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The Problem

Plastics have become an intregral part of everyday life. It would be difficult to identify a manufacturing process which does not use plastics in one form or another. Even products which appear to be composed exclusively of metals are usually coated, sealed, or adhesively joined using polymeric materials which improve the performance, appearance, and longevity of the metal products.

Plastics have achieved widespread acceptance due to the virtually limitless combinations of plastic types, fillers, and additives which can be compounded at relatively low costs and processed by a wide variety of methods. This gives plastic producers the ability to tailor their products to the specific needs of manufacturers with great precision. By properly selecting the plastic types, additives, and fillers, as well as blends of different plastic types, the physical, chemical, and thermal properties of a plastic can be made to meet or exceed the performance requirements of almost any application.

However, while the limitless variety of plastics is an invaluable asset to a designer selecting a plastic, it is the designer's biggest limitation when selecting an adhesive. The countless adhesives available, coupled with the virtually limitless grades of plastics available, make it highly unlikely that there will be any specific bond strength data for the specific adhesive/plastic combination in the designer's application. Moreover, every year new grades of plastic are created, and old grades of plastic are dis-continued or reformulated, making the acquisition of comprehensive bond strength data on specific grades virtually impossible.

The Solution

Bond Strength Information

This guide is designed to indicate the bondability of the 34 most commonly used plastic types, without performing the impossible task of actually testing each individual grade. This was accomplished using two basic approaches. For the first approach, 17 of the 34 plastics which were evaluated were compounded specifically to determine the effect different additives and fillers had on the bondability of these plastics. Once the designer identifies the tested formulations containing the same fillers and additives as the particular grade in his design, he can then pinpoint the adhesives which performed the best on that material and will have a general idea of what bond strengths can be achieved. For the other 17 plastics, commercially available grades were selected to represent each major category available based on the major end-use applications of that plastic, the fillers and additives typically used with that plastic, and/or the chemical structure of that plastic. Again, the bond strength information supplied can then be used as an indicator of the bondability of a material.

Adhesive Information

An adhesive cannot be selected for an application solely on the basis of bond strength information. Other factors such as the cure speed, environmental resistance, thermal resistance, and suitability for automation of an adhesive will play a critical role in determining the best adhesive for a specific application. To give a designer insight into these design parameters, an in-depth description of the three adhesive types most commonly used for bonding plastics, namely cyanoacrylates, two-part no-mix acrylics, and light curing acrylics, has been included in this guide. These adhesive sections contain a general description of each adhesive, a detailed discussion of the chemical structure and cure mechanism of each adhesive, and the benefits and limitations of using each adhesive.

Plastic Information

A manufacturer may have the flexibility to select the material which is best suited for the application in terms of performance and bondability. To aid the designer, an in-depth discussion of each of the plastic types is included. Information covered includes a general description of the plastic and its properties, as well as a list of trade names, suppliers, typical applications, and pricing information.

Surface Treatments

Some applications will require the use of plastics which are inherently difficult to bond. In these cases, the use of a surface treatment is necessary to effectively utilize the adhesive. For each individual material, two of the more commonly used surface treatments, surface roughening and polyolefin primers, were evaluated. In addition, the 12 most commonly used surface treatments are briefly described in the Surface Treatments section.

Bond Design Information

Finally, a manufacturer may have a design in which he desires to incorporate an adhesively bonded joint. To effectively design that joint, the designer must know which parameters are critical to the bond strengths achieved by a bonded joint and the effect that changing these parameters will have. A bond design section which reviews the basics of designing an adhesively bonded single lap joint is included in an attempt to give the designer insight into this area. Although most "real world" bond geometries are more complex than single lap joints, this information can be extrapolated as a general indicator of the effects caused by changing bond geometries.

How To Use The Plastic Bonding Chapters

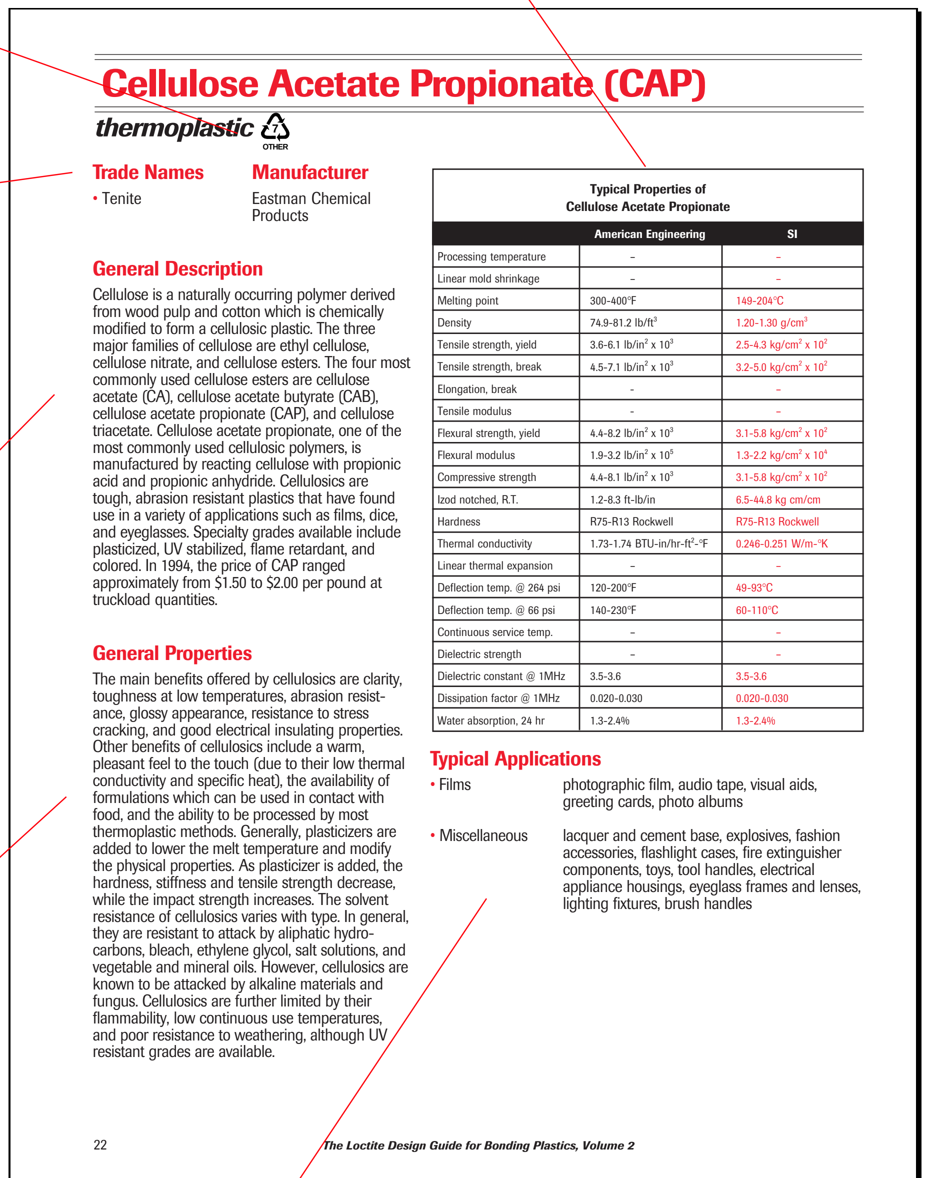
Recycling Symbol
Illustrates the appropriate recycling symbol for the indicated plastic type, when appropriate.

Typical Property Table
Provides data on typical physical properties for each plastic.

Trade Names
Lists common suppliers of each resin and the trade names for their products.

General Description
Provides information concerning the chemical structure, typical cost and types of grades available for each plastic.

General Properties
Describes the key characteristics of the plastic.



Cellulose Acetate Propionate (CAP)

thermoplastic (7 OTHER)

Trade Names
• Tenite

Manufacturer
Eastman Chemical Products

General Description
Cellulose is a naturally occurring polymer derived from wood pulp and cotton which is chemically modified to form a cellulosic plastic. The three major families of cellulose are ethyl cellulose, cellulose nitrate, and cellulose esters. The four most commonly used cellulose esters are cellulose acetate (CA), cellulose acetate butyrate (CAB), cellulose acetate propionate (CAP), and cellulose triacetate. Cellulose acetate propionate, one of the most commonly used cellulosic polymers, is manufactured by reacting cellulose with propionic acid and propionic anhydride. Cellulosics are tough, abrasion resistant plastics that have found use in a variety of applications such as films, dice, and eyeglasses. Specialty grades available include plasticized, UV stabilized, flame retardant, and colored. In 1994, the price of CAP ranged approximately from $1.50 to $2.00 per pound at truckload quantities.

General Properties
The main benefits offered by cellulosics are clarity, toughness at low temperatures, abrasion resistance, glossy appearance, resistance to stress cracking, and good electrical insulating properties. Other benefits of cellulosics include a warm, pleasant feel to the touch (due to their low thermal conductivity and specific heat), the availability of formulations which can be used in contact with food, and the ability to be processed by most thermoplastic methods. Generally, plasticizers are added to lower the melt temperature and modify the physical properties. As plasticizer is added, the hardness, stiffness and tensile strength decrease, while the impact strength increases. The solvent resistance of cellulosics varies with type. In general, they are resistant to attack by aliphatic hydrocarbons, bleach, ethylene glycol, salt solutions, and vegetable and mineral oils. However, cellulosics are known to be attacked by alkaline materials and fungus. Cellulosics are further limited by their flammability, low continuous use temperatures, and poor resistance to weathering, although UV resistant grades are available.

Typical Properties of Cellulose Acetate Propionate

	American Engineering	SI
Processing temperature	–	–
Linear mold shrinkage	–	–
Melting point	300-400°F	149-204°C
Density	74.9-81.2 lb/ft^3	1.20-1.30 g/cm^3
Tensile strength, yield	3.6-6.1 lb/in^2 x 10^3	2.5-4.3 kg/cm^2 x 10^2
Tensile strength, break	4.5-7.1 lb/in^2 x 10^3	3.2-5.0 kg/cm^2 x 10^2
Elongation, break	-	–
Tensile modulus	-	–
Flexural strength, yield	4.4-8.2 lb/in^2 x 10^3	3.1-5.8 kg/cm^2 x 10^2
Flexural modulus	1.9-3.2 lb/in^2 x 10^5	1.3-2.2 kg/cm^2 x 10^4
Compressive strength	4.4-8.1 lb/in^2 x 10^3	3.1-5.8 kg/cm^2 x 10^2
Izod notched, R.T.	1.2-8.3 ft-lb/in	6.5-44.8 kg cm/cm
Hardness	R75-R13 Rockwell	R75-R13 Rockwell
Thermal conductivity	1.73-1.74 BTU-in/hr-ft^2-°F	0.246-0.251 W/m-°K
Linear thermal expansion	–	–
Deflection temp. @ 264 psi	120-200°F	49-93°C
Deflection temp. @ 66 psi	140-230°F	60-110°C
Continuous service temp.	–	–
Dielectric strength	–	–
Dielectric constant @ 1MHz	3.5-3.6	3.5-3.6
Dissipation factor @ 1MHz	0.020-0.030	0.020-0.030
Water absorption, 24 hr	1.3-2.4%	1.3-2.4%

Typical Applications
- Films: photographic film, audio tape, visual aids, greeting cards, photo albums
- Miscellaneous: lacquer and cement base, explosives, fashion accessories, flashlight cases, fire extinguisher components, toys, tool handles, electrical appliance housings, eyeglass frames and lenses, lighting fixtures, brush handles

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Typical Applications
Lists markets where the plastic is used and the specific applications.

Adhesive Shear Strength Table

For a detailed explanation of the information contained in the Adhesive Shear Strength table, please turn to the next page.

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Cellulose Acetate Propionate — Tenite 3754000012 produced by Eastman Performance Products

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	3 rms	400 2.8	1950 13.5	2150 14.8	1550 10.7	1200 8.3	1850 12.8
Roughened	19 rms	400 2.8	1950 13.5	1550 10.7	1550 10.7	900 6.2	1850 12.8
Antioxidant	0.15% Irganox 1010	400 2.8	1950 13.5	2150 14.8	1550 10.7	700 4.8	1850 12.8
UV stabilizer	0.2% Chimasorb 994	400 2.8	>2450Δ >16.9Δ	2000 13.8	2000 13.8	550 3.8	1850 12.8
Flame retardant	17% Reofos 35	250 1.7	1350 9.3	1000 6.9	900 6.2	650 4.5	1300 9.0
Plasticizer	9% Benzoflex 988	250 1.7	1050 7.2	1200 8.3	1150 7.9	650 4.5	1500 10.3
Lubricant	0.1% Zinc Stearate	250 1.7	1950 13.5	2150 14.8	750 5.2	350 2.4	1850 12.8
Filler #1	17% 497 Fiberglass	400 2.8	1950 13.5	>2200Δ >15.2Δ	1550 10.7	650 4.5	>1900† >13.1†
Filler #2	17% Omyacarb F $CaCO_3$	650 4.5	>1950 >13.5	>2150Δ >14.8Δ	1550 10.7	1200 8.3	>1600† >11.0†
Colorant	1% Green	400 2.8	1950 13.5	2150 14.8	1550 10.7	850 5.9	1850 12.8
Antistatic	1.5% Markstat AL-12	1700 11.7	>2200Δ >15.2Δ	1800 12.4	>2450Δ >16.9Δ	400 2.8	>2250Δ >15.5Δ

NOTES:

Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.

† = Due to the **severe deformation** of the block shear specimens, testing was stopped before the actual bond strength achieved by the adhesive could be determined (the adhesive bond never failed).

▩ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

▩ (red) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, and Loctite 3105 and 3311, light curing acrylic adhesives, typically achieved the highest bond strengths on CAP. Depend 330, a two-part no-mix acrylic adhesive, achieved the second highest bond strengths, followed by Black Max 380, a rubber toughened cyanoacrylate adhesive.

Surface Treatments

Prism Primer 770, when used in conjunction with Prism 401, or 4011 with 7701, had no overall statistically significant effect on the formulations of CAP which were evaluated. However, it did cause a statistically significant decrease in bond strengths achieved on the UV stabilized and antistatic formulations, and a statistically significant increase for the glass and calcium carbonate filled formulations. Surface roughening caused either no effect or a statistically significant decrease in the bondability of CAP.

Other Important Information

- Cellulosics can be stress cracked by uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately.
- Cellulosics are compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

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Other Important Information

Contains information on compatibility with cleaners and other miscellaneous information.

Surface Treatments

The effect of the polyolefin primer and surface roughening is summarized here. In addition, any information on common surface treatment methods is provided.

Adhesive Performance

Summarizes the results of the adhesive shear strength evaluation table.

How To Use The Adhesive Shear Strength Table

Surface Roughness
The root-mean-squared (RMS) surface roughness of the material. This was evaluated on the unfilled plastic and the roughened unfilled plastic to show the effect of the roughening process.

Shading
When a cell is shaded grey, the addition of the indicated additive or filler (or surface roughening) has resulted in a statistically significant increase in bondability of the formulation in comparison to the unfilled resin. A statistically significant decrease is denoted by red shading. If there was a change in the failure mode, the cell is also shaded accordingly.

Unfilled Resin
The unfilled resin, used as the base resin for all of the compounded formulations, is listed at the top of the table next to each plastic type. Each individual formulation was then produced by compounding the unfilled resin with a single additive or filler, and was compared to the unfilled resin to determine if the additive or filler had a statistically significant effect on the bondability of the resin. The effect of the surface roughening was also evaluated on the unfilled resin and analyzed for statistical significance.

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Acetal Homopolymer — **Delrin 100 produced by Dupont Polymers**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	30 rms	100 0.7	200 1.4	1700 11.7	500 3.5	50 0.3	250 1.7
Roughened	47 rms	150 1.0	600 4.1	1700 11.7	500 3.5	100 0.7	250 1.7
Antioxidant	0.2% Irganox 1010	100 0.7	400 2.8	1700 11.7	500 3.5	50 0.3	250 1.7
UV stabilizer	0.2% Tinuvin 328 0.4% Tinuvin 770	100 0.7	900 6.2	1700 11.7	500 3.5	50 0.3	300 2.1
Impact Modifier	30% Estane 5708F1	100 0.7	350 2.4	1700 11.7	500 3.5	50 0.3	350 2.4
Lubricant	0.88% N,N'-Ethylene bisstearamide wax	100 0.7	350 2.4	1700 11.7	900 6.2	50 0.3	450 3.1
Glass filler	20% type 3090 glass fiber	100 0.7	1100 7.6	2800 19.3	1100 7.6	50 0.3	300 2.1
PTFE filler	15% PTFE MP1300	100 0.7	200 1.4	1700 11.7	100 0.7	50 0.3	250 1.7
Colorant	4% 3972 colorant	100 0.7	200 1.4	1700 11.7	500 3.5	50 0.3	250 1.7
Antistatic	1.5% Markstat AL12	150 1.0	1750 12.1	1700 11.7	1100 7.6	50 0.3	250 1.7
Acetal copolymer	Celcon courtesy of Hoechst Celanese	50 0.3	100 0.7	300 2.1	100 0.7	200 1.4	200 1.4

NOTES:
■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.
■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Single Line
A single line in the table indicates that the plastic evaluated below the line was compounded from the unfilled resin and compared to the unfilled resin for statistically significant changes in bondability.

