is applied.

When parts are to be stored before additional processing, hot alkaline cleaning is often followed by the application of a rust preventative.

Pickling

Cleaning a part by *pickling* is done by applying chemicals to dissolve surface oxides. Pickling solutions remove only the surface contaminants without effecting the base material.

Etching

When a surface is being *etched*, a chemical solution removes both the oxides and part of the underlying surface.

The difference between etching and pickling is a matter of severity. Pickling removes *only* the surface oxides, whereas etching removes both surface oxides and part of the underlying surface.

Conversion

Surface cleaning through a *conversion* process changes the original surface into a new material. The three types of conversion processes include *phosphating*, *chromating*, and *anodizing*.

Phosphating

Phosphating is a process in which a crystalline film is produced on a metal surface by a phosphoric acid solution to increase the corrosion resistance and the adhesion of the surface. It is effective for most adhesives.

When the part is dipped or sprayed with a phosphoric acid solution, a small portion of the metal surface dissolves and a layer of zinc phosphate or iron phosphate crystals is formed on the surface.

Chromating

Chromating is a process in which a noncrystalline film is produced on a metal surface by a chromic acid solution.

Like phosphating, chromating reduces corrosion and increases the adhesion of most adhesives.

Anodizing

Anodizing is a process used on aluminum surfaces in which a protective oxide is electrolytically applied. Anodizing is used on aluminum surfaces *only*, not on any other metals.

Spraying vs. Immersion

Differences between spray and *immersion* treatments are:

SPRAYING	IMMERSION
Smaller volumes	Larger volumes
Most shapes	Submersible shapes
Requires more plumbing	Requires less plumbing
More energy to operate	Less energy to operate

PLASTIC GUIDE

AND

BONDING RECOMMENDATIONS

THERMOPLASTICS

Thermoplastics soften when heated above glass transition temperatures and can be reworked or reshaped.

Acetal (POM) polyoxymethylene - available in homopolymer and copolymer grades. Strong, tough, chemical-resistant plastic typically used in plumbing valves, appliance parts, toys, and automotive hardware for applications that are subject to wear and mechanical stress.

Bonding Techniques: It is extremely difficult to achieve true adhesion to acetals because of their chemical inertness. Bond strength is achieved primarily by mechanical keying to surface irregularities. Strength can be increased by abrasion or flame treating.

Recommended Plexus Adhesives: MA310,MA330

Acrylic Polymethyl Methacrylate (PMMA). Acrylic plastics are lightweight, rigid, transparent materials that are tough and dimensionally stable. They can be easily fabricated and typically are used in windows, signs, lighting fixtures, decorative furniture, and packaging.

Bonding Techniques: Acrylics can be easily bonded with many different types of adhesives and chemicals.

Recommended Plexus Adhesives: All methacrylate adhesives will structurally bond PMMA and will outperform the plastic they are bonding.

Cellulosics (CAL,CAB,CAP) - Cellulosics are tough, moderate-cost plastics with good clarity and strength. They are typically used for toys, tools, packaging, and home furnishings.

Bonding Techniques: Cellulosics may have a slight acid residue on the surface. This can be neutralized with a weak basic solution of bicarbonate or ammonia. Abrading may be needed to improve adhesion.

Recommended Plexus Adhesives: MA310,MA320,MA330

Fluoroplastics

A class of polymers with a fluorinated backbone structure, fluoroplastics include:

- Polytetrafluoroethylene (PTFE)
- Fluorinated ethylene propylene (FEP)
- Perfluoroalkoxy resin (PFA)
- Polychlorotrifluoroethylene (PCTFE)
- Ethylene chlorotrifluoroethylene copolymer (ECTFE)
- Ethylene tetrafluoroethylene copolymer (ETFE)
- Polyvinylidene fluoride (PVDF)

Bonding Techniques: Most fluoroplastics are highly resistant to adhesive and chemical bonding due to their low polarity which inhibits surface wetting. A primer or etching material should be used to enhance bond strength. PFA, PCTFE, ECTFE, and PVDF may be relatively easily bonded with Plexus™ Adhesives.

Recommended Plexus™ Adhesives: Call our Adhesives Technical Service Department for information.

Ketone-Based Resins

Member resins can be used at high temperatures, have excellent chemical resistance, high strength, and good resistance to burning. Polyetherether Ketone (PEEK) is the most common commercially available Ketone. Typical areas of use are electrical wire and cable housings, appliance components, medical prostheses, and aircraft interiors.