Double Line
A double line in the table indicates that the plastic evaluated below this line is either a commercially available grade or a different plastic type than the unfilled resin, neither of which are compared to the unfilled resin for statistically signifi-cant changes in bondability.

Notes
This section explains the superscripts and shading used in the table.

Plastic Description
The plastic formulations which were selected were selected in two ways. For some plastics, commercially available grades were selected to represent each of the major categories of that plastic. For example, when testing ionomers, resins were selected for each of the major cation types, while for phenolics, grades were selected to represent each of the major end uses, such as electric, heat resistant, and chemical resistant grades. The remaining plastics were specifically compounded for the purpose of determining the effect of individual additives and fillers on the bondability of that material.

• Commercially Available Grades
If commercially available grades were evaluated, then the specific grades which were tested will be listed in the left-hand column of this table along with a short description of each grade.

• Specialty Formulations
If specialty formulations were compounded, then the additive or filler type, as well as the specific concentration and product used, will be listed in the left-hand column of this table.

Cyanoacrylate Adhesives

General Description

Cyanoacrylates are one-part, room-temperature curing adhesives that are available in viscosities ranging from water-thin liquids to thixotropic gels. When pressed into a thin film between two surfaces, cyanoacrylates cure rapidly to form rigid thermoplastics with excellent adhesion to most substrates.

One of the benefits cyanoacrylates offer is the availability of a wide variety of specialty formulations with properties tailored to meet particularly challenging applications. For example, rubber-toughened cyanoacrylates offer high peel strength and impact resistance to complement the high shear and tensile strengths characteristic of cyanoacrylates. Thermally resistant cyanoacrylates are available which offer excellent bond strength retention after exposure to temperatures as high as 250°F for thousands of hours. Moreover, "Surface-insensitive" cyanoacrylates offer rapid fixture times and cure speeds on acidic surfaces, such as wood or dichromated metals, which could slow the cure of a cyanoacrylate. In some cases, the use of a general-purpose cyanoacrylate adhesive was hampered by the appearance of a white haze around the bondline. This phenomenon is known as "blooming" or "frosting" and occurs when cyanoacrylate monomer volatizes, reacts with moisture in the air, and settles on the part. To eliminate this problem, "Low Odor/Low Bloom" cyanoacrylates were developed. They have a lower vapor pressure than standard cyanoacrylates and therefore are less likely to volatize. While advances in cyanoacrylate formulating technology have played a key role in offering additional benefits to the end user, there have also been important developments in cyanoacrylate primer and accelerator technology.

Accelerators speed the cure of cyanoacrylate adhesives and are primarily used to reduce cure and fixture times, to cure fillets on bondlines and/or excess adhesive. Accelerators consist of an active ingredient dispersed in a solvent. The accelerator is typically applied to a substrate surface prior to the application of the adhesive. Once the carrier solvent has evaporated, the cyanoacrylate can immediately be applied and its cure initiated by the active species that the accelerator has left behind. Depending on the particular solvent and active species present in the accelerator, the solvent can require 10 to 60 seconds to evaporate, and the active species can have an on-part life ranging from 1 minute to 72 hours. Accelerator can also be sprayed over a drop of free cyanoacrylate to rapidly cure it. This technique has been widely used for wire tacking in the electronics industry.

Another benefit offered by cyanoacrylates is the availability of primers which enable them to form strong bonds with polyolefins and other hard to bond plastics such as fluoropolymers and acetal resins. Like the accelerators, polyolefin primers consist of an active ingredient dispersed in a solvent. Once the carrier solvent has evaporated, the surface is immediately ready for bonding, and the primer will have an on-part life ranging from 4 minutes to one hour. Depending on the plastic, bond strengths up to 20 times the unprimed bond strength can be achieved.

Chemistry

Cyanoacrylate adhesives are cyanoacrylate esters, of which methyl and ethyl cyanoacrylates are the most common. Cyanoacrylates undergo anionic polymerization in the presence of a weak base, such as water, and are stabilized through the addition of a weak acid. When the adhesive contacts a surface, the water present on the surface neutralizes the acidic stabilizer in the adhesive, resulting in the rapid polymerization of the cyanoacrylate.

Advantages

- One part system
- Solvent free
- Rapid room temperature cure
- Excellent adhesion to many substrates
- Easy to dispense in automated systems
- Wide range of viscosities available
- Excellent bond strength in shear and tensile mode
- Primers available for polyolefins and difficult to bond plastics

Disadvantages

- Poor peel strength
- Limited gap cure
- Poor durability on glass
- Poor solvent resistance
- Low temperature resistance
- Bonds skin rapidly
- May stress crack some plastics

Light Curing Acrylic Adhesives

General Description

Light curing acrylic adhesives are supplied as one-part, solvent-free liquids with viscosities ranging from 50 cP to thixotropic gels. Upon exposure to light of the proper intensity and spectral output, these adhesives cure rapidly to form thermoset polymers with excellent adhesion to a wide variety of substrates. The cure times of light curing acrylic adhesives are dependent on many parameters, however, cure times of 2 to 60 seconds are typical and cure depths in excess of 0.5" (13 mm) are possible. Formulations of light curing acrylic adhesives are available which vary in cured properties from very rigid, glassy materials to soft, flexible elastomers.

Light curing acrylic adhesives cure rapidly on demand, which minimizes work in progress and offers virtually unlimited repositioning time. In addition, the wide range of viscosities available facilitates the selection of a product for automated dispensing. These qualities make light curing acrylics ideally suited for automated bonding processes.

Chemistry

Light curing acrylic adhesives are composed of a blend of monomers, oligomers, and polymers containing the acrylate functionality to which photoinitiator is added. Upon exposure to light of the proper intensity and spectral output, the photoinitiator decomposes to yield free radicals. The free radicals then initiate polymerization of the adhesive through the acrylate groups to yield a thermoset polymer.

When the adhesive is cured in contact with air, the free radicals created by the decomposition of the photoinitiator can be scavenged by oxygen prior to initiating polymerization. This can lead to incomplete cure of the adhesive at the adhesive/oxygen interface, yielding a tacky surface. To minimize the possibility of forming a tacky surface, the irradiance of light reaching the adhesive can be increased, the spectral output of the light source can be matched to the absorbance spectrum of the photoinitiator, and/or the adhesive can be covered with a nitrogen blanket during cure.

Advantages

- Cure on demand
- Good environmental resistance
- Wide range of viscosities available
- Solvent free
- Good gap filling
- One part
- Dispensing is easily automated
- Clear bondlines
- Rapid fixture and complete cure
- Wide range of physical properties

Disadvantages

- Light must be able to reach bondline
- Oxygen can inhibit cure
- Equipment expense for light source
- Ozone created by high intensity light source must be vented

Two-Part No-Mix Acrylic Adhesives

General Description

Two-part no-mix acrylic adhesives consist of a resin and an activator. The resin component is a solvent-free, high viscosity liquid, typically in the range of 10,000 to 100,000 cP, while the activator component is generally a solvent dispersion of the cure catalyst.

If the carrier solvent present in the activator solvent dispersion is undesirable, the pure catalyst is also available as a solvent-free activator. However, when using a solvent-free activator, the amount of activator applied must be tightly controlled, as excessive activator will detrimentally affect the performance of the adhesive.

The base resin of two-part no-mix acrylic adhesives can also be heat cured. A typical heat cure cycle is ten minutes at 300°F (149°C). Heat curing normally offers higher bond strengths and shorter cure times. However, heating the adhesive lowers the resin's viscosity and may result in some adhesive flow out of large gaps. In some instances, it is desired to use a combination of these two cure methods, fixturing the assembly with activator prior to heat cure.

Application Method

When an activator is used, the adhesive is cured in the following manner:

- The resin is applied to one of the substrate surfaces
- The activator is applied to the other surface
- The activator's carrier solvent is allowed to flash off
- The two surfaces are mated together
- The catalyst from the activator then initiates the polymerization of the resin

Typically, these systems develop fixture strength in two minutes and full strength in 4-24 hours. The activator serves only as a catalyst for the polymerization of the resin, so when using an activator, the ratio of activator to resin is not critical. However, this is not the case for solventless activators, because the activator is so concentrated that excess activator can prevent the adhesive from forming an intimate bond with the substrate. Since polymerization is initiated at the interface between the activator and resin, the cure depth is limited. Typically, the maximum cure depth is 0.030" (0.76 mm) from this interface.

Chemistry

The base resin consists of an elastomer dissolved in acrylic monomers. Peroxides are then blended in to provide the resin with a source of free radicals. The elastomer forms a rubbery phase which gives the adhesive its toughness and the acrylic monomers form the thermoset polymer matrix which gives the adhesive its environmental resistance and strength.

The cure catalyst used in the activator is a copper salt compounded with the products from the condensation reaction of an amine and an aldehyde. This catalyst is often diluted in a solvent, although it is also supplied neat. Upon contact of the cure catalyst with the base resin, the peroxide in the base resin decomposes to yield free radicals. These radicals then initiate polymerization through the acrylate groups on the monomer in the base resin.

Advantages

- No mixing required
- Good environmental resistance
- High peel and impact strength
- Bonds to lightly contaminated surfaces
- Fast fixture and cure
- Room temperature cure
- Good adhesion to many substrates
- Cure can be accelerated with heat

Disadvantages

- Difficult to automate dispensing
- Messy
- Activator may contain solvents
- Unpleasant odor
- Limited cure through depth
- Yellow coloration of cured adhesive

Why Bond Plastics With Loctite Adhesives?

Advantages Over Other Assembly Methods

According to the "Engineer's Guide To Plastics," published by *Materials Engineering*, adhesives are the most versatile assembly method for plastics. They are listed as being capable of joining 36 types of plastics compared to 28 types of mechanical fasteners, the next most versatile method. Methods such as staking and ultrasonic welding are limited by comparison, being suitable for 15 and 18 plastics, respectively.

Advantages Versus Mechanical Fasteners

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

- They create stresses in the plastic which may lead to distortion or cracking; adhesives do not.
- There are extra components which must be purchased and inventoried. Adhesives require no extra components.
- They require altering the design of the product to include bosses and holes. Adhesives require no special features.
- Their appearance often interferes with the styling of the product. Adhesives are invisible inside a bonded joint.
- They concentrate all of the holding power at the fastener location, causing the applied load to be carried by a small area of plastic. Adhesives spread the load evenly over the entire joint area.

Advantages Versus 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.

- Ultrasonic welding is not usable for thermosets. Adhesives are.
- Joining of plastics to metal, glass, or other materials is not feasible in most cases. Adhesives do this easily.
- The design of joints is restricted to geometries which are favorable to the process. Ideally, they should have a small, uniform contact area to concentrate the ultrasonic energy.
  Adhesives can accommodate irregular bond lines.
- The capability of joining different thermoplastics in the same assembly is limited to those which are chemically compatible and have similar melting points. Adhesives are not restricted in this way.
- Ultrasonic welding requires investment in machinery as well as special tooling for each part. Adhesives require no machinery or tooling.

Advantages Versus Solvent Welding

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

- Solvent welding cannot be used with dissimilar materials such as metals or glass. Adhesives do the job.
- Solvents will not work with thermoset plastics. Adhesives will.
- Solvents are more likely to cause stress cracking than are adhesives.
- The time between application of the solvent and joining the parts is critical. The joints are weak if too much solvent remains in the bond area or if too much solvent has flashed off prior to assembly. Adhesives have a much less critical open time.
- Solvent cementing is not capable of joining parts with significant gaps between them. Adhesives tolerate much larger gaps.

Advantages Over Other Adhesives

Loctite cyanoacrylate and acrylic adhesives are the first choice for speed, ease of use, and overall convenience. They are adhesives that easily adapt themselves to high-speed production lines without heat curing ovens or mixing equipment. When total costs of the finished product are considered, they are often the most economical.

When compared to other adhesives, such as hot melts, epoxies, urethanes, or solvent cements, Loctite adhesives have the same basic advantages that they have on other substrates.

Advantages Versus Epoxies

Epoxies, when first introduced, 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 useful materials. However, they are not the easiest materials to use for the following reasons:

- They usually must be mixed immediately prior to use, requiring extensive hand labor or sophisticated mixing equipment.

- The time from mixing to use is often critical to success, but is difficult to control, particularly when the production rate is irregular.
- Limits to pot life often cause waste of material.
- Epoxies requiring heat cures have limited usefulness on heat sensitive plastics.
- Cure times without heat are too long for automated assembly.

Advantages Versus Hot Melts

Hot melts are low cost, single component, fast-setting adhesives. As such, they often find use bonding packaging components, furniture or toys. Their limitations, however, are significant.

- Hot melts have poor temperature resistance.
- They require special equipment to melt and dispense the adhesive.
- They are messy.
- Control of the joint open time is critical to performance.
- Material held in the melted form for extended periods of time may degrade.

Advantages Versus Solvent Cements

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

- They have poor resistance to heat and solvents.
- They produce solvent fumes which may be toxic or flammable.
- The open time of the bonded joint is critical.
- They require an extensive drying time.
- Solvent trapped inside the joint may lead to porosity or weakness.

Acetal Homopolymer

thermoplastic

Trade Names / Manufacturer

Trade Names	Manufacturer
• Celcon	Hoechst Celanese
• Delrin	E.I. DuPont
• Iupital	Mitsubishi Gas
• Kemlex	Ferro Corporation
• Tenac	Asahi Chemical
• Ultraform	BASF

General Description

Acetal homopolymer is a highly crystalline thermoplastic produced by polymerizing formaldehyde and capping each end of the polymer chain with acetate groups. The polymer is properly called polyo-xymethylene (POM) and has a backbone comprised of repeating -CH_2O- units. Acetal copolymer is manufactured by copolymerizing trioxane with relatively small amounts of a comonomer. The comonomer randomly distributes carbon-carbon bonds in the polymer chain which help to stabilize the resin against environmental degradation. The relatively low cost of acetals, in addition to their good balance of mechanical, chemical, and electrical properties, makes them well suited for replacing metal and other structural materials. Specialty grades available include glass filled, low friction/low wear, antistatic and conductive, mineral-coupled, UV stabilized, pigmented, toughened (elastomer modified), and abrasion resistant grades. In 1994, the price of acetal homopolymer ranged approximately from $1.25 to $2.00 per pound at truckload quantities.

General Properties

Acetals exhibit high physical strength, as well as excellent creep and impact resistance. Due to their extremely low water absorption rate, the electrical properties and dimensional stability of acetal resins are minimally affected by atmospheric moisture. The dielectric constant of an acetal resin varies only slightly over a wide frequency range, its dielectric strength is high, and a volume resistivity of 10^{15} ohm-cm makes it a good electrical insulator. Acetals are resistant to solvents, ethers, oils, greases, gasoline, and other organic compounds, and are especially well suited for use with methanol-based fuels. They are resistant to moderate strength acids, but are not recommended for use with strong acids. Acetal homopolymer is very resistant to wear due to its hard surface and low coefficient of friction (0.1 to 0.3).

Typical Properties of Acetal Homopolymer

	American Engineering	SI
Processing temperature	350-420°F	117-216°C
Linear mold shrinkage	0.001-0.025 in/in	0.001-0.025 cm/cm
Melting point	325-355°F	163-179°C
Density	84.3-96.1 lb/ft^3	1.35-1.54 g/cm^3
Tensile strength, yield	6.0-10.0 lb/in^2 x 10^3	4.2-7.0 kg/cm^2 x 10^2
Tensile strength, break	5.8-10.0 lb/in^2 x 10^3	4.2-7.0 kg/cm^2 x 10^2
Elongation, break	5.0-80.0%	5.0-80.0%
Tensile modulus	3.0-5.0 lb/in^2 x 10^5	2.1-3.5 kg/cm^2 x 10^4
Flexural strength, yield	7.1-15.6 lb/in^2 x 10^3	5.0-11.0 kg/cm^2 x 10^2
Flexural modulus	2.2-5.7 lb/in^2 x 10^5	1.5-4.0 kg/cm^2 x 10^4
Compressive strength	4.5-17.6 lb/in^2 x 10^3	3.2-12.4 kg/cm^2 x 10^2
Izod notched, R.T.	0.5-2.8 ft-lb/in	2.7-15.1 kg cm/cm
Hardness	R117-R120 Rockwell	R117-R120 Rockwell
Thermal conductivity	-	-
Linear thermal expansion	0.5-11.0 in/in-°F x 10^{-5}	0.9-19.8 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	195-325°F	91-163°C
Deflection temp. @ 66 psi	300-345°F	149-174°C
Continuous service temp.	212-221°F	100-105°C
Dielectric strength	380-500 V/10^{-3} in	1.5-2.0 V/mm x 10^4
Dielectric constant @ 1MHz	3.5-4.2	3.5-4.2
Dissipation factor @ 1MHz	0.001-0.009	0.001-0.009
Water absorption, 24hr	0.16-0.35%	0.16-0.35%

Acetal homopolymer is UL94HB rated for flammability, and has continuous service temperatures in the range of 212°F (100°C) to 221°F (105°C).