Bonding Techniques: Due to their inherent toughness, Ketone based plastics may require some surface preparation prior to bonding. Slight abrasion will increase adhesive bond strength.

Recommended Plexus™ Adhesives: MA310, MA320, MA330

Nitrile

A polymer resin which provides good gas barrier, chemical resistance, and taste and odor retention properties. These resins, have moderately high tensile properties and good impact resistance. They are used principally in the packaging of food other than beverages.

Bonding Techniques: Nitrile thermoplastics do not generally require bonding.

Recommended Plexus™ Adhesives: Call our Adhesives Technical Service Department.

Nylon

Polyamides offer a combination of properties that includes high strength at elevated temperatures, toughness at low temperatures, stiffness, wear and abrasion resistance, and good chemical resistance. Nylons are available in four general classifications:

Nylon 6: Polymerized by reactions of ring compounds that contain both acid and amine groups on the monomer.

Nylon 6/6: Polymerized by reaction of a dibasic acid and a diamine.

Nylon 10 and 11: More flexible nylon polymers.

Nylon 6 and 6/6: Constitute the bulk of domestic production largely because they offer the most favorable combination of price, properties, and processability.

Bonding Techniques: Although a solvent wipe or slight abrasion will increase bond properties, most grades of Nylon 6 and Nylon 6/6 can be structurally bonded as is with Plexus Methacrylate MA310.

Recommended Plexus™ Adhesives: **MA310,MA330**

Polyamideimides (PAIS) High-temperature engineering plastics produced primarily by condensation. These materials are characterized by superior mechanical properties at temperatures up to 500°F, good dimensional stability, and good creep, impact, and chemical resistance. They are used in aerospace, transportation, chemical processing, and electrical industries.

Bonding Techniques: Abrasion is necessary to achieve a good structural bond.

Recommended Plexus™ Adhesives: Call 1-800-323-5158 for recommendations.

Polyarylate

This resin class is heat-resistant with excellent toughness, UV stability, flexural recovery, dimensional stability, flame retardance, and electrical properties. Polyarylates are used in automotive applications such as headlight housings, exterior trims, and door handles. They are also found in safety equipment, electrical housings and covers, and exterior applications.

Bonding Techniques: Polyarylate polymers, when blended with polyesters, may be structurally bonded as is with methacrylate adhesives.

Recommended Plexus Adhesives: MA310,MA320,MA330

Polybutylene (PB)

Resins that are semi-crystalline polyolefin thermoplastics based on poly and homopolymers and a series of poly copolymers. Major applications include pipe, packaging, blow molded vessels, and hot melt adhesives and sealants. The largest current market for PB is in pipe applications, including hot and cold plumbing.

Bonding Techniques: PB resins require a solvent wipe, primer, and abrasion to achieve a good bond.

Recommended Plexus Adhesives: Call our Adhesives Technical Service Department.

Polycarbonate (PC)

Polycarbonates offer an excellent balance of toughness, clarity, and high heat deflection temperatures. Major applications generally require at least two of these properties. New applications for PC or blends have resulted from the replacement of traditional materials such as wood, metal, and glass. Major market segments where PC has a broad range of applications are automotive, electronics, business machines, lighting, and appliances.

Bonding Techniques: PCs are generally bondable as is. Because of surface sensitivity, products that contain solvents may cause stress cracking and should be avoided. All adhesives should be tested on stressed parts.

Recommended Plexus Adhesives: MA200, MA320, 3940

Polyester Thermoplastic

Polybutylene terephthalate (PBT), polyethylene terephthalate (PET), and blends can replace such materials as ceramics, metals, composites, and other plastics because of their outstanding strength at extreme temperatures and resistance to most chemicals, weathering, radiation, and burning. These materials are suitable for electrical components, electronic devices, and chemical processing equipment, as well as for parts for the aerospace, transportation, appliance, and safety industries.

Bonding Techniques: Polyester thermoplastics and their alloys and blends can be bonded with minimal surface preparation.

Recommended Plexus Adhesives: All Plexus methacrylates will structurally bond to these resins and alloys. Call 1-800-323-5158 for specific recommendation.

Polyethylene (PE)

PEs are characterized by good chemical resistance, toughness, flexibility, good barrier properties, and low cost. Typical applications include packaging, housewares, and wire and cable coatings. PE densities vary as follows:

- Ultra low density (ULDPE)
- Linear low density (LLDPE)
- High molecular weight, high density (HMW-HDPE)
- Ultra high molecular weight (UHMW-PE)

Bonding Techniques: Because of their nonpolar nature, these plastics require an oxidation treatment using flames, plasma, or chemical etching to enhance adhesive bond.

Recommended Plexus Adhesives: Priming is necessary, using oxidation treatment. Best results using MA310 or MA320.

Polyphenylene Oxide (PPO)

Modified PPO alloys are tough, impact-resistant, and dimensionally stable plastics that have good electrical properties and are moderate in cost. Applications for blends and alloys include internal automotive parts and components (instrument panels, seat backs, rear spoilers, and wheel covers), telecommunications, business machines, and appliances.

Bonding Techniques: Modified PPO alloys can be bonded with Plexus methacrylates as is.

Recommended Plexus Adhesives: MA310, MA320, MA340

Polyphenylene Sulfide (PPS)

PPS offers an excellent balance of high-temperature resistance, chemical resistance, low flammability, dimensional stability, and electrical properties. The material can be filled with reinforcing fibers and filler for injection molding. The primary use of PPS is electrical components and connectors.

Bonding Techniques: PPS is very inert. Bond strength is achieved primarily through keying to surface imperfections. Most bonding applications will require an abrasion to enhance bond strength.

Recommended Plexus Adhesives: MA310, MA330

Polypropylene (PP)

PP is characterized by low cost, good heat resistance, chemical resistance, and good mechanical strength. Typical applications include housewares, packaging, medical disposables, and transportation.

Bonding Techniques: As with all polyolefins, a pretreatment of the surface is necessary to increase adhesion.

Recommended Plexus Adhesives: Call our Adhesives Technical Service for appropriate adhesive and surface treatment.

Styrenic Resins

Plastics based on styrene resins have high heat-deflection temperatures, are hard and rigid, and have good dimensional stability. High-impact grades are available. Major applications are packaging, appliances, transportation, furniture, and housewares. Styrene-containing thermoplastics include:

- ABS (acrylonitrile, butadiene, and styrene)
- ACS (acrylonitrile, chlorinated polyethylene, styrene)
- ASA (acrylic- styrene-acrylonitrile terpolymers)
- PS (polystyrene)
- SAN (styrene-acrylonitrile)

Bonding Techniques: Plexus methacrylates will generally produce strong bonds on styrenics without surface preparation.

Recommended Plexus Adhesives: MA200, MA300, MA310, MA320, MA330, MA550

Sulfone-Based Resins

Polysulfone is a transparent, heat-resistant, ultra-stable, high performance engineering thermoplastic. It has low flammability, smoke emission, and rigidity at high temperatures. Typical applications include food handling equipment, coil bobbins, and chemical processing equipment.

Bonding Techniques: Polysulfones are easily stress cracked by solvent-based adhesives which should be avoided. Plexus methacrylates will structurally bond unprepared surfaces.

Recommended Plexus Adhesives: MA300, MA320, MA550

Thermoplastic Elastomers (TPE)

TPE materials combine the processability of thermoplastic with the performance properties of thermoset rubber. TPE's advantages over rubber include: little or no compounding, simpler processing, shorter processing times, lower energy consumption, recyclability of scrap, lower density, and compatibility with common plastic processing methods such as blow molding and thermoforming. There are five generic classes of TPEs:

- Styrenic block copolymers
- Polyolefin blends (TPOs)
- Elastomeric alloys
- Thermoplastic polyurethanes (TPUs)
- Thermoplastic polyamides

Applications include nontire automotive, major and small appliances, building construction, and electrical insulations.

Bonding Techniques: Thermoplastic elastomers vary in their bondability due to the different alloy mixtures that may occur.

Recommended Plexus Adhesives: MA320. For specific application recommendations call 1-800-323-5158

Vinyl-Based Resins

Polyvinyl chloride (PVC) is the most versatile of all plastics because of its blending compatibility with plasticizers, stabilizers, and other additives. It can be used to manufacture products ranging from heavy-walled pressure pipe to thin, crystal-clear food packaging; or from house siding to surgical gloves. Vinyl-based resins consist of three types: suspension, dispersion, and chlorinated.