Typical Applications

• Automotive	fasteners, carburetor floats, knobs, fuel pump housings
• Industrial Machinery	valves, conveying equipment, rollers, springs
• Plumbing	ballcocks, faucet cartridges, impellers, shower heads, faucet underbodies
• Electronics	keytops, switches, buttons
• Miscellaneous	A/V cassette components, toiletry articles, zippers, bearings, toy parts

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Acetal Homopolymer **Delrin 100 produced by Dupont Polymers**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	30 rms	100 0.7	200 1.4	1700 11.7	500 3.5	50 0.3	250 1.7
Roughened	47 rms	150 1.0	600 4.1	1700 11.7	500 3.5	100 0.7	250 1.7
Antioxidant	0.2% Irganox 1010	100 0.7	400 2.8	1700 11.7	500 3.5	50 0.3	250 1.7
UV stabilizer	0.2% Tinuvin 328 0.4% Tinuvin 770	100 0.7	900 6.2	1700 11.7	500 3.5	50 0.3	300 2.1
Impact Modifier	30% Estane 5708F1	100 0.7	350 2.4	1700 11.7	500 3.5	50 0.3	350 2.4
Lubricant	0.88% N,N'-Ethylene bisstearamide wax	100 0.7	350 2.4	1700 11.7	900 6.2	50 0.3	450 3.1
Glass filler	20% type 3090 glass fiber	100 0.7	1100 7.6	2800 19.3	1100 7.6	50 0.3	300 2.1
PTFE filler	15% PTFE MP1300	100 0.7	200 1.4	1700 11.7	100 0.7	50 0.3	250 1.7
Colorant	4% 3972 colorant	100 0.7	200 1.4	1700 11.7	500 3.5	50 0.3	250 1.7
Antistatic	1.5% Markstat AL12	150 1.0	1750 12.1	1700 11.7	1100 7.6	50 0.3	250 1.7
Acetal copolymer	Celcon courtesy of Hoechst Celanese	50 0.3	100 0.7	300 2.1	100 0.7	200 1.4	200 1.4

NOTES: ■ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

■ (pink) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, when used in conjunction with Prism Primer 770, or 4011 with 7701, achieved the highest bond strengths on all of the acetal formulations which were evaluated. Prism 401, 4011 and Super Bonder 414, cyanoacrylate adhesives, achieved the second highest bond strengths followed by Loctite 3105 and 3311 light curing acrylic adhesives. Black Max 380, a rubber toughened cyanoacrylate adhesive, and Depend 330, a two-part no-mix adhesive, achieved the lowest bond strengths on acetal polymers. The addition of an antistatic additive to acetal homopolymer resulted in a large, statistically significant increase in the bond strengths achieved when using Prism 401, 4011 or Super Bonder 414.

Surface Treatments

Surface roughening either caused no effect or a statistically significant increase in bond strength achieved on acetal homopolymer. The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, caused a statistically significant increase in the bondability of both acetal homopolymer and copolymer.

Other Important Information

- The surface of acetals tends to be very dry, so an accelerator may be necessary to speed the cure of cyanoacrylates.
- Acetal homopolymers are compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Acrylic (PMMA)

thermoplastic

Trade Names / Manufacturer

- Acrylite — CYRO Industries
- Acrylt — Sumitomo Chemical
- Diakon — ICI Americas
- Modar — ICI Acrylics
- Plexiglas — Rohm & Haas
- Shinkolite — Mitsubishi Rayon
- Sumipex — Sumitomo Chemical
- Zylar — Novacor Chemicals

General Description

Polymethyl methacrylate, the most common member of the acrylic family, is produced through free-radical polymerization of the monomer, which is initiated by a reactive chemical or radiant energy. The monomer is produced when acetone cyanohydrin is heated with methanol in the presence of concentrated sulfuric acid. The optical clarity, rigidity, wide selection of colors, and ability to resist sunlight and other environmental stresses, make acrylics ideal for replacing glass in light transmisssion applications. Specialty grades of acrylic include impact resistant grades and a full range of transparent, translucent, and opaque colors. In 1994, the price of acrylics ranged approximately from $1.25 to $1.75 per pound at truckload quantities.

General Properties

A transparency equal to glass and outstanding weatherability are acrylic's most notable properties. Years of testing with sunlight and artificial light sources have resulted in no appreciable yellowing or loss in the physical properties of acrylics. They have good tensile and flexural strength, but even low stresses can cause surface crazing if applied for extended periods of time. Acrylics are more rigid than most thermoplastics, but a large unsupported sheet will deform permanently under a continuous load, even from its own weight. Acrylics are not recommended for high temperature applications, illustrated by their continuous service temperatures of 170°F (76°C) to 190°F (88°C), though annealing can be used to increase this temperature. Acrylics are chemically resistant to many chemicals, however, are attacked by ketones, esters, aromatic and chlorinated hydrocarbons. Although acrylics are combustible, they are widely used in building interiors and lighting fixtures, posing minimal safety hazards provided that the pertinent building codes and applicable Underwriter Laboratory standards are observed.

Typical Properties of Acrylic

	American Engineering	SI
Processing temperature	350-570°F	177-299°C
Linear mold shrinkage	0.003-0.007 in/in	0.003-0.007 cm/cm
Melting point	–	-
Density	65.6-76.2 lb/ft^3	1.05-1.22 g/cm^3
Tensile strength, yield	1.5-10.5 lb/in^2 x 10^3	1.1-7.4 kg/cm^2 x 10^2
Tensile strength, break	1.3-12.8 lb/in^2 x 10^3	0.9-9.0 kg/cm^2 x 10^2
Elongation, break	0.5-75.0%	0.5-75.0%
Tensile modulus	1.5-7.0 lb/in^2 x 10^5	1.1-4.9 kg/cm^2 x 10^4
Flexural strength, yield	1.7-3.1 lb/in^2 x 10^3	1.2-2.2 kg/cm^2 x 10^2
Flexural modulus	0.01-6.2 lb/in^2 x 10^5	0.0-4.4 kg/cm^2 x 10^4
Compressive strength	6.0-18.5 lb/in^2 x 10^3	4.2-13.0 kg/cm^2 x 10^2
Izod notched, R.T.	0.2-2.0 ft-lb/in	0.9-10.8 kg cm/cm
Hardness	M65-M100	M65-M100
Thermal conductivity	1.3-1.5 BTU-in/hr-ft^2-°F	0.19-0.22 W/m-°K
Linear thermal expansion	3.3-5.6 in/in-°F x 10^{-5}	5.9-10.1 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	150-225°F	66-107°C
Deflection temp. @ 66 psi	–	-
Continuous service temp.	170-190°F	77-88°C
Dielectric strength	260-760 V/10^{-3} in	1.0-3.0 V/mm x 10^4
Dielectric constant @ 1MHz	2.2-3.9	2.2-3.9
Dissipation factor @ 1MHz	0.025-0.045	0.025-0.045
Water absorption, 24 hr	0.1-0.5%	0.1-0.5%

Typical Applications

- Construction — enclosures for swimming pools and buildings, paneling, break resistant security glazing, tinted sunscreens, domed skylights, lighting fixtures
- Automotive parts — lenses, medallions, nameplates, instrument panels, signals
- Household — lavatory and vanity tops, tubs, counters, furniture
- Medical — IV systems, blood pumps, filters, y-sites, luers
- Miscellaneous — display cabinets, appliances, false fingernails, aviation canopies

ADHESIVE SHEAR STRENGTH

(psi)
(MPa)

Acrylic **Perspex CP80 produced by ICI Acrylics Inc.**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	3 rms	600 4.1	>3950Δ >27.2Δ	250 1.7	>2900Δ >20.0Δ	1150 7.9	1750 12.1
Roughened	34 rms	1500 10.3	2150 14.8	400 2.8	>2900Δ >20.0Δ	650 4.5	1750 12.1
Antioxidant	0.1% Irganox 245	1400 9.7	>3950Δ >27.2Δ	350 2.4	>2900Δ >20.0Δ	1150 7.9	1750 12.1
UV stabilizer	0.6% Uvinul 3039	1450 10.0	>3950Δ >27.2Δ	250 1.7	>2900Δ >20.0Δ	1150 7.9	1750 12.1
Flame retardant	17% Phoschek P-30	1050 7.2	>5050Δ >34.8Δ	>5250Δ >36.2Δ	>2900Δ >20.0Δ	1150 7.9	1750 12.1
Lubricant	5% Witconol NP-330	>3050Δ >21.0Δ	>3950Δ >27.2Δ	350 2.4	>4550Δ >31.4Δ	1150 7.9	1250 8.6
Impact modifier	29% Paraloid EXL3330	1250 8.6	>3950Δ >27.2Δ	1250 8.6	2900 20.0	650 4.5	1750 12.1
Plasticizer	9% Benoflex 50	600 4.1	>3000Δ >20.7Δ	250 1.7	>2900Δ >20.0Δ	1150 7.9	1750 12.1
Colorant A	1% OmniColor Pacific Blue	1550 10.7	>3350Δ >23.1Δ	250 1.7	>2900Δ >20.0Δ	1150 7.9	1350 9.3
Colorant B	0.5% 99-41-042 Green	600 4.1	>2350Δ >16.2Δ	250 1.7	>2900Δ >20.0Δ	450 3.1	1750 12.1
Antistatic	1.5% Markstat AL-48	>2150Δ >14.8Δ	>3950Δ >27.2Δ	250 1.7	>2900Δ >20.0Δ	1150 7.9	1750 12.1

NOTES: Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.
■ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.
■ (pink) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, 4011 and Super Bonder 414, cyanoacrylate adhesives, created bonds which were stronger than the acrylic substrate for most of the formulations evaluated. Loctite 3105 and 3311, light curing acrylic adhesives, normally achieved the second highest bond strengths. Black Max 380, a rubber toughened cyanoacrylate adhesive, and Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths on PMMA. However, when using Black Max 380, the addition of lubricant or antistatic agents resulted in the bond strengths increasing from average strengths to substrate failure.

Surface Treatments

The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, caused a statistically significant decrease in the bond strengths achieved on all the formulations of acrylic which were evaluated, with the exception of the flame retarded formulation. Surface roughening caused a statistically significant increase in bond strengths achieved when using Black Max 380, but caused either no effect or a statistically significant decrease in bond strength for all the other adhesives evaluated.

Other Important Information

- Acrylics can be stress cracked by uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately.
- Acrylics are compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately.
- Acrylics are incompatible with anaerobic adhesives.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Acrylic-Styrene-Acrylonitrile (ASA)

thermoplastic

Trade Names / Manufacturer

Trade Names	Manufacturer
• Centrex	Monsanto Chemical
• Geloy	GE Plastics
• Kibisan	Chi Mei Industrial
• Luran	BASF
• Terblend	BASF

General Description

ASA is an amorphous terpolymer of acrylic, styrene, and acrylonitrile that is produced by mass copolymerization or by grafting styrene-acrylonitrile to the acrylic elastomer backbone. The plastic is known for its toughness, outdoor weatherability, and UV resistance. Specialty grades available include impact resistant, high-gloss, and alloys with PVC and polycarbonate. In 1994, the price of ASA ranged approximately from $1.50 to $2.25 per pound at truckload quantities.

General Properties

The acrylic elastomer in ASA gives the resin its excellent weatherability characteristics, while the styrene imparts the pleasing surface appearance. ASA can have notched Izod impact strength values as high as 20 ft-lb/in (108 kg-cm/cm), and a tensile strength as high as 11,400 psi (800 kg/cm^2) ASA is also known for its glossy surface. For example, there are commercially available grades designed for use as capstock in sheet coextrusion processes which have a 60 degree gloss value of 95. With a heat deflection temperature at 264 psi of no more than 225°F (107°C), ASA is not recommended for use in high temperature applications. ASA has good resistance to oils, greases, and salt solutions, but is attacked by ketones, esters, aromatic compounds, chlorinated solvents, and some alcohols.

Typical Properties of Acrylic-Styrene-Acrylonitrile

	American Engineering	SI
Processing temperature	450-520°F	232-271°C
Linear mold shrinkage	0.005-0.006 in/in	0.005-0.006 cm/cm
Melting point	–	–
Density	65.6-75.5 lb/ft^3	1.05-1.21 g/cm^3
Tensile strength, yield	4.6-7.5 lb/in^2 x 10^3	3.2-5.3 kg/cm^2 x 10^2
Tensile strength, break	5.5-11.4 lb/in^2 x 10^3	3.9-8.0 kg/cm^2 x 10^2
Elongation, break	3.0-70.0%	3.0-70.0%
Tensile modulus	3.0-4.0 lb/in^2 x 10^5	2.1-2.8 kg/cm^2 x 10^4
Flexural strength, yield	7.0-12.1 lb/in^2 x 10^3	4.9-8.5 kg/cm^2 x 10^2
Flexural modulus	2.4-5.7 lb/in^2 x 10^5	1.7-4.0 kg/cm^2 x 10^4
Compressive strength	–	–
Izod notched, R.T.	0.3-20.0 ft-lb/in	1.6-108.0 kg cm/cm
Hardness	R85-R109 Rockwell	R85-R109 Rockwell
Thermal conductivity	–	–
Linear thermal expansion	4.9-8.3 in/in-°F x 10^{-5}	8.8-14.9 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	170-225°F	77-107°C
Deflection temp. @ 66 psi	185-230°F	85-110°C
Continuous service temp.	–	–
Dielectric strength	400-500 V/10^{-3} in	1.6-2.0 V/mm x 10^4
Dielectric constant @ 1MHz	3.2-3.6	3.2-3.6
Dissipation factor @ 1MHz	0.0004-0.019	0.0004-0.019
Water absorption, 24 hr	0.10-0.40%	0.10-0.40%

Typical Applications

- **Automotive** — body moldings, bumper parts
- **Construction** — wall fixtures, downspouts, gutters, house siding profiles
- **Sporting goods** — snowmobile and ATV housings, camper tops, windsurfer boards
- **Miscellaneous** — garden hose fittings, telephone handsets, swimming pool steps

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Acrylic-Styrene-Acrylonitrile **Geloy XP1001-100 produced by GE Plastics**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	4 rms	>1650Δ >11.4Δ	>1750Δ >12.1Δ	>1750Δ >12.1Δ	>1700Δ >11.7Δ	950 6.6	1300 9.0
Roughened	28 rms	>1650Δ >11.4Δ	>1900Δ >13.1Δ	1150 7.9	>1850Δ >12.8Δ	700 4.8	1300 9.0
Antioxidant	0.2% Irganox 245	>1650Δ >11.4Δ	>1750Δ >12.1Δ	>1750Δ >12.1Δ	>1700Δ >11.7Δ	950 6.6	1300 9.0
UV stabilizer	0.5% Tinuvin 770 0.5% Tinuvin P	>1300Δ >9.0Δ	>1750Δ >12.1Δ	>1750Δ >12.1Δ	>1700Δ >11.7Δ	950 6.6	1300 9.0
Flame retardant	20% F2016	>1650Δ >11.4Δ	>1750Δ >12.1Δ	>1750Δ >12.1Δ	>1700Δ >11.7Δ	650 4.5	1300 9.0
Impact modifier	9% Paraloid EXL3330	>1650Δ >11.4Δ	>1750Δ >12.1Δ	>1750Δ >12.1Δ	>1850Δ >12.8Δ	950 6.6	1300 9.0
Lubricant	0.3% Mold Wiz INT SP8	>1650Δ >11.4Δ	>1750Δ >12.1Δ	>1750Δ >12.1Δ	>1700Δ >11.7Δ	950 6.6	1300 9.0
Colorant	1% OmniColor Nectarine	>1650Δ >11.4Δ	>1750Δ >12.1Δ	>1750Δ >12.1Δ	>1700Δ >11.7Δ	950 6.6	1300 9.0
Antistatic	1.5% Dehydat 93P	>1650Δ >11.4Δ	>1750Δ >12.1Δ	>1750Δ >12.1Δ	>1700Δ >11.7Δ	950 6.6	1300 9.0

NOTES:

Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.

■ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

■ (red) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

The four cyanoacrylates tested, namely Black Max 380, Prism 401 and 4011, and Super Bonder 414, all created bonds which were stronger than the substrate on almost all of the ASA formulations evaluated. Loctite 3105 and 3311, light curing acrylic adhesives, did not achieve substrate failure, but did perform well on ASA. Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths on ASA.

Surface Treatments

The effect of using Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, could not be determined because both primed and unprimed ASA achieved substrate failure for most of the formulations evaluated. Surface roughening had an inconsistent effect on the bondability of ASA.

Other Important Information

- ASA can be stress cracked by uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately.
- ASA is compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately.
- ASA is incompatible with anaerobic adhesives.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Acrylonitrile-Butadiene-Styrene (ABS)

thermoplastic 7 OTHER

Trade Names	Manufacturer
• Cevian	Hoescht Celanese
• Cycolac	General Electric
• Lustran	Monsanto Chemical
• Magnum	Dow Chemical
• Shinko-Lac	Mitsubishi Rayon
• Taitalac	Taita Chemical Co.
• Toyolac	Toray Industries

General Description

ABS is a generic name for a versatile family of amorphous thermoplastics produced by combining three monomers, acrylonitrile, butadiene, and styrene. The ratio of these monomers, as well as the molecular structure, can be manipulated to optimize the characteristics of the resulting polymer. Acrylonitrile contributes chemical resistance and thermal stability. Butadiene contributes product toughness, impact resistance, and property retention at low temperatures. Styrene contributes rigidity, surface appearance, and processability. The resultant polymer's properties can vary over a large range to suit the manufacturer's needs. For this reason, ABS is widely used in countless applications throughout industry. Specialty grades available include general-purpose, glass filled, electroplateable, heat resistant, clear, high and low gloss, structural foam, and flame retardant grades. In 1994, the price of ABS ranged from $1.00 to $3.00 per pound at truckload quantities.

Typical Properties of Acrylonitrile-Butadiene-Styrene

	American Engineering	SI
Processing temperature	400-525°F	204-274°C
Linear mold shrinkage	0.002-0.007 in/in	0.002-0.007 cm/cm
Melting point	–	–
Density	63.7-79.9 lb/ft^3	1.02-1.28 g/cm^3
Tensile strength, yield	4.6-7.9 lb/in^2 x 10^3	3.2-5.6 kg/cm^2 x 10^2
Tensile strength, break	4.0 - 12.0 lb/in^2 x 10^3	2.8 - 8.4 kg/cm^2 x 10^2
Elongation, break	1.0 - 50.0 %	–
Tensile modulus	2.0 - 12.0 lb/in^2 x 10^5	1.4-8.4 kg/cm^2 x 10^4
Flexural strength, yield	6.2-20.0 lb/in^2 x 10^3	4.4-14.1 kg/cm^2 x 10^2
Flexural modulus	2.5-4.4 lb/in^2 x 10^5	1.8-3.1 kg/cm^2 x 10^4
Compressive strength	6.0-17.0 lb/in^2 x 10^3	4.2-12.0 kg/cm^2 x 10^2
Izod notched, R.T.	0.5-12.0 ft-lb/in	2.7-64.8 kg cm/cm
Hardness	R95-R125 Rockwell	–
Thermal conductivity	1.2-1.6 BTU-in/hr-ft^2-°F	0.17-0.23 W/m-°K
Linear thermal expansion	1.1-5.7 in/in-°F x 10^{-5}	2.0-10.3 cm/cm-°C
Deflection temp. @ 264 psi	170-240°F	77-116°C
Deflection temp. @ 66 psi	190-245°F	88-118°C
Continuous service temp.	130-180°F	54-82°C
Dielectric strength	350-500 V/10^{-3} in	1.4-2.0 V/mm x 10^4
Dielectric constant @ 1MHz	3.1-3.4	3.1-3.4
Dissipation factor @ 1MHz	0.008-0.009	0.008-0.009
Water absorption, 24hr	0.1-0.5%	0.1-0.5%

General Properties

ABS offers an excellent combination of toughness and rigidity at a low cost. Typical notched impact strength ranges from 0.5 to 12 ft-lb/in (2.7 to 64.8 kg cm/cm), while typical tensile modulii range from 200,000 to 1,200,000 psi (14,000 to 84,000 kg/cm^2). In addition to its toughness, ABS has a high dimensional stability (which permits tight mold tolerances), a pleasing surface appearance, and is very easy to process. ABS is a relatively good electrical insulator and is suitable for secondary insulating applications. ABS is chemically resistant to acids and bases, but is not recommended for use with esters, ketones, or aldehydes. ABS has poor resistance to UV exposure, resulting in significant changes in its appearance and mechanical properties. To address this limitation, there are protective coatings available which enhance ABS's resistance to UV degradation. Some grades of ABS are created by adding a fourth monomer, such as the addition of alpha methyl styrene to create a heat resistant grade. Clear grades are created by adding methyl methacrylate, giving ABS the ability to transmit 75 to 80% of light.

Typical Applications

- Medical — piercing pins, clamps, filter casings, stopcocks, check valves, blood dialyzers
- Miscellaneous — appliances, business machines, telephones, luggage, power tools, bathtubs, pipe fittings, toys, faucets, shower heads, sporting goods, automotive applications

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Acrylonitrile-Butadiene-Styrene

Cycolac GPM 6300 produced by GE Plastics

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	3 rms	950 6.6	>3500$^{\Delta}$ >24.1$^{\Delta}$	>3350† >23.1†	>3500$^{\Delta}$ >24.1$^{\Delta}$	300 2.1	>3500† >24.1†
Roughened	48 rms	1400 9.7	>3500$^{\Delta}$ >24.1$^{\Delta}$	>3350† >23.1†	>3500$^{\Delta}$ >24.1$^{\Delta}$	1300 9.0	>3500† >24.1†
Antioxidant	0.1% Iragaphos 168 0.16% Irganox 245 0.04% Irganox 1076	950 6.6	>3500$^{\Delta}$ >24.1$^{\Delta}$	>3350† >23.1†	>3500$^{\Delta}$ >24.1$^{\Delta}$	150 1.0	>3500† >24.1†
UV stabilizer	0.4% UV5411 0.4% UV3346 0.1% Ultranox 626	950 6.6	>3500$^{\Delta}$ >24.1$^{\Delta}$	>3350† >23.1†	>3500$^{\Delta}$ >24.1$^{\Delta}$	300 2.1	>3500† >24.1†
Flame retardant	13.5% DE83R 3% Chlorez 700 SS 4% 772VHT Antimony Oxide	950 6.6	>3500$^{\Delta}$ >24.1$^{\Delta}$	>3350† >23.1†	>3500$^{\Delta}$ >24.1$^{\Delta}$	300 2.1	>3500† >24.1†
Smoke suppressant	5% Firebrake ZB Zinc Borate	650 4.5	>3500$^{\Delta}$ >24.1$^{\Delta}$	>3350† >23.1†	>3500$^{\Delta}$ >24.1$^{\Delta}$	300 2.1	>3500† >24.1†
Lubricant	0.2% N,N'-Ethylene bisstearamide	950 6.6	>3500$^{\Delta}$ >24.1$^{\Delta}$	>3350† >23.1†	>3500$^{\Delta}$ >24.1$^{\Delta}$	300 2.1	>3500† >24.1†
Glass filler	20% Type 3540 glass fiber	950 6.6	>3500$^{\Delta}$ >24.1$^{\Delta}$	>3350† >23.1†	>3500$^{\Delta}$ >24.1$^{\Delta}$	300 2.1	>3500† >24.1†
Colorant	4% 7526 colorant	950 6.6	>3500$^{\Delta}$ >24.1$^{\Delta}$	>3350† >23.1†	>3500$^{\Delta}$ >24.1$^{\Delta}$	300 2.1	>3500† >24.1†
Antistatic	3% Armostat 550	>3500$^{\Delta}$ >24.1$^{\Delta}$	>3500$^{\Delta}$ >24.1$^{\Delta}$	>3350† >23.1†	>3500$^{\Delta}$ >24.1$^{\Delta}$	300 2.1	>3500† >24.1†

NOTES:

Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.

† = Due to the **severe deformation** of the block shear specimens, testing was stopped before the actual bond strength achieved by the adhesive could be determined (the adhesive bond never failed).

■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

□ = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, 4011 and Super Bonder 414, cyanoacrylate adhesives, and Loctite 3105 and 3311, light curing acrylic adhesives, created bonds which were stronger than the ABS substrate. The bond strengths achieved using Black Max 380, a rubber toughened cyanoacrylate, were generally the second highest. However, the addition of an antistatic agent resulted in a large, statistically significant increase in the bond strengths achieved on ABS. Depend 330, a two-part no-mix acrylic adhesive, consistently achieved the lowest bond strengths.

Surface Treatments

Surface roughening caused a statistically significant increase in the bond strengths achieved when using Black Max 380 and Depend 330. The effect of surface roughening could not be determined for Prism 401, 4011, Super Bonder 414, Loctite 3105 and 3311 because the bonds created by these adhesives were stronger than the ABS substrate for both the treated and untreated ABS. Likewise, the effect of using Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, could not be determined.

Other Important Information

- ABS can be stress cracked by uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately.
- ABS is compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately.
- ABS is incompatible with anaerobic adhesives.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Allylic Ester (DAP, DAIP)

thermoset

Trade Names

- Cosmic DAP
- Dapex

Manufacturer

Cosmic Plastics
Rogers Corporation

General Description

Diallyl phthalate (DAP) is the most commonly used of the allylic esters, which are a branch of the polyester family. The backbone of the diallyl phthalate monomer is made of a chain of benzene rings and allyl groups which is formed from a condensation reaction of phthalic anhydride and allyl alcohol. The monomer is then made into a thermoset resin using a peroxide, which may then be further polymerized to create a thermoset plastic using a variety of methods. Specialty grades available include flame retarded and mineral, glass, and synthetic fiber filled. In 1994, the price of DAP ranged approximately from $2.50 to $6.00 per pound at truckload quantities.

General Properties

Allylic esters are among the most versatile of the thermosetting resins. Allylic resins are chosen for applications that require outstanding dimensional stability, ease of molding, low water absorption, and excellent electrical properties. Diallyl phthalate has a continuous service temperature as high as 500°F (260°C). Diallyl isophthalate, a similar but more expensive resin, may be used if superior dimensional and thermal stability is required. Allylic esters have excellent resistance to aliphatic hydrocarbons, oils, and alcohols, but are not recommended for use with phenols and oxidizing acids.

Typical Applications

- Electrical — connectors, switches, transformer cases, automotive distributor caps, insulators, potentiometers
- Miscellaneous — tubing, ducting, radomes, junction boxes, aircraft and missile parts

Typical Properties of Diallyl Phthalate

	American Engineering	SI
Processing temperature	250-350°F	121-177°C
Linear mold shrinkage	0.002-0.008 in/in	0.002-0.008 cm/cm
Melting point	–	-
Density	87.4-137.3 lb/ft^3	1.40-2.20 g/cm^3
Tensile strength, yield	3.0-3.4 lb/in^2 x 10^3	2.1-2.4 kg/cm^2 x 10^2
Tensile strength, break	1.0-12.5 lb/in^2 x 10^3	0.7-8.8 kg/cm^2 x 10^2
Elongation, break	–	-
Tensile modulus	13.0-20.0 lb/in^2 x 10^5	9.1-14.1 kg/cm^2 x 10^4
Flexural strength, yield	7.3-23.0 lb/in^2 x 10^3	5.1-16.2 kg/cm^2 x 10^2
Flexural modulus	6.7-26.0 lb/in^2 x 10^5	4.7-18.3 kg/cm^2 x 10^4
Compressive strength	21.0-32.0 lb/in^2 x 10^3	14.8-22.5 kg/cm^2 x 10^2
Izod notched, R.T.	0.3-7.0 ft-lb/in	1.6-37.8 kg cm/cm
Hardness	–	–
Thermal conductivity	2.1-3.3 BTU-in/hr-ft^2-°F	0.30-0.48 W/m°-K
Linear thermal expansion	0.3-3.5 in/in-°F x 10^{-5}	0.5-6.3 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	250-550°F	121-288°C
Deflection temp. @ 66 psi	280-600°F	138-316°C
Continuous service temp.	300-500°F	149-260°C
Dielectric strength	330-480 V/10^{-3} in	1.3-1.9 V/mm x 10^4
Dielectric constant @ 1MHz	3.5-4.6	3.5-4.6
Dissipation factor @ 1MHz	0.010-0.180	0.010-0.180
Water absorption, 24 hr	0.15-0.30%	0.15-0.30%

ADHESIVE SHEAR STRENGTH

(psi)
(MPa)

Diallyl Phthalate **DAP courtesy of Rogers Corporation**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Grade RX3-1-525F	short glass fiber reinforced flame retardant black coloring - 18 rms	>1950Δ >13.5Δ	>3150Δ >21.7Δ	150 1.0	>2700Δ >18.6Δ	350 2.4	350 2.4
Grade RX3-1-525F roughened	28 rms	>1950Δ >13.5Δ	>3150Δ >21.7Δ	300 2.1	>2700Δ >18.6Δ	1400 9.7	350 2.4
Grade RX1310	short glass fiber reinforced green coloring – 16 rms	>1700Δ >11.7Δ	>2350Δ >16.2Δ	150 1.0	>3000Δ >20.7Δ	650 4.5	450 3.1
Grade RX1310 roughened	27 rms	>1700Δ >11.7Δ	>2350Δ >16.2Δ	550 3.8	>3000Δ >20.7Δ	2150 14.8	1450 10.0
Grade RX1-510N	mineral filled blue coloring 14 rms	>1700Δ >11.7Δ	>2900Δ >20.0Δ	100 0.7	>2750Δ >19.0Δ	500 3.5	300 2.1
Grade RX1-510N roughened	24 rms	>2550Δ >17.6Δ	>2900Δ >20.0Δ	1050 7.2	>2750Δ >19.0Δ	2300 15.9	1700 11.7

NOTES:

Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.

■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

The four cyanoacrylates tested, namely Prism 401, 4011, Super Bonder 414, and Black Max 380, created bonds which were stronger than the three grades of DAP evaluated. Depend 330, a two-part no-mix acrylic adhesive, and Loctite 3105 and 3311, light curing acrylic adhesives, achieved modest bond strengths on DAP. There were no statistically significant differences between the bondability of the three grades of DAP evaluated.

Surface Treatments

The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, significantly lowered the bond strengths achieved on DAP. Surface roughening caused a statistically significant increase in bond strength when using Depend 330 and Loctite 3105 and 3311. The effect of surface roughening on the bond strengths achieved by cyanoacrylate adhesives could not be determined because both roughened and unroughened DAP bonded with cyanoacrylates resulted in substrate failure.

Other Important Information

- Allylic esters are compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Cellulose Acetate Propionate (CAP)

thermoplastic 7 OTHER

Trade Names

- Tenite

Manufacturer

Eastman Chemical Products

General Description

Cellulose is a naturally occurring polymer derived from wood pulp and cotton which is chemically modified to form a cellulosic plastic. The three major families of cellulose are ethyl cellulose, cellulose nitrate, and cellulose esters. The four most commonly used cellulose esters are cellulose acetate (CA), cellulose acetate butyrate (CAB), cellulose acetate propionate (CAP), and cellulose triacetate. Cellulose acetate propionate, one of the most commonly used cellulosic polymers, is manufactured by reacting cellulose with propionic acid and propionic anhydride. Cellulosics are tough, abrasion resistant plastics that have found use in a variety of applications such as films, dice, and eyeglasses. Specialty grades available include plasticized, UV stabilized, flame retardant, and colored. In 1994, the price of CAP ranged approximately from $1.50 to $2.00 per pound at truckload quantities.

General Properties

The main benefits offered by cellulosics are clarity, toughness at low temperatures, abrasion resistance, glossy appearance, resistance to stress cracking, and good electrical insulating properties. Other benefits of cellulosics include a warm, pleasant feel to the touch (due to their low thermal conductivity and specific heat), the availability of formulations which can be used in contact with food, and the ability to be processed by most thermoplastic methods. Generally, plasticizers are added to lower the melt temperature and modify the physical properties. As plasticizer is added, the hardness, stiffness and tensile strength decrease, while the impact strength increases. The solvent resistance of cellulosics varies with type. In general, they are resistant to attack by aliphatic hydrocarbons, bleach, ethylene glycol, salt solutions, and vegetable and mineral oils. However, cellulosics are known to be attacked by alkaline materials and fungus. Cellulosics are further limited by their flammability, low continuous use temperatures, and poor resistance to weathering, although UV resistant grades are available.