Bonding Techniques: Rigid and flexible, PVC can be bonded with little or no surface preparation using many solvent-based products. Due to recent legislation, however, solvents used in PVC bonding are being phased out. Many of today's adhesives will bond PVC, but the resulting bond is generally brittle or weak. PVC can also be bonded using methacrylates to achieve a flexible structural bond.

Recommended Plexus Adhesives: All Plexus Methacrylate Adhesives will structurally bond these resins.

THERMOSETS

Thermosetting resins solidify when cured by mixing and/or heating and, once cured, cannot be remelted or remolded.

Allyl

The most widely used commercial allyls are the monomers and prepolymers of diallyl phthalate and diallyl isophthalate and are readily converted into thermoset molding compounds and preimpregnated cloths. These resins retain their electrical properties under high temperature and humidity. Moldings are characterized by dimensional stability, chemical resistance, mechanical strength, and heat resistance. Applications for allyls generally include electrical and electronics.

Bonding Techniques: Allyls require a solvent cleaning or abrasion to improve bond strength.

Recommended Plexus Adhesives: Testing of the particular allyl is necessary for specific Plexus methacrylate recommendations.

Bismaleimides (BMI)

BMI's are a high-temperature resistant class of thermosetting polymeric materials and are often processed into prepregs, which can be further processed into composite structures.

Original large scale use of BMI's was in printed circuit boards.

They are now found in many high-performance structural composites used in the aerospace industry.

Bonding Techniques: For a specific application recommendation, call 1-800-323-5158

Recommended Plexus Adhesives: BMI's are bonded by all Plexus Adhesive products. Testing of the particular BMI is necessary for specific Plexus' methacrylate recommendations.

Epoxy

Epoxy's consist of a variety of crosslinking materials that contain the epoxy or oxyrane group. The epoxy group is reactive to a wide range of curing agents or hardeners. Curing can take place at room temperature or at elevated temperatures. The inherent properties of epoxy resins include: good adhesion to many substrates, low shrinkage, high electrical resistivity, good corrosion resistance, and good thermal properties. These properties make epoxy resins useful in many applications, including adhesives, laminating, potting, and composite matrices.

Bonding Techniques: Epoxy's are generally easily bonded with many different chemical adhesives. Adhesion can be improved by abrasion.

Recommended Plexus Adhesives: Epoxy's are bonded by all Plexus Adhesive products. For a specific application recommendation, call 1-800-323-5158

Phenolic

Phenolic resin, the reaction product of phenol and formaldehyde, is a heat-cured thermoset. The crosslinked structure formed by the reaction is the source of its excellent properties. Phenolics are best used in applications calling for heat resistance, dimensional stability, creep resistance, and tight dimensional tolerances. They are available in two classes: general-purpose, widely used in high-temperature electricals, such as ovens, toasters, and wiring devices; and engineering phenolics, typically used in areas where strength, wear, hardness, electrical properties, and impact resistance are required.

Bonding Techniques: Phenolics can be bonded as is or by solvent wiping and abrading to enhance bond.

Recommended Plexus™ Adhesives: All Plexus Methacrylate Adhesives will structurally bond phenolics.

Polyester

Unsaturated polyesters are extremely versatile. They can be rigid, resilient, flexible, or flame-retardant. They can be unfilled, filled, reinforced, or pigmented. They are widely used in applications as diverse as boats, shower stalls, recreational vehicles, automotive exterior parts, appliances, cultured marble, corrosion-resistant tanks, furniture, and bowling balls. Thermoset polyesters can be formulated in the following ways:

- **FRP** *Fiber Reinforced Plastic.* Often referred to as FRP fiber reinforced thermoset polyesters can be processed by a lay-up method, compression, resin transfer, injection molding, filament winding, continuous processing, or pultrusion methods.
- **SMC** *Sheet Molding Compound.* Resin, glass fiber, filler, thickener, mold release, pigment, and catalyst are combined and compression molded into panels or sheets.
- **BMC** *Bulk Molding Compound.* Dough-like materials that are prepared with a sigma blade mixer and are compression molded into large and small parts.

Bonding Techniques: Polyester thermosets can generally be bonded *as is* although some adhesive products in use today require a primer. Adhesion can be increased by solvent wiping or abrasion, although abrasion will weaken the substrate.