Typical Properties of Cellulose Acetate Propionate

	American Engineering	SI
Processing temperature	–	–
Linear mold shrinkage	–	–
Melting point	300-400°F	149-204°C
Density	74.9-81.2 lb/ft^3	1.20-1.30 g/cm^3
Tensile strength, yield	3.6-6.1 lb/in^2 x 10^3	2.5-4.3 kg/cm^2 x 10^2
Tensile strength, break	4.5-7.1 lb/in^2 x 10^3	3.2-5.0 kg/cm^2 x 10^2
Elongation, break	-	–
Tensile modulus	-	–
Flexural strength, yield	4.4-8.2 lb/in^2 x 10^3	3.1-5.8 kg/cm^2 x 10^2
Flexural modulus	1.9-3.2 lb/in^2 x 10^5	1.3-2.2 kg/cm^2 x 10^4
Compressive strength	4.4-8.1 lb/in^2 x 10^3	3.1-5.8 kg/cm^2 x 10^2
Izod notched, R.T.	1.2-8.3 ft-lb/in	6.5-44.8 kg cm/cm
Hardness	R75-R13 Rockwell	R75-R13 Rockwell
Thermal conductivity	1.73-1.74 BTU-in/hr-ft^2-°F	0.246-0.251 W/m-°K
Linear thermal expansion	–	–
Deflection temp. @ 264 psi	120-200°F	49-93°C
Deflection temp. @ 66 psi	140-230°F	60-110°C
Continuous service temp.	–	–
Dielectric strength	–	–
Dielectric constant @ 1MHz	3.5-3.6	3.5-3.6
Dissipation factor @ 1MHz	0.020-0.030	0.020-0.030
Water absorption, 24 hr	1.3-2.4%	1.3-2.4%

Typical Applications

- Films: photographic film, audio tape, visual aids, greeting cards, photo albums
- Miscellaneous: lacquer and cement base, explosives, fashion accessories, flashlight cases, fire extinguisher components, toys, tool handles, electrical appliance housings, eyeglass frames and lenses, lighting fixtures, brush handles

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Cellulose Acetate Propionate

Tenite 3754000012 produced by Eastman Performance Products

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	3 rms	400 2.8	1950 13.5	2150 14.8	1550 10.7	1200 8.3	1850 12.8
Roughened	19 rms	400 2.8	1950 13.5	1550 10.7	1550 10.7	900 6.2	1850 12.8
Antioxidant	0.15% Irganox 1010	400 2.8	1950 13.5	2150 14.8	1550 10.7	700 4.8	1850 12.8
UV stabilizer	0.2% Chimasorb 994	400 2.8	>2450$^{\Delta}$ >16.9$^{\Delta}$	2000 13.8	2000 13.8	550 3.8	1850 12.8
Flame retardant	17% Reofos 35	250 1.7	1350 9.3	1000 6.9	900 6.2	650 4.5	1300 9.0
Plasticizer	9% Benzoflex 988	250 1.7	1050 7.2	1200 8.3	1150 7.9	650 4.5	1500 10.3
Lubricant	0.1% Zinc Stearate	250 1.7	1950 13.5	2150 14.8	750 5.2	350 2.4	1850 12.8
Filler #1	17% 497 Fiberglass	400 2.8	1950 13.5	>2200$^{\Delta}$ >15.2$^{\Delta}$	1550 10.7	650 4.5	>1900† >13.1†
Filler #2	17% Omyacarb F $CaCO_3$	650 4.5	>1950 >13.5	>2150$^{\Delta}$ >14.8$^{\Delta}$	1550 10.7	1200 8.3	>1600† >11.0†
Colorant	1% Green	400 2.8	1950 13.5	2150 14.8	1550 10.7	850 5.9	1850 12.8
Antistatic	1.5% Markstat AL-12	1700 11.7	>2200$^{\Delta}$ >15.2$^{\Delta}$	1800 12.4	>2450$^{\Delta}$ >16.9$^{\Delta}$	400 2.8	>2250$^{\Delta}$ >15.5$^{\Delta}$

NOTES:

Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.

† = Due to the **severe deformation** of the block shear specimens, testing was stopped before the actual bond strength achieved by the adhesive could be determined (the adhesive bond never failed).

■ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

■ (pink) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, and Loctite 3105 and 3311, light curing acrylic adhesives, typically achieved the highest bond strengths on CAP. Depend 330, a two-part no-mix acrylic adhesive, achieved the second highest bond strengths, followed by Black Max 380, a rubber toughened cyanoacrylate adhesive.

Surface Treatments

Prism Primer 770, when used in conjunction with Prism 401, or 4011 with 7701, had no overall statistically significant effect on the formulations of CAP which were evaluated. However, it did cause a statistically significant decrease in bond strengths achieved on the UV stabilized and antistatic formulations, and a statistically significant increase for the glass and calcium carbonate filled formulations. Surface roughening caused either no effect or a statistically significant decrease in the bondability of CAP.

Other Important Information

- Cellulosics can be stress cracked by uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately.
- Cellulosics are compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Epoxy

thermoset

Trade Names	Manufacturer
• Araldite	Ciba-Geigy Corp.
• Conapoxy	Conap, Inc.
• Eccogel	Emerson & Cuming
• Eccoseal	Emerson & Cuming
• Epolite	Hexcel Corp.
• EPON	Shell Chemical Co.
• Epoxylite	Epoxylite Corp.
• Lytex	Premix, Inc.
• Maraglas	Acme
• Paraplast	Hexcel Corp.
• Fixmaster Poxy Pak	Loctite
• Quatrex	Dow Chemical
• Ren	Ciba-Geigy Corp.
• Scotchply	3M Industrial Chemicals
• Stycast	Emerson & Cuming
• Tactix	Dow Chemical

General Description

Epoxies are polymers that have epoxide groups, or oxirane rings, in their molecular structure. They are usually nonmelting thermosetting materials, but linear, high molecular weight thermoplastic epoxies are also available. Thermoset epoxies are usually supplied as one-part frozen premixes or two-part systems. Room temperature curing formulations are available, but heat curing epoxies typically have shorter cure cycles and superior physical properties. Epoxies may utilize many different curing agents including aromatic amines, anhydrides, carboxylic acids, phenol novolacs, and amino resins. The large number of variations possible in the chemical structure and cure mechanism of epoxies, coupled with their ability to be compounded with a wide variety of additives and fillers, has lead to epoxies' use in a vast variety of applications. Epoxies find use as adhesives, coatings, and binding resins in composite structures. Specialty grades available include, but are not limited to, electrically conductive, thermally conductive, fiber reinforced, wear resistant, and machinable grades. In 1994, the price of epoxies ranged approximately from $1.00 to $25.00 per pound at truckload quantities.

General Properties

Due to the vast array of fillers and different types of epoxy resins, the properties of epoxies vary substantially. Epoxies are generally very strong, heat, chemical, and abrasion resistant plastics. Glass fiber reinforced epoxy resins provide excellent strength-to-weight ratios and are used in many high technology applications. Many retain excellent electrical properties in extreme conditions and are used in heavy electrical applications that require long-term outdoor exposure. The excellent abrasion and chemical resistance of epoxy resins has led to their widespread use as flooring, coatings for pipes, and components for chemical scrubbers, as well as in marine applications. Epoxies are also well-known for their adhesive abilities, which accounts for much of their use. Most epoxies are resistant to a wide variety of chemicals, including hydrocarbons, esters, bases, and salts. However, epoxies can be attacked by phenols, ketones, ethers, and concentrated acids.

Typical Properties of Epoxy

	American Engineering	SI
Processing temperature	125-250°F	52-121°C
Linear mold shrinkage	0.001-0.015 in/in	0.001-0.015 cm/cm
Melting point	–	-
Density	43.7-139.2 lb/ft^3	0.70-2.23 g/cm^3
Tensile strength, yield	5.8-10.5 lb/in^2 x 10^3	4.1-7.4 kg/cm^2 x 10^2
Tensile strength, break	1.1-12.5 lb/in^2 x 10^3	0.8-8.8 kg/cm^2 x 10^2
Elongation, break	1.1-8.5%	1.1-8.5%
Tensile modulus	2.0-8.0 lb/in^2 x 10^5	1.4-5.6 kg/cm^2 x 10^4
Flexural strength, yield	4.0-25.0 lb/in^2 x 10^3	2.8-17.6 kg/cm^2 x 10^2
Flexural modulus	1.4-8.0 lb/in^2 x 10^5	1.0-5.6 kg/cm^2 x 10^4
Compressive strength	6.8-37.0 lb/in^2 x 10^3	4.8-26.0 kg/cm^2 x 10^2
Izod notched, R.T.	0.3-No Break ft-lb/in	1.6-No Break kg cm/cm
Hardness	D60-D96 Rockwell	D60-D96 Rockwell
Thermal conductivity	0.1-4.6 BTU-in/hr-ft^2-°F	0.014-0.663W/m°-K
Linear thermal expansion	1.2-11.1 in/in-°F x 10^{-5}	2.2-20.0 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	-	-
Deflection temp. @ 66 psi	-	-
Continuous service temp.	200-400°F	93-204°C
Dielectric strength	300-525 V/10^{-3} in	1.2-2.1 V/mm x 10^4
Dielectric constant @ 1MHz	2.7-4.7	2.7-4.7
Dissipation factor @ 1MHz	0.001-0.100	0.001-0.100
Water absorption, 24 hr	0.10-0.70%	0.10-0.70%

Typical Applications

• Coatings	marine coatings, chemical scrubbers, pipes
• Electronic	encapsulation and casting of transistors, integrated circuits, switches, coils, insulators, bushings
• Miscellaneous	adhesives, solder masks, rocket motor casings, pressure vessels, flooring, highway paving

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Epoxy **Loctite products**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
G-10 Epoxyglass	manufactured by Westinghouse Corp. 21 rms	3200 22.1	3350 23.1	250 1.7	3600 24.8	1000 6.9	1500 10.3
G-10 roughened	33 rms	3200 22.1	2150 14.8	1500 10.3	1800 12.4	1700 11.7	1500 10.3
Loctite Fixmaster Poxy Pak	92 rms	2100 14.5	>3200Δ >22.1Δ	2850 19.7	2650 18.3	1000 6.9	1550 10.7
Loctite Fixmaster Poxy Pak roughened	167 rms	3750 25.9	>3200Δ >22.1Δ	>2650Δ >18.3Δ	>3750Δ >25.9Δ	>1600Δ >11.0Δ	1550 10.7
Loctite Fixmaster Fast Cure Epoxy	116 rms	1600 11.0	1500 10.3	2100 14.5	2750 19.0	1350 9.3	1250 8.6
Loctite Fixmaster Fast Cure Epoxy roughened	134 rms	>1850Δ >12.8Δ	>1900Δ >13.1Δ	>1700Δ >11.7Δ	>1900Δ >13.1Δ	>1200Δ >8.3Δ	2050 14.1

NOTES:
Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.
■ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.
■ (red) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

The four cyanoacrylate adhesives evaluated, namely Black Max 380, Prism 401, 4011 and Super Bonder 414, achieved the highest bond strengths on the various types of epoxies tested. Loctite 3105 and 3311, light curing acrylic adhesives, and Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths.

Surface Treatments

Surface roughening usually caused either no effect or a statistically significant increase in the bond strengths achieved on epoxy. The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, caused a significant decrease in the bond strengths achieved for most of the epoxies evaluated.

Other Important Information

- Epoxy is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Fluoropolymers (PTFE, FEP, PFA, ETFE)

thermoplastic

OTHER

Trade Names / Manufacturer

Trade Names	Manufacturer
• Algoflon	Ausimont USA, Inc.
• Chemfluor	Norton Performance
• Fluon	ICA Americas Inc.
• Hostaflon	Hoeschst Celanese
• Teflon	E.I. DuPont

General Description

Polytetrafluoroethylene (PTFE) is a highly crystalline thermoplastic which is produced by free radical polymerization of tetrafluoroethylene. The resulting polymer has a linear molecular structure of repeating $-CF_2-CF_2-$ units. Due to PTFE's excellent chemical resistance, high melting point, low coefficient of friction, and outstanding resistance to flammability, it is usually used in applications which require long-term performance in extreme service environments. Specialty grades available include glass, glass/molysulfide, mica, carbon black, graphite, bronze, and ceramic filled grades. In 1994, the price of PTFE ranged approximately from $5.00 to $15.00 per pound at truckload quantities.

General Properties

Although PTFE's tensile strength, wear resistance, and creep resistance are low in comparison to other engineering thermoplastics, it has excellent impact strength, a coefficient of friction which is lower than almost any other material, a high oxygen index, and it will not support combustion. In addition, PTFE has useful mechanical properties at temperatures ranging from -328°F (-200°C) to 500°F (260°C). It has exceptional chemical resistance to most organic compounds including solvents, strong acids, and strong bases. PTFE is an outstanding electrical insulator, and it has a low dielectric constant and loss factor which are both stable over a wide range of temperatures and frequencies. It has an extremely high melt viscosity, so it cannot be processed by conventional melt extrusion or molding techniques. Methods for processing the resin are similar to those used with some metals and ceramics, such as compression of the powdered resin followed by high temperature sintering. Other fluorinated polymers, such as fluorinated ethylene propylene (FEP), perfluoroalkoxyethylene (PFA), polychlorotrifluoroethylene (PCTFE), and ethylene-tetrafluoroethylene copolymer (ETFE), have properties very similar to PTFE, but they can be processed by the usual thermoplastic methods.

Typical Properties of Polytetrafluoroethylene

	American Engineering	SI
Processing temperature	-	-
Linear mold shrinkage	0.030-0.130 in/in	0.030-0.130 cm/cm
Melting point	620-710°F	327-377°C
Density	112.4-150.5 lb/ft^3	1.80-2.41 g/cm^3
Tensile strength, yield	3.2-3.5 lb/in^2 x 10^3	2.2-2.5 kg/cm^2 x 10^2
Tensile strength, break	1.0-6.5 lb/in^2 x 10^3	0.7-4.6 kg/cm^2 x 10^2
Elongation, break	2.0-650.0%	2.0-650.0%
Tensile modulus	0.4-2.5 lb/in^2 x 10^5	0.3-1.8 kg/cm^2 x 10^4
Flexural strength, yield	0.9-4.7 lb/in^2 x 10^3	0.6-3.3 kg/cm^2 x 10^2
Flexural modulus	0.9-2.2 lb/in^2 x 10^5	0.6-1.5 kg/cm^2 x 10^4
Compressive strength	1.3-12.0 lb/in^2 x 10^3	0.9-8.4 kg/cm^2 x 10^2
Izod notched, R.T.	3.0-4.1 ft-lb/in	16.2-22.1 kg cm/cm
Hardness	D55-D75 Rockwell	D55-D75 Rockwell
Thermal conductivity	0.7-6.4 BTU-in/hr-ft^2-°F	0.10-0.92W/m°-K
Linear thermal expansion	1.0-10.3 in/in-°F x 10^{-5}	1.8-18.5 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	130-512°F	54-267°C
Deflection temp. @ 66 psi	150-550°F	66-288°C
Continuous service temp.	475-500°F	246-260°C
Dielectric strength	600-900 V/10^{-3} in	2.4-3.5 V/mm x 10^2
Dielectric constant @ 1MHz	2.1-2.4	2.1-2.4
Dissipation factor @ 1MHz	0.0001-0.0030	0.0001-0.0030
Water absorption, 24 hr	0.01-0.10%	0.01-0.10%

Typical Applications

• Electrical	high-temperature, high-performance wire and cable insulation, sockets, pins, connectors
• Mechanical	bushings, rider rings, seals, bearing pads, valve seats
• Nonstick coatings	home cookware, tools, food processing equipment
• Miscellaneous	conveyor parts, packaging, flame-retardant laminates, chemical processing equipment

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polytetrafluoroethylene

Teflon courtesy of E.I. DuPont Polymers

Loctite Industrial Adhesive	Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive	--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin 88 rms	200 1.4	350 2.4	1050 7.2	300 2.1	100 0.7	150 1.0
Roughened 349 rms	200 1.4	350 2.4	800 5.5	700 4.8	250 1.7	300 2.1
Teflon treated with Acton Fluoro Etch	950 6.6	1800 12.4	1550 10.7	1750 12.1	450 3.1	750 5.2
Teflon treated with Gore Tetra Etch	1350 9.3	1900 13.1	1200 8.3	1800 12.4	350 2.4	700 4.8
Ethylene tetrafluoroethylene copolymer (ETFE)	50 0.3	100 0.7	>1650 >11.4	100 0.7	50 0.3	100 0.7
Fluorinated ethylene-propylene (FEP)	<50 <0.3	<50 <0.3	<50 <0.3	<50 <0.3	<50 <0.3	<50 <0.3
Polyperfluoroalkoxyethylene (PFA)	<50 <0.3	100 0.7	400 2.8	50 0.3	<50 <0.3	50 0.3

NOTES: ■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401 used in conjunction with Prism Primer 770, or 4011 with 7701, achieved the highest bond strengths on all the unetched fluoroplastics. Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, typically achieved the next highest bond strengths while Black Max 380, a rubber toughened cyanoacrylate adhesive, Depend 330, a two-part no-mix acrylic adhesive, and Loctite 3105 and 3311, light curing acrylic adhesives, achieved the lowest bond strengths.

Surface Treatments

Acton FluoroEtch and Gore Tetra-Etch both caused large, statistically significant increases in the bond strengths achieved on PTFE. Surface roughening caused either no effect or small, statistically significant increase in the bond strengths achieved on PTFE. The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, caused a statistically significant increase in the bondability of the unprimed fluoropolymers, however, the effect was most pronounced on the PTFE and ETFE. Neither UV-ozone treatment nor plasma treatment caused an increase in the bondability of PTFE.

Other Important Information

- PTFE and all other fluorinated polymers are compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.
- For information on the chemical etchants call:

Acton Technologies, Inc.
100 Thompson Street
P.O. Box 726
Pittston, Pennsylvania 18640
(717) 654-0612

W.L. Gore & Associates, Inc.
1505 North Fourth Street
P.O. Box 3000
Flagstaff, Arizona 86003-3000
1-800-344-3644

Ionomer

thermoplastic

OTHER

Trade Names

- Formion
- Surlyn

Manufacturer

A. Schulman
DuPont

General Description

Ionomers are copolymers of ethylene and meth(acrylic) acid whose physical structure is distinguished by interchain ionic bonding. This bonding takes place between metal cations, such as zinc, sodium, and lithium, and an anion, such as the carboxylate group. Due to the dissociation of the interchain ionic bonding at high temperatures, ionomers can be processed using standard thermoplastic methods. Fillers are not typically used with ionomers, however glass fiber filled grades are available. In 1994 dollars, the price of ionomers ranged approximately from $1.50 to $2.25 per pound at truckload quantities.

General Properties

Properties of the ionomer resins vary with the amount and type of metal cation and the proportion of comonomer. Ionomers containing the zinc cation have better flow, impact strength, tear strength, paint adhesion and lower moisture absorption. Those containing the sodium cation offer lower haze and improved stress crack resistance, while the addition of the lithium cation increases the modulus. The good thermal stability, outstanding chemical resistance, and low moisture vapor transmission of ionomers result from their polyolefin-like structure. However, the interchain ionic crosslinking contributes excellent abrasion, puncture, and impact resistance, as well as low temperature toughness. Moreover, most ionomers have good optical clarity, and the less crystalline grades have superior clarity. Most commercial grades of ionomers comply with FDA regulations for food contact and food packaging which leads to their widespread use in this industry as a film. Ionomers weather poorly, consequently UV absorbers and stabilizers must be used in applications requiring resistance to weathering. Solvent resistance varies with the level of metal cation, but most ionomers are insoluble in common organic solvents at room temperature and resistant to mild acids and bases.

Typical Properties of Ionomer

	American Engineering	SI
Processing temperature	450-500°F	232-260°C
Linear mold shrinkage	0.003-0.006 in/in	0.003-0.006 cm/cm
Melting point	175-205°F	79-96°C
Density	58.7-62.4 lb/ft^3	0.94-1.00 g/cm^3
Tensile strength, yield	1.3-5.8 lb/in^2 x 10^3	0.9-4.1 kg/cm^2 x 10^2
Tensile strength, break	2.4-5.1 lb/in^2 x 10^3	1.7-3.6 kg/cm^2 x 10^2
Elongation, break	150-520%	150-520%
Tensile modulus	0.1-0.5 lb/in^2 x 10^5	0.1-0.4 kg/cm^2 x 10^4
Flexural strength, yield	-	-
Flexural modulus	0.1-2.5 lb/in^2 x 10^5	0.1-1.8 kg/cm^2 x 10^4
Compressive strength	-	-
Izod notched, R.T.	7.0-No Break ft-lb/in	38.7-No Break kg cm/cm
Hardness	D50-D68 Rockwell	D50-D68 Rockwell
Thermal conductivity	1.6-2.1 BTU-in/hr-ft^2-°F	0.23-0.30 W/m-°K
Linear thermal expansion	6.1-13.0 in/in-°F x 10^{-5}	11.0-23.4 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	85-115°F	29-46°C
Deflection temp. @ 66 psi	100-180°F	38-82°C
Continuous service temp.	-	-
Dielectric strength	400-450 V/10^{-3} in	1.6-1.8 V/mm x 10^4
Dielectric constant @ 1MHz	-	-
Dissipation factor @ 1MHz	0.002-0.003	0.002-0.003
Water absorption, 24 hr	-	-

Typical Applications

- Packaging — vacuum packaging of meat, tear-open packages for food and pharmaceutical products, heavy gauge film for electronic products
- Sporting goods — golf balls, bowling pins, ice skates, ski boots, wrestling mats
- Automotive parts — bumper guards, exterior trim
- Miscellaneous — foam to make buoys, thin films for bulletproof glass

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Ionomer **Surlyn courtesy of E.I. DuPont**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Grade 7940	4 rms	200 1.4	>1200† >8.3†	>1200† >8.3†	>1200† >8.3†	450 3.1	>1200† >8.3†
7940 roughened	68 rms	>1200† >8.3†	>1200† >8.3†	>1200† >8.3†	>1200† >8.3†	450 3.1	>1200† >8.3†
Grade 8940	4 rms	200 1.4	>1200† >8.3†	>1200† >8.3†	>1200† >8.3†	350 2.4	>1200† >8.3†
8940 roughened	68 rms	>1200† >8.3†	>1200† >8.3†	>1200† >8.3†	>1200† >8.3†	350 2.4	>1200† >8.3†
Grade 9950	4 rms	50 0.3	>1200† >8.3†	>1200† >8.3†	>1200† >8.3†	350 2.4	>1200† >8.3†
9950 roughened	68 rms	800 5.5	>1200† >8.3†	>1200† >8.3†	>1200† >8.3†	350 2.4	>1200† >8.3†

NOTES:
† = Due to the **severe deformation** of the block shear specimens, testing was stopped before the actual bond strength achieved by the adhesive could be determined (the adhesive bond never failed).
■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, and Loctite 3105 and 3311, light curing acrylic adhesives, all created bonds which were stronger than the ionomer substrate. Black Max 380, a rubber toughened cyanoacrylate adhesive, and Depend 330, a two-part no-mix adhesive, both achieved the significantly lowest bond strengths. There was no statistically significant difference between the bondability of the three grades of Surlyn evaluated, with the exception of the low bond strengths achieved by Black Max 380 on Surlyn 9950.

Surface Treatments

Surface roughening caused a large, statistically significant increase in the bond strengths achieved by Black Max 380, but had no statistically significant effect with Depend 330. The effect of Prism Primer 770 or 7701, and surface roughening with Prism 401, 4011, Super Bonder 414, Loctite 3105 or 3311, could not be determined because with both the treated and untreated ionomer, the bonds created were stronger than the ionomer substrate.

Other Important Information

- Ionomers can be stress cracked by uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Liquid Crystal Polymer (LCP)

thermoplastic

Trade Names

- Granlar
- HX Series
- Vectra
- Xydar

Manufacturer

Granmont Inc.
E.I. DuPont
Hoescht Celanese
Amoco Perform. Products

General Description

Liquid crystal polymers (LCP), properly called wholly aromatic copolyesters, can be based on terephthalic acid, p,p-dihydroxybiphenyl, and p-hydroxybenzoic acid. The compounds react to form tightly packed, rigid polymer chains consisting of long, flat monomeric units. LCP's resistance to weathering, radiation, burning, and almost all chemicals, as well as its outstanding strength at extreme temperatures, makes it a suitable replacement for most other engineering materials, including metals and ceramics. Specialty grades available include glass, carbon, and mineral filled, as well as wear resistant, colored, and alloyed. In 1994, the price of LCP ranged approximately from $7.00 to $12.00 per pound at truckload quantities.

General Properties

LCP has outstanding mechanical properties at both ambient and extreme temperatures. For example, LCP can have a tensile modulus as high as 1.20x10^6 psi (8.4x10^4 kg/cm2) at 575°F (308°C), which exceeds that of most other engineering thermoplastics at room temperature. Grades of LCP have tensile strengths in excess of 20,000 psi (1400 kg/cm2), a compressive strength of more than 6,000 psi (422 kg/cm2), and its mechanical properties improve at subzero temperatures. LCP is resistant to virtually all chemicals, including acids, organic hydrocarbons, and boiling water. It is attacked by concentrated, boiling caustic but is unaffected by milder solutions. LCP is also unaffected by ionizing and Cobalt 60 radiation up to 10 billion rads, it withstands high levels of UV radiation, and is transparent to microwaves. It is an electrical insulator with good arc resistance, is UL rated for continuous electrical service at 464°F (240°C), and can be used for applications with intermittent temperatures up to 600°F (316°C). LCP is inherently flame resistant, rated UL94 V-0, and will not sustain combustion. It has remarkable thermal oxidative stability with a decomposition temperature of greater than 1000°F (550°C) in air.

Typical Properties of Liquid Crystal Polymer

	American Engineering	SI
Processing temperature	500-700°F	260-371°C
Linear mold shrinkage	0.001-0.002 in/in	0.001-0.002 cm/cm
Melting point	530-670°F	277-354°C
Density	93.0-111.7 lb/ft^3	1.49-1.79 g/cm^3
Tensile strength, yield	21.5-30.0 lb/in^2 x 10^3	15.1-21.1 kg/cm^2 x 10^2
Tensile strength, break	9.0-30.0 lb/in^2 x 10^3	6.3-21.1 kg/cm^2 x 10^2
Elongation, break	1.0-3.0%	1.0-3.0%
Tensile modulus	14.6-32.0 lb/in^2 x 10^5	10.3-22.5 kg/cm^2 x 10^4
Flexural strength, yield	13.7-27.0 lb/in^2 x 10^3	9.6-26.0 kg/cm^2 x 10^2
Flexural modulus	13.9-23.2 lb/in^2 x 10^5	9.8-16.3 kg/cm^2 x 10^4
Compressive strength	6.5-11.6 lb/in^2 x 10^3	4.6-8.2 kg/cm^2 x 10^2
Izod notched, R.T.	0.7-3.1 ft-lb/in	3.8-16.7 kg cm/cm
Hardness	R95-R110 Rockwell	R95-R110 Rockwell
Thermal conductivity	0.9-3.1 BTU-in/hr-ft^2-°F	0.13-0.45W/m-°K
Linear thermal expansion	0.1-1.5 in/in-°F x 10^{-5}	0.2-2.7 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	350-660°F	170-349°C
Deflection temp. @ 66 psi	-	-
Continuous service temp.	-	-
Dielectric strength	550-900 V/10^{-3} in	2.2-3.5 V/mm x 10^4
Dielectric constant @ 1MHz	3.1-4.3	3.1-4.3
Dissipation factor @ 1MHz	0.020-0.030	0.020-0.030
Water absorption, 24 hr	0.01-0.10%	0.01-0.10%

Typical Applications

- Electrical — stator insulation, rotors, boards for motors, burn-in sockets, interface connectors
- Heavy Industry — chemical process and oil field equipment

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Liquid Crystal Polymer

Xydar courtesy of Amoco Performance Products

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
G-540	40% glass reinforced 63 rms	500 3.5	300 2.1	400 2.8	350 2.4	450 3.1	650 4.5
G-540 roughened	58 rms G-930	1050 7.2	1100 7.6	1050 7.2	1100 7.6	1150 7.9	650 4.5
G-930	30% glass reinforced 106 rms	350 2.4	300 2.1	500 3.5	350 2.4	500 3.5	500 3.5
G-930 roughened	G-930 roughened 113 rms	1200 8.3	1450 10.0	1550 10.7	1250 8.6	900 6.2	500 3.5

NOTES: ■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

Adhesive Performance

Black Max 380, a rubber toughened cyanoacrylate adhesive, Prism 401, 4011 and Super Bonder 414, cyanoacrylate adhesives, Depend 330, a two-part no-mix acrylic adhesive, and Loctite 3105 and 3311, light curing acrylic adhesives, all achieved moderate bond strengths on LCP.

Surface Treatments

Surface roughening caused a large, statistically significant increase in the bond strengths achieved on LCP for all the adhesives evaluated, except Loctite 3105 and 3311, for which surface roughening had no statistically significant effect. Although the process of surface roughening did not result in a significant increase in the surface roughness of the LCP, it removed a surface layer, which resulted in higher bond strengths. The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, resulted in no statistically significant change in the bondability of LCP.

Other Important Information

- LCP is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Phenolic

thermoset

Trade Names

- Durez
- Fiberite FM
- Plaslok
- Plenco
- Polychem
- Pyrotex
- Rogers RX
- Tecolite

Manufacturer

Occidental Chemical
ICI/Fiberite
Plaslok Corporation
Plastics Engineering Co.
Budd Company
Raymark Friction Co.
Rogers Corporation
Toshiba Chemical Products

General Description

Phenolic resins are usually produced by reacting phenol and formaldehyde. The resins are then subsequently heat cured to form the highly crystalline, thermosetting phenolic polymer. Due to phenolics' thermoset structure, and high crosslink density, they have outstanding rigidity, dimensional stability, chemical resistance, and thermal stability. The major limitation to using phenolics is that they are difficult to process, requiring heat cure cycles under pressure. In addition, phenolics are only available in dark colors because of the oxidative discoloration which takes place during polymerization. Insulating adhesives, molded items, and the bonding agents used in plywood and waferboard are just some of phenolic's many applications. Specialty grades available include cotton, rope, glass, and mineral filled grades, as well as heat resistant and electric grades. In 1994, the price of phenolic ranged approximately from $0.75 to $2.25 per pound at truckload quantities.

Typical Properties of Phenolic

	American Engineering	SI
Processing temperature	230-350°F	110-177°C
Linear mold shrinkage	0.002-0.009 in/in	0.002-0.009 cm/cm
Melting point	-	-
Density	83.7-99.9 lb/ft^3	1.34-1.60 g/cm^3
Tensile strength, yield	6.0-8.0 lb/in^2 x 10^3	4.2-5.6 kg/cm^2 x 10^2
Tensile strength, break	5.0-9.0 lb/in^2 x 10^3	3.5-6.3 kg/cm^2 x 10^2
Elongation, break	0.1-1.0%	0.1-1.0%
Tensile modulus	10.0-16.0 lb/in^2 x 10^5	7.0-11.2 kg/cm^2 x 10^4
Flexural strength, yield	6.5-15.0 lb/in^2 x 10^3	4.6-10.5 kg/cm^2 x 10^2
Flexural modulus	8.0-17.5 lb/in^2 x 10^5	5.6-12.3 kg/cm^2 x 10^4
Compressive strength	23.5-34.0 lb/in^2 x 10^3	16.5-23.9 kg/cm^2 x 10^2
Izod notched, R.T.	0.3-0.7 ft-lb/in	1.4-3.8 kg cm/cm
Hardness	M50-M120 Rockwell	M50-M120 Rockwell
Thermal conductivity	3.0-10.6 BTU-in/hr-ft^2-°F	0.43-1.47 W/m°-K
Linear thermal expansion	1.5-3.4 in/in-°F x 10^{-5}	2.7-6.1 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	250-500°F	121-260°C
Deflection temp. @ 66 psi	-	-
Continuous service temp.	350-450°F	177-232°C
Dielectric strength	200-400 V/10^{-3} in	0.8-1.6 V/mm x 10^4
Dielectric constant @ 1MHz	4.4-9.2	4.4-9.2
Dissipation factor @ 1MHz	0.030-0.070	0.030-0.070
Water absorption, 24 hr	0.03-0.80%	0.03-0.80%

General Properties

Phenolics have moderate strength compared to other plastics, but high hardness and greater rigidity than most thermoplastics and many thermosets. Some grades of phenolic are comparable to much more expensive engineering resins, with continuous service temperatures in excess of 400°F (204°C). In addition, the excellent electrical properties of phenolic are maintained at these elevated temperatures. Phenolics have outstanding creep resistance, very low mold shrinkage, and they change size only slightly with changes in temperature. Typical of a thermoset plastic, the chemical resistance of phenolics is excellent. Phenolics are resistant to hydrocarbons, phenols, and ethers, however, are severely attacked by acids and bases. Many grades have excellent flame resistance, and receive UL 94 ratings of HB and V-0.