Recommended Plexus™ Adhesives: FRPs can be bonded as is with MA200, MA310, MA320, MA330, A0420, and MA550.

Polyurethanes (PUR)

Polyurethane has become a generic name for plastics which use polyisocyanates. The term *polyurethane* is usually applied to final products used in industry. PURs have great diversity in processing with isocyanate chemistry and polymer backbones to determine physical forms and properties of a finished product. The tailoring of products to fit applications makes it difficult to describe general or average properties. PURs can be processed to be like soft rubber or stiff plastic, blown to soft or hard foams, or reinforced with various fillers and fibers. A typical processing method is reaction injection molding (RIM). RIM urethanes are fast, two-component, mixing-activated plastics and are used to mold large, complex parts at high speed.

Bonding Techniques: Bondability of urethanes will depend on how they have been compounded and processed, but is generally good to excellent with Plexus Methacrylate Adhesives. Additives used to achieve a smooth, paintable surface produce variations in compatibility with adhesives.

Recommended Plexus™ Adhesives: RIM urethanes may be structurally bonded using MA200, MA320, and A0420.

Polyurea

Polyurea is a thermosetting polymer formed by a controlled reaction of formaldehyde with various compounds that contain amino group NH_2 . The application of heat in the presence of acid catalysts converts the material into a hard, infusible product. Molding compounds are formed into rigid electrical and decorative products. They can also be filled to add strength, improve dimensional stability, and reduce molded-in stresses. Primary applications for filled urea molding compounds are molded dinnerware, ashtrays, razor housings, appliance components, lavatory bowls, and toilet seats.

Recommended Plexus™ Adhesives: MA310, MA320

Alloys and Blends

These performance plastics are ideal candidates to replace such traditional materials as metal, glass, and wood. Because their properties can be tailored to specific applications, alloys and blends can be developed to meet design goals. These new engineered plastics are now being used significantly in the automotive, electronics, and appliance industries.

Recommended Plexus™ Adhesives: Testing of the particular alloy or blend is necessary for specific Plexus methacrylate recommendations call 1-800-323-5158.

Hierarchy of Plastics

Plastics Group

Typical Members

THERMOPLASTICS:

Commodity:	Low density polyethylene (LDPE) Polypropylene homopolymer (PP) Crystal polystyrene (PS) Rigid Polyvinyl Chloride (PVC)
Intermediate:	Polymethyl Methacrylate (PMMA) Acrylonitrile-butadiene-styrene terpolymer (ABS) Cellulose acetate butyrate (CAB) Thermoplastic olefin elastomer (TPO)
Engineering:	Acetal (Polyoxymethylene) Nylon-6/6, 30% glass fiber Polycarbonate (PC) Polyphenylene sulfide (PPS)
Advanced:	Liquid-crystal polymer Polytetraflouroethylene (PTFE) Polyetheretherketone (PEEK) Polyethersulfone (PES)

THERMOSETS:

Alkyd polyester
Epoxy, general-purpose
Phenolic, general-purpose
Urea-formaldehyde, black

Common Alloys and Blends

All listed Trade Names are ® Registered

Alloy or Blend	Trade Name	Supplier	Key Properties
ABS/PC	Triax 2000	Monsanto	Heat resistance, processability, low temperature/impact resistance.
	Pulse	Dow	
	Bayblend	Mobay	
Acetal/ elastomer	Delrin	DuPont	Stiffness, toughness, fatigue, wear.
ASA/PC	Duraloy	Celanese	
	GX 200	GE Plastics	Impact resistance, thermal stability, weatherability.
	Terblends	BASF	
Nylon/ABS	Triax 1000	Monsanto	Heat and chemical resistance, good flow, low cost, low temperature/impact resistance.
Nylon/elastomers	Zytel ST	DuPont	Improved toughness and fatigue resistance, chemical and heat resistance.
	Nylon 7000	Celanese	
	Capron	Allied	
	Grilon	EMS-American Grilon	
Nylon/PE PC/PBT	Selar RB	DuPont	Heat/chemical resistance. High impact resistance and modulus over a wide temperature range.
	Xenoy	GE Plastics	
PC/PET	Makroblend	Mobay	Low temperature/impact/chemical/UV resistance.
PC/TPU	Texin	Mobay	Stiffness, wear, low temperature/impact resistance.
PEEK/PES	Victrex	ICI	High HDT, low cost, impact resistance.
PET/PBT	Valox	GE Plastics	Heat resistance, fast molding, low cost.
	El Series	Thermofil	
	Celanex	Celanese	
Polyester/ elastomer	Rynite SST	DuPont	Stiffness, toughness, high temperature/solvent resistance.
	Valox VCT	GE Plastics	
	Duraloy	Celanese	
	Pocan	Mobay	