Typical Applications

- Appliances — handles, knobs, bases, end panels
- Automotive — brake components, electric motors, rotors, fuse blocks, coil towers solenoid covers and housings, ignition parts
- Electrical — terminal switches and blocks, plugs, receptacles, circuit breakers, light sockets, control housings, high performance connectors and coil bobbins
- Miscellaneous — adhesives, commutators, timers, pulleys, cookware handles

ADHESIVE SHEAR STRENGTH

(psi)
(MPa)

Phenolic **Durez courtesy of Occidental Chemical Corporation**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
General-purpose 25000118	cellulose, wood flour, zinc stearate, and calcium stearate filled with black pigment	1600 11.0	600 4.1	150 1.0	400 2.8	900 6.2	1100 7.6
25000118 roughened		1600 11.0	600 4.1	150 1.0	400 2.8	900 6.2	1450 ■ 10.0 ■
Glass filled 32245	mineral filled in addition to general-purpose ingredients	1500 10.3	450 3.1	150 1.0	250 1.7	850 5.9	600 4.1
Heat resistant 152118	mineral filled in addition to general-purpose ingredients	>1750Δ >12.1Δ	1800 12.4	100 0.7	1800 12.4	500 3.5	1250 8.6
Electric grade 156122	glass, mineral filled in addition to general-purpose ingredients	>1650Δ >11.4Δ	400 2.8	150 1.0	400 2.8	600 4.1	1050 7.2
Plenco 04300	mineral filled, heat resistant courtesy of Plastics Engineering Company	>1900Δ >13.1Δ	>1750Δ >12.1Δ	50 0.3	>2300Δ >15.9Δ	>1800Δ >12.4Δ	750 5.2

NOTES:
Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.
■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

Adhesive Performance

Black Max 380, a rubber toughened cyanoacrylate adhesive, and Loctite 3105 and 3311, light curing acrylic adhesives, achieved the highest bond strengths on most of the grades of phenolic which were evaluated. Prism 401, 4011 and Super Bonder 414, cyanoacrylate adhesives, and Depend 330, a two-part no-mix acrylic adhesive, typically achieved lower bond strengths, but still created bonds of significant strength.

Surface Treatments

The use of Prism primer 770, in conjunction with 401, or 4011 with 7701, caused a statistically significant decrease in the bondability of the various grades of phenolic which were evaluated. Surface roughening caused a statistically significant increase in the bond strengths achieved on phenolics when using Loctite 3105 and 3311, but had no significant effect when using any of the other adhesives.

Other Important Information

- Phenolic is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polyamide

thermoplastic ♳ OTHER

Trade Names	Manufacturer
• Adell	Adell Plastics, Inc.
• Akulon	DSM Engineering
• Amilan	Toray Industries
• Ashlene	Ashley Polymers
• Capron	Allied-Signal Corp
• Celstran	Hoescht Celanese
• Minlon	E.I DuPont
• Nybex	Ferro Corporation
• PA	Bay Resins
• Rilsan	Atochem N.A.
• Ultramid	BASF
• Vestamid	Huls America
• Vydyne	Monsanto Chemical
• Zytel	E.I. DuPont

Typical Properties of Polyamide

	American Engineering	SI
Processing temperature	425-545°F	218-285°C
Linear mold shrinkage	0.007-0.018 in/in	0.007-0.018 cm/cm
Melting point	420-430°F	216-221°C
Density	68.7-73.0 lb/ft^3	1.10-1.17 g/cm^3
Tensile strength, yield	5.0-15.0 lb/in^2 x 10^3	3.5-10.5 kg/cm^2 x 10^2
Tensile strength, break	7.4-12.5 lb/in^2 x 10^3	5.2-8.8 kg/cm^2 x 10^2
Elongation, break	10-300%	10-300%
Tensile modulus	1.0-5.0 lb/in^2 x 10^5	0.7-3.5 kg/cm^2 x 10^4
Flexural strength, yield	9.5-19.0 lb/in^2 x 10^3	6.7-13.4 kg/cm^2 x 10^2
Flexural modulus	1.2-4.9 lb/in^2 x 10^5	0.8-3.4 kg/cm^2 x 10^4
Compressive strength	1.2-14.2 lb/in^2 x 10^3	0.8-10.0 kg/cm^2 x 10^2
Izod notched, R.T.	0.5-2.5 ft-lb/in	2.7-13.5 kg cm/cm
Hardness	R75-R120 Rockwell	R75-R120 Rockwell
Thermal conductivity	1.2-2.0 BTU-in/hr-ft^2-°F	0.17-0.29 W/m-°K
Linear thermal expansion	3.9-6.0 in/in-°F x 10^{-5}	7.0-10.8 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	110-410°F	43-210°C
Deflection temp. @ 66 psi	250-420°F	121-216°C
Continuous service temp.	175-240°F	79-116°C
Dielectric strength	300-500 V/10^3 in	1.2-2.2 V/mm x 10^4
Dielectric constant @ 1MHz	3.1-4.1	3.1-4.1
Dissipation factor @ 1MHz	3.1-4.1	3.1-4.1
Water absorption, 24 hr	0.25-3.0%	0.25-3.0%

General Description

Polyamide, commonly called nylon, is a semi-crystalline thermoplastic which is composed of linear aliphatic segments that are connected by amide linkages. Polyamide can be produced either by the polymerization of a lactam and an amino acid or a dibasic acid and a diamine. The wide variety of routes by which nylon can be produced, make it possible to tailor the backbone to meet specific needs. The various types of nylon are identified by number designations which represent the number of carbon atoms in each of the starting materials. For example, nylon 6/6 is made from the 6-carbon hexamethylenediamine and a 6-carbon adipic acid. Specialty grades available include lubricated, plasticized, flame retardant, and glass filled. In 1994, the price of nylon 6 ranged approximately from $1.75 to $16.50 per pound at truckload quantities.

General Properties

All nylons absorb moisture from the atmosphere, and the water that enters their structure causes dimensional changes and acts as a plasticizer. These factors must be taken into account when designing a critical part constructed of polyamide. The plastic is inexpensive and has excellent tensile strength which are reasons for its widespread use as a fiber. Unfilled polyamide is biologically inert, and most grades have been cleared for food contact use by the FDA. Nylons are resistant to many chemicals, including ketones, fully halogenated hydrocarbons, esters, fuels, and brake fluids. Polar solvents tend to be absorbed much like water, and strong acids, oxidizing agents and some concentrated salts will attack them. Gradual oxidation occurs in polyamide at elevated temperatures, but short-term exposures can exceed 400°F (200°C). Some heat-stabilized grades have been rated up to 265°F (130°C) for electrical applications, but mechanical application ratings are lower.

Typical Applications

• Automotive	electrical connectors, wire jackets, emission canisters, light duty gears, fan blades, brake fluid and power steering reservoirs, valve covers, steering column housings, emission control valves, mirror housings
• Electronic	cable ties, plugs, connectors, coil forms, terminals

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polyamide **Nylon 6–Capron 8202 produced by Allied-Signal**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	11 rms	2450 16.9	4500 31.0	1600 11.0	4100 28.3	450 3.1	1400 9.7
Roughened	15 rms	2450 16.9	4500 31.0	1600 11.0	4100 28.3	450 3.1	1400 9.7
Antioxidant	0.35% Irganox B1171	2450 16.9	4500 31.0	250 1.7	4100 28.3	450 3.1	1400 9.7
UV stabilizer	0.63% Chimasorb 944	2450 16.9	4500 31.0	1600 11.0	4100 28.3	450 3.1	1400 9.7
Impact modifier	5% EXL 3607	>2200Δ >15.2Δ	>4500Δ >31.0Δ	>1600Δ >11.0Δ	>4300Δ >29.7Δ	450 3.1	1400 9.7
Flame retardant	18% PO-64P 4% Antimony Oxide	1700 11.7	4500 31.0	1600 11.0	4100 28.3	450 3.1	1400 9.7
Lubricant #1	0.5% Aluminum Stearate	1450 10.0	4500 31.0	350 2.4	4600 31.7	450 3.1	1400 9.7
Lubricant #2	0.5% Moldwiz INT-33PA	2450 16.9	>4500Δ >31.0Δ	550 3.8	>3750Δ >25.9Δ	450 3.1	1050 7.2
Glass filler	30% Type 3450 Glass Fiber	2450 16.9	>4700Δ >32.4Δ	150 1.0	>4450Δ >30.7Δ	450 3.1	1400 9.7
Talc filler	30% Mistron CB Talc	2450 16.9	2200 15.2	2100 14.5	2750 19.0	450 3.1	1400 9.7
Plasticizer	4% Ketjen-Flex 8450	3300 22.8	>4550Δ >31.4Δ	650 4.5	>4450Δ >30.7Δ	450 3.1	1400 9.7
Antistatic	5% Larostat HTS 906	2450 16.9	>3100Δ >21.4Δ	350 2.4	>4100Δ >28.3Δ	450 3.1	1400 9.7

NOTES:

Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.

■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

- Consumer goods — ski boots, ice skates supports, racquetball racquets, ballpoint pens
- Miscellaneous — oven cooking bags, gun stocks, air conditioner hose, brush bristles, sutures, fishing line, mallet heads, combs, furniture parts

Adhesive Performance

Prism 401, 4011 and Super Bonder 414, cyanoacrylate adhesives, achieved the highest bond strengths, typically in excess of 4000 psi. Black Max 380, a rubber toughened cyanoacrylate adhesive, achieved the second highest bond strengths, followed by Loctite 3105 and 3311, light curing acrylic adhesives. Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths.

Surface Treatments

Surface roughening caused a statistically significant increase in the bond strengths achieved when using Depend 330, but it did not have any statistically significantly effect with any of the other adhesives. The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, caused either no effect, or a statistically significant decrease in the bondability of nylon 6, on all of the formulations which were evaluated.

Other Important Information

- Polyamide is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polybutylene Terephthalate (PBT)

thermoplastic 7 OTHER

Trade Names / Manufacturer

Trade Names	Manufacturer
• Arnite	DSM Engineering
• Celanex	Hoescht Celanese
• Minlon	E.I. DuPont
• Pocan	Albis Corporation
• Toray	Toray Industries
• Ultradur	BASF
• Valox	General Electric
• Vybex	Ferro Corporation

General Description

Polybutylene terephthalate (PBT) is a crystalline thermoplastic polyester formed by the catalyzed melt polycondensation of dimethyl terephthalate and 1,4-butanediol. The resulting polymer is known for its good mechanical properties, low moisture absorption, and chemical resistance. Specialty grades available include glass filled, mineral filled, impact resistant, and flame retardant grades. In 1994, the price of PBT ranged approximately from $2.00 to $4.00 per pound at truckload quantities.

General Properties

The most notable properties of PBT are its chemical resistance and mechanical properties. PBT offers good resistance to water, weak acids and bases, ketones, alcohols, glycols, ethers, aliphatic hydrocarbons, and chlorinated aliphatic hydrocarbons at room temperature. At temperatures up to 140°F (60°C), PBT is resistant to transmission fluid, brake fluid, gasoline, and motor oil. It is not recommended for use in strong bases at any temperature, or in aqueous mediums at temperatures above 125°F (52°C). PBT has good tensile strength, high dimensional stability, and a lubricity which makes it very resistant to wear. It has a relatively low heat deflection temperature, but glass filled grades can increase this to over 400°F (204°C). Due to the extremely low water absorption of PBT (0.05%-0.15%), its dimensional stability and electrical properties are unaffected by high humidity conditions. It has a volume resistivity independent of temperature that exceeds 10^{16} ohm-cm. In medical applications, PBT is suitable for sterilization with ethylene oxide, but does not have enough heat resistance to be steam sterilized.

Typical Properties of Polybutylene Terephthalate

	American Engineering	SI
Processing temperature	400-500°F	204-274°C
Linear mold shrinkage	0.001 - 0.004 in/in	0.001 - 0.004 cm/cm
Melting point	-	-
Density	62.4-81.2 lb/ft^3	1.00-1.30 g/cm^3
Tensile strength, yield	4.6-7.9 lb/in^2 x 10^3	3.2-5.6 kg/cm^2 x 10^2
Tensile strength, break	4.0-12.0 lb/in^2 x 10^3	2.8-8.4 kg/cm^2 x 10^2
Elongation, break	1.0-50.0%	1.0-50.0%
Tensile modulus	2.0-12.0 lb/in^2 x 10^5	1.4-8.4 kg/cm^2 x 10^4
Flexural strength, yield	6.2-20.0 lb/in^2 x 10^3	4.4-14.1 kg/cm^2 x 10^2
Flexural modulus	2.5-4.4 lb/in^2 x 10^5	1.8-3.1 kg/cm^2 x 10^4
Compressive strength	6.5-17.0 lb/in^2 x 10^3	4.6-12.0 kg/cm^2 x 10^2
Izod notched, R.T.	0.5-12.0 ft-lb/in	2.7-64.8 kg cm/cm
Hardness	R95-R125 Rockwell	R95-R125 Rockwell
Thermal conductivity	1.2-1.6 BTU-in/hr-ft^2-°F	0.17-0.23 W/m°K
Linear thermal expansion	1.1-5.7 in/in-°F x 10^{-5}	2.0-10.3 cm/cm °C x 10^{-5}
Deflection temp. @ 264 psi	170-240°F	77-116°C
Deflection temp. @ 66 psi	190-245°F	88-118°C
Continuous service temp.	130-180°F	54-82°C
Dielectric strength	350-500 V/10^{-3} in	1.4-2.0 V/mm x 10^4
Dielectric constant @ 1MHz	3.1-3.4	3.1-3.4
Dissipation factor @ 1MHz	0.008-0.009	0.008-0.009
Water absorption, 24hr	0.008-0.009	0.008-0.009

Typical Applications

• Automotive	brake system parts, distributor caps, fuel injection modules, grille opening panels
• Electronics	connectors, switches, relays, TV tuners, motor housings, fuse cases, light sockets
• Medical	specialty syringes, irrigation and wound drainage systems, check valves, catheter housings
• Miscellaneous	industrial zippers, power tool housings, hair dryers, calculators, cooker-fryer handles, iron and toaster housings, food processor blades

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polybutylene Terephthalate

Valox courtesy of GE Plastics

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		—	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	—	—	3311 Light Cure Acrylic
Unfilled resin grade 325	4 rms	100 0.7	250 1.7	>3150 Δ >21.7 Δ	250 1.7	100 0.7	200 1.4
Grade 325 roughened	60 rms	500 3.5	950 6.6	1450 10.0	2150 14.8	200 1.4	600 4.1
Grade DR51	15% glass reinforced	100 0.7	400 2.8	4200 29.0	450 3.1	100 0.7	200 1.4
Grade 420	30% glass reinforced	200 1.4	300 2.1	>4150 Δ >28.6 Δ	550 3.8	150 1.0	600 4.1
Grade 508	30% glass reinforced alloy	450 3.1	2100 14.5	3350 23.1	1800 12.4	1650 11.4	1250 8.6
Grade 732E	30% glass/mineral reinforced	950 6.6	>2650 Δ >18.3 Δ	>2900 Δ >20.0 Δ	>2200 Δ >15.2 Δ	950 6.6	1750 12.1
Grade 735	40% glass/mineral reinforced	900 6.2	>2600 Δ >17.9 Δ	>2800 Δ >19.3 Δ	>2650 Δ >18.3 Δ	350 2.4	750 5.2
Grade 830	30% glass reinforced alloy	150 1.0	600 4.1	>4050 Δ >27.9 Δ	350 2.4	150 1.0	550 3.8
Grade 850	15% glass reinforced PBT alloy	200 1.4	400 2.8	>4400 Δ >30.3 Δ	1100 7.6	150 1.0	700 4.8

NOTES:

Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.

■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, used in conjunction with Prism Primer 770, or 4011 with 7701, achieved the highest bond strengths on all the grades of PBT which were evaluated. The other adhesives also achieved high bond strengths, but their respective performances were not as consistent throughout the different grades of PBT. Typically, Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, achieved the highest bond strengths, followed by Loctite 3105 and 3311, light curing acrylic adhesives. Black Max 380, a rubber toughened cyanoacrylate adhesive, and Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths on PBT.

Surface Treatments

Surface roughening, plasma treatment, UV-ozone treatment, and the use of Loctite Prism Primer 770 or 7701 have all proven to cause large, statistically significant increases in the bondability of PBT.