Common Alloys and Blends (Continued)

Alloy or Blend	Trade Name	Supplier	Key Properties
Polysulfone/ABS	Mindel	Amoco	Heat resistance, can be plated, low cost.
PPO/Nylon	Noryl GTX	GE Plastics	High temperature/chemical resistance, low moisture absorption, dimensional stability.
PPO/PBT	Gemax	GE Plastics	High temperature resistance, dimensional stability.
PPO/Ps	Noryl	GE Plastics	Heat resistance, toughness, improved processing, low cost, low moisture absorption.
SAM/ABS	Cadon	Monsanto	Heat/impact resistance, low cost.
TPE alloy	Bexloy V	DuPont	Tailored stiffness, impact strength, control shrinkage.

Brand Name/Generic Plastic Index

All listed brands are ®Registered

Brand Name	Generic Plastic	Manufacturer
Absafil	ABS (Glass-Reinforced)	Akzo Engineering
Acrylafil	Styrene-Acrylonitrile	Akzo
Acrylite	Acrylic, Thermoplastic	Cyro
Adell	Polyamide (Nylon)	Adell
Adell Er	Polypropylene	Adell
Akulon	Polyamide	Schulman
Alathon	Polyethylene	DuPont
Algoflon	PTFE	Ausimont
Alpha	Vinyl	Dexter
Apci	Vinyl	Air Products
Aropol	Polyester, Thermoset	Ashland
Ashlene	Polyamide (Nylon)	Ashley
Aspect	Polyester, Thermoplastic (TPE's)	Phillips
Astryon	Polypropylene	Himont
Bakelite	Polyethylene	Union Carbide
Boltaron	Vinyl	Gen Corp.
Calibre	Polycarbonate	Dow
Capron	Polyamide (Nylon)	Allied Signal
Celanex	Polyester, Thermoplastic (PBT)	Hoechst Celanese
Celcon	Acetal	Hoechst Celanese
Chevron	Polyethylene	Chevron
CR	Polyamide (Nylon)	Custom Resins
Cycolac	ABS	GE Plastics
Cyglas	Polyester, Thermoset	American Cyanamid
Deirin	Acetal (Homopolymer)	DuPont
Duraflex	Polybutylene	Shell
Dural	Vinyl	Dexter
Durez	Alkyd Molding Compound	Occidental
Durez	Phenolic Molding Compound	Occidental
Dylene	Polystyrene	Arco
Dylite	Polystyrene	Arco
Ektra	Polyester, Thermoplastic (TPE's)	Eastman
Empec	Polyethylene	Monmouth
Empec	Polypropylene	Monmouth
Escorene	Polyethylene	Exxon
Escorene	Polypropylene	Exxon
Estane	Polyurethane	Goodrich
Ethofil	Polyethylene (Glass-Fiber Reinforced)	Akzo

Brand Name/Generic Plastic Index (Continued)**All listed brands are ® Registered**

Brand Name	Generic Plastic	Manufacturer
Fiberfil	Polyester, Thermoplastic (PBT)	Akzo
Fiberite	Phenolic Molding Compound	ICI Fiberite
Fina	Polypropylene	Fina
Fluon	PTFE	ICI
Formaidafil	Acetal	Akzo Engineering
Fortiflex	Polyethylene	Soltex
Fortilene	Polypropylene	Soltex
Fortron	Polyphenylene Sulfide	Hoechst Celanese
Geon	Vinyl	Goodrich
Glaskyd	Alkyd Molding Compound	American Cyanide
Grilon	Polyamide (Nylon)	EMS
Haysite	Polyester, Thermoset	Haysite
Hazar	PE-CTFE	Ausimont
Hetron	Polyester, Thermoset	Ashland
Higlass	Polypropylene	Himont
Hostaflon	PTFE	Hoechst Celanese
Hostalen	Polyethylene	Hoechst Celanese
Hostyren	Polystyrene	Hoechst Celanese
Huntsman	Polypropylene	Huntsman
Impet	Polyester, Thermoplastic (PBT)	Hoechst Celanese
Kohinor	Vinyl	Pantasote
Lexan	Polycarbonate	GE Plastics
Lucite	Acrylic, Thermoplastic	DuPont
Lustran	ABS	Monsanto
Lustran	Styrene-acrylonitrile	Monsanto
Maclin	Vinyl	Maclin
Magnum	ABS	Dow Plastics
Makrolon	Polycarbonate	Mobay
Maranyl	Polyamide	ICI
Marlex	Polyethylene	Phillips
Marlex	Polypropylene	Phillips
Minde	Sulfane Polymers	Amoco
Noryl	Polyphenylene-Oxide (Modified)	GE Plastics
Nyafil	Polyamide	Akzo
Nycast	Polyamide	Cast Nylons
Nycoa	Polyamide	Nylon Corp.
Nydur	Polyamide	Mobay
Nylatron	Polyamide	Polymer
Oxy	Vinyl	Occidental
Oxyblend	Vinyl	Occidental
Paxon	Polyethylene	Allied Signal
Pellethane	Polyurethane	Dow
Petlon	Polyester, Thermoplastic (PET)	Mobay

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Brand Name/Generic Plastic Index (Continued)

All listed brands are ®Registered

Brand Name	Generic Plastic	Manufacturer
Petra	Polyester, Thermoplastic (PET, Reinforced)	Allied Signal
Petrothene	Polyethylene	Quantum
Petrothene	Polypropylene	Quantum
Plenco	Phenolic Molding Compound	Plastics Engineering
Plexiglass	Acrylic, Thermoplastic	Rohm & Haas
Pliovic	Vinyl	Goodyear
Pocan	Polyester, Thermoplastic (TPEs)	Mobay
Polycarbafil	Polycarbonate (Glass-Fiber Reinforced)	Akzo
Polyfort	Polypropylene	Schulman
Polysar	Polystyrene	Polysar
Prerm-glas	Polyester, Thermoset	Premix
Profil	Polypropylene	Akzo
Radilon	Polyamide	Radilon
Resinoid	Phenolic Molding Compound	Resinoid
Rexene	Polyethylene	Rexene
Rogers RX, FS	Diallyl Plthalate Molding Compound	Rogers
Ryton	Polyphenylene Sulfide	Phillips
SMC	Polyester, Thermoset	BP Chemicals
Styrafil	Polystyrene	Akzo
Styropor	Polystyrene	BASF
Sulfil	Polyphenylene Sulfide	Akzo
Tedur	Polyphenylene Sulfide	Mobay
Teflon	FEP	DuPont
Teflon	PTFE	DuPont
Tefzel	PE-CTFE (Modified)	DuPont
Temprite	Vinyl (PVC)	Goodrich
Tenite	Cellulose Acetate	Eastman
Tenite	Polypropylene	Eastman
Texalon	Polyamide	Texapol
Texin	Polyurethane	Mobay
Thermocomp	Polyamide	ICI Advanced
Thermocomp	Polycarbonate	ICI
Thermofil	Polycarbonate	Thermofil
TMC	Polyester, Thermoset	BP Chemicals
Torlon	Polyamide-imide	Amoco
Udel	Sulfane Polymers	Amoco
Ultem	Polyetherimide	GE Plastics
Ultradur	Polyester, Thermoplastic (TPEs)	BASF
Ultraform	Acetal	BASF
Ultramid	Polyamide	BASF

Brand Name/Generic Plastic Index (Continued)**All listed brands are® Registered**

Brand Name	Generic Plastic	Manufacturer
Valite	Phenolic Molding Compound	Valite
Valox	Polyester, Thermoplastic (PBT)	GE Plastics
Vandac	Polyester, Thermoplastic (PBT Alloy)	Hoechst Celanese
Vandarl	Polyester, Thermoplastic (PBT Alloy)	Hoechst Celanese
Vectra	Polyester, Thermoplastic (LCD)	Hoechst Celanese
Victrex	Peek	ICI
Vista	Vinyl	Vista
Vydyne	Polyamide	Monsanto
Wellamid	Polyamide	Wellman
Xenoy	Polyester, Thermoplastic (PBT/PQ)	GE Plastics
Zytel	Polyamide (Nylon)	DuPont