Other Important Information

- Good solvents for PBT are hexafluoroisopropanol, trifluoroacetic acid, o-chlorophenol, and mixtures of phenol with chlorinated aliphatic hydrocarbons.
- PBT is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polycarbonate (PC)

thermoplastic

Trade Names / Manufacturer

Trade Names	Manufacturer
• Calibre	Dow Chemical
• Karlex	Ferro Corporation
• Lexan	General Electric
• Makrolon	Miles Inc.
• Novarex	Mitsubishi Chemical
• Panlite	Teijin Chem Ltd.
• Sinvet	Enichem Elastomers

General Description

In the polycarbonate resin, carbonate groups are used to link groups of dihydric or polyhydric phenols. General-purpose polycarbonate is formed by reacting bisphenol A with phosgene, but formulations using other polyhydric phenols are available. These include specialty resins which meet industry codes for flame retardance and smoke density, and resins with increased melt strength for extrusion and blow molding. Polycarbonate is a versatile and popular blend material for polyester and ABS, and is widely used in the medical device industry as a replacement for glass. Additives and coatings are commonly used and can greatly improve creep resistance, mold shrinkage, tensile modulus, thermal stability, weatherability, and all strength characteristics of standard polycarbonate. In 1994, the price of PC ranged approximately from $2.50 to $5.00 per pound at truckload quantities.

General Properties

Polycarbonate offers a unique combination of outstanding clarity and high impact strength. In addition, it is very dimensionally stable and has low flammability. These characteristics make polycarbonate well suited for light transmission applications, such as automotive taillight housings. Due to the low levels of monomers and catalysts used in processing polycarbonate, it is generally biocompatible and suited for use in medical applications where device surfaces may come into contact with blood or other bodily fluids. PC offers a limited resistance to chemicals and is soluble in many organic solvents. When solvent welding or adhesively joining parts, this makes PC prone to stress cracking. This can be overcome by selecting an adhesive with a rapid cure mechanism, an adhesive with a low tendency to induce stress cracking, and/or annealing the part prior to adhesive application.

Typical Properties of Polycarbonate

	American Engineering	SI
Processing temperature	500-575°F	260-302°C
Linear mold shrinkage	0.003-0.007 in/in	0.003-0.007 cm/cm
Melting point	-	-
Density	70.5-80.5 lb/ft^3	1.13-1.29 g/cm^3
Tensile strength, yield	8.4-9.6 lb/in^2 x 10^3	5.9-6.7 kg/cm^2 x 10^2
Tensile strength, break	7.4-10.9 lb/in^2 x 10^3	5.2-7.7 kg/cm^2 x 10^2
Elongation, break	97.0-136.0%	97.0-136.0%
Tensile modulus	3.1-3.5 lb/in^2 x 10^5	2.2-2.5 kg/cm^2 x 10^4
Flexural strength, yield	12.4-14.0 lb/in^2 x 10^3	8.7-9.8 kg/cm^2 x 10^2
Flexural modulus	3.2-3.5 lb/in^2 x 10^5	2.2-2.5 kg/cm^2 x 10^4
Compressive strength	9.9-11.1 lb/in^2 x 10^3	7.0-7.8 kg/cm^2 x 10^2
Izod notched, R.T.	11.3-17.0 ft-lb/in	60.8-91.8 kg cm/cm
Hardness	R120-R125 Rockwell	R120-R125 Rockwell
Thermal conductivity	1.3-1.6 BTU-in/hr-ft^2-°F	0.19-0.23 W/m-°K
Linear thermal expansion	2.9-3.9 in/in-°F x 10^{-5}	5.2-7.0 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	200-350°F	93-177°C
Deflection temp. @ 66 psi	280-350°F	138-177°C
Continuous service temp.	240-275°F	116-135°C
Dielectric strength	375-500 V/10^{-3} in	1.5-2.0 V/mm x 10^4
Dielectric constant @ 1MHz	2.7-3.2	2.7-3.2
Dissipation factor @ 1MHz	0.009-0.010	0.009-0.010
Water absorption, 24 hr	0.1-0.3%	0.1-0.3%

Typical Applications

• Packaging	reusable bottles, frozen foods, large water bottles
• Food Service	beverage pitchers, mugs, food processor bowls, tableware, microwave cookware
• Automotive Parts	lamp housings and lenses, electrical components, instrument panels
• Medical	filter housings, tubing connectors, surgical staplers, eyewear
• Miscellaneous	bulletproofing, computer housings, aircraft interiors

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polycarbonate **Calibre 300-4 produced by Dow Chemical**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	3 rms	750 5.2	3850 26.6	2000 13.8	1600 11.0	1100 7.6	3700 25.5
Roughened	18 rms	1600 11.0	4500 31.0	3400 23.5	3950 27.2	1100 7.6	4550 31.4
Antioxidant	0.1% Irgafos 168 0.1% Irganox 1076	750 5.2	3850 26.6	2000 13.8	3950 27.2	550 3.8	3700 25.5
UV stabilizer	0.4% Tinuvin 234	750 5.2	3850 26.6	2000 13.8	1600 11.0	450 3.1	3700 25.5
Flame retardant	2% BT-93 1% Antimony oxide	1300 9.0	>4100Δ >28.3Δ	>3800Δ >26.2Δ	>3400Δ >23.5Δ	300 2.1	3700 25.5
Impact modifier	5% Paraloid EXL3607	1000 6.9	3850 26.6	2000 13.8	>4500Δ >31.0Δ	500 3.5	3700 25.5
Lubricant	0.3% Mold Wiz INT-33UDK	1300 9.0	3850 26.6	2000 13.8	3850 26.6	1100 7.6	3700 25.5
Glass filler	23% Type 3090 glass fiber	1150 7.9	3850 26.6	600 4.1	2700 18.6	1100 7.6	4850 33.5
Colorant	4% CPC07327	1650 11.4	3850 26.6	500 3.5	3950 27.2	1100 7.6	3700 25.5

NOTES:
- Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.
- (grey box) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.
- (red box) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, 4011 and Super Bonder 414, cyanoacrylate adhesives, and Loctite 3105 and 3311, light curing acrylic adhesives, achieved the highest bond strengths on PC, although there was no set trend in the magnitude of the bond strengths achieved by the three adhesives. Black Max 380, a rubber toughened cyanoacrylate adhesive, and Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths on PC.

Surface Treatments

Surface roughening either caused no effect or a statistically significant increase in the bondability of PC. The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, caused a statistically significant decrease in the bond strengths achieved on PC for most of the formulations evaluated.

Other Important Information

- Polycarbonate is generally compatible with acrylic and cyanoacrylate adhesives, but there is a potential for stress cracking. In addition, polycarbonate can be attacked by the activators for two-part no-mix acrylic adhesives before the adhesive has cured. Any excess activator should be removed from the surface of the polycarbonate immediately.
- Polycarbonate is incompatible with anaerobic adhesives.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polyester

thermoset

Trade Names	Manufacturer
• Aropol	Ashland Chemical Company
• Dielectrite	Industrial Dielectric
• Durez	Occidental Chemical Company
• Polylite	Reichhold Chemical Company
• Premi-Glas	Premix, Inc.
• Premi-Ject	Premix, Inc.
• Stypol	Cook Composites

General Description

Thermoset polyesters and alkyd compounds are produced by the reaction of an organic alcohol with an organic acid. The term alkyd is used for those resins which use the lowest amounts of monomer. Polyesters can be created with a tremendous variety of different monomers and catalysts. They are known for their excellent electrical properties and are widely used in home electrical appliances that require high temperature stability. Specialty grades available include flame retardant, glass filled, and magnetizable ferrite filled grades. In 1994, the price of thermoset polyesters ranged approximately from $0.50 to $3.00 per pound at truckload quantities.

General Properties

Thermoset polyesters and alkyd molding compounds are dense materials having specific gravities that range from 1.2 to 2.0. They are also very strong and rigid as illustrated by tensile strengths as high as 14,000 psi and flexural strengths as high as 20,000 psi, respectively. Thermoset polyesters have moderate impact strengths ranging from 1.6 to 10.6 ft-lb/in (8.6 to 57.2 kg cm/cm). Polyesters have good dielectric strength at high temperatures and outstanding resistance to breakdown under electrical arc and tracking conditions. Thermal and dimensional stability is good up to 450°F (230°C). Some grades have high flammability ratings even when molded into sheets as thin as 0.020 in. Thermoset polyesters have good chemical resistance to many chemicals, including alcohols, ethers, salts, organic and inorganic acids. However, they are attacked by hydrocarbons, phenols, ketones, esters, and oxidizing acids.

Typical Properties of Thermoset Polyester

	American Engineering	SI
Processing temperature	300-350°F	148.9-176.7°C
Linear mold shrinkage	0.001-0.007 in/in	0.001-0.007 cm/cm
Melting point	-	-
Density	72.4-124.9 lb/ft^3	1.2-2.0 g/cm^3
Tensile strength, yield	2.6-11.0 lb/in^2 x 10^3	1.8-7.7 kg/cm^2 x 10^2
Tensile strength, break	3.7-12.1 lb/in^2 x 10^3	2.6-8.5 kg/cm^2 x 10^2
Elongation, break	1.0-4.2%	1.0-4.2%
Tensile modulus	1.2-6.4 lb/in^2 x 10^5	0.8-4.5 kg/cm^2 x 10^4
Flexural strength, yield	11.1-20.5 lb/in^2 x 10^3	7.8-14.4 kg/cm^2 x 10^2
Flexural modulus	4.7-7.4 lb/in^2 x 10^5	3.3-5.2 kg/cm^2 x 10^4
Compressive strength	17.5-24.3 lb/in^2 x 10^3	12.3-17.1 kg/cm^2 x 10^2
Izod notched, R.T.	1.6-10.6 ft-lb/in	8.6-57.2 kg cm/cm
Hardness	5-70 Barcol	5-70 Barcol
Thermal conductivity	-	-
Linear thermal expansion	1.0-2.0 in/in-°F x 10^{-5}	1.8-3.6 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	160-500°F	71.1-260°C
Deflection temp. @ 66 psi	-	-
Continuous service temp.	120-220°F	48.9-104.4°C
Dielectric strength	350-500 V/10^{-3} in	1.4-2.0 V/mm x 10^4
Dielectric constant @ 1MHz	3.2-4.5	3.2-4.5
Dissipation factor @ 1MHz	0.007-0.025	0.007-0.025
Water absorption, 24 hr	0.1-0.2%	0.1-0.2%

Typical Applications

- Electronic — automotive ignition components, appliances, switch boxes, breaker components, encapsulation
- Miscellaneous — boat hulls, shower stalls, cookware

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Thermoset Polyester

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
C-685 Black 183	20-30% glass fiber mineral filled 15 rms	>1350Δ >9.3Δ	>1350Δ >9.3Δ	350 2.4	>1900Δ >13.1Δ	700 4.8	600 4.1
C-685 roughened	33 rms Cyglas courtesy of American Cyanamid	>900Δ >6.2Δ	1200 8.3	650 4.5	800 5.5	700 4.8	1650 11.3
Dielectrite 48-53 E	courtesy of Industrial Dielectrics	>1400Δ >9.7Δ	>1400Δ >9.7Δ	>600Δ >4.1Δ	>1300Δ >9.0Δ	450 3.1	1100 7.6
Dielectrite 44-10	Unspecified glass fill courtesy of Industrial Dielectrics	>1450Δ >10.0Δ	>1300Δ >9.0Δ	350 2.4	>1350Δ >9.3Δ	650 4.5	1150 7.9
Dielectrite 46-16-26	Unspecified glass fill courtesy of Industrial Dielectrics	>2100Δ >14.5Δ	>2050Δ >14.1Δ	450 3.1	>1950Δ >13.5Δ	600 4.1	1000 6.9
Dielectrite 46-3	Unspecified glass fill courtesy of Industrial Dielectrics	>1600Δ >11.0Δ	>1550Δ >10.7Δ	250 1.7	>1250Δ >8.6Δ	700 4.8	650 4.5

NOTES:

Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.

■ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

■ (red) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, and Black Max 380, a rubber toughened cyanoacrylate adhesive achieved the highest bond strengths on the thermoset polyester, typically achieving substrate failure. Loctite 3105 and 3311, light curing acrylic adhesives, had the second highest bond strengths and Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths.

Surface Treatments

The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, is not recommended as it significantly decreased the bond strengths achieved on the grades of thermoset polyester which were evaluated. Surface roughening caused either no effect or a statistically significant increase in the bond strengths achieved by the acrylic adhesives. However, surface roughening typically resulted in a statisically significant increase in the bond strengths achieved by cyanoacrylate adhesives.

Other Important Information

- Thermoset polyester is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polyetheretherketone (PEEK)

thermoplastic 7 OTHER

Trade Names

- Arlon
- Victrex PEEK

Manufacturer

Greene, Tweed & Co.
Victrex, USA

General Description

Polyetheretherketone, a poly(aryletherketone), is a linear, semi-crystalline, wholly aromatic polymer. It offers outstanding thermal stability and is resistant to a wide range of chemicals. Due to PEEK's suitability for extreme service conditions, it has found use in many demanding niche applications such as high temperature bearings and aircraft radomes and fairings. Specialty grades available include glass, carbon, and PTFE filled grades. In 1994, the price of PEEK ranged approximately from $31.00 to $35.00 per pound at truckload quantities.

General Properties

PEEK is a high performance thermoplastic which is well suited for high-temperature environments. In addition, it has good mechanical properties, including a flexural modulus among the highest of all thermoplastics. Furthermore, the addition of fillers to PEEK typically increases both its modulus and thermal stability. PEEK is suitable for applications that will see intermittent exposure to temperatures up to 600°F (315°C) and has a maximum continuous service temperature of approximately 480°F (250°C). Unfilled PEEK meets UL94 V-0 flammability requirements and generates very little smoke upon combustion. PEEK resists mild acids and bases at elevated temperatures, superheated water up to 500°F (260°C), and most common organic solvents. PEEK also has outstanding resistance to radiation, significantly greater than polystyrene, the second most radiation resistant polymeric material. Samples of PEEK have withstood 1100 Mrads without significantly degrading. Sunlight and weathering resistance are also good, with no loss of properties evident after one year of outdoor exposure.

Typical Properties of Polyetheretherketone

	American Engineering	SI
Processing temperature	700-750°F	371-399°C
Linear mold shrinkage	0.001 - 0.005 in/in	0.001 - 0.005 cm/cm
Melting point	630-640°F	332-338°C
Density	84.3-96.8 lb/ft^3	1.35-1.55 g/cm^3
Tensile strength, yield	16.9-31.2 lb/in^2 x 10^3	11.9-21.9 kg/cm^2 x 10^2
Tensile strength, break	13.1-26.1 lb/in^2 x 10^3	9.2-18.7 kg/cm^2 x 10^2
Elongation, break	2.0-8.0%	2.0-8.0%
Tensile modulus	9.0-35.5 lb/in^2 x 10^5	6.3-23.6 kg/cm^2 x 10^4
Flexural strength, yield	21.6-39.8 lb/in^2 x 10^3	15.2-28.0 kg/cm^2 x 10^2
Flexural modulus	4.0-20.0 lb/in^2 x 10^5	2.8-14.1 kg/cm^2 x 10^4
Compressive strength	11.0-32.0 lb/in^2 x 10^3	7.7-22.5 kg/cm^2 x 10^2
Izod notched, R.T.	0.9-2.2 ft-lb/in	4.7-11.9 kg cm/cm
Hardness	M100-M124 Rockwell	M100-M124 Rockwell
Thermal conductivity	1.5-6.5 BTU-in/hr-ft^2-°F	0.22-0.94 W/m°K
Linear thermal expansion	0.7-1.8 in/in-°F x 10^{-5}	1.3-3.2 cm/cm °C x 10^{-5}
Deflection temp. @ 264 psi	350-610°F	177-321°C
Deflection temp. @ 66 psi	500-640°F	260-338°C
Continuous service temp.	428-480°F	220-249°C
Dielectric strength	350-500 V/10^{-3} in	1.4-2.0 V/mm x 10^4
Dielectric constant @ 1MHz	3.0-4.2	3.0-4.2
Dissipation factor @ 1MHz	0.001-0.005	0.001-0.005
Water absorption, 24hr	0.06-0.18%	0.06-0.18%

Typical Applications

- Aerospace — wire and cable insulation, coatings, EMI/RFI shields
- Miscellaneous — high temperature bearings, compressor parts, nuclear power plant and oil well applications, military equipment

ADHESIVE SHEAR STRENGTH

(psi)
(MPa)

Polyetheretherketone

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Victrex 450G control	unfilled resin courtesy of Victrex, USA 4 rms	150 1.0	250 1.7	250 1.7	200 1.4	350 2.4	1100 7.6
450G roughened	22 rms	700 4.8	350 2.4	350 2.4	300 2.1	350 2.4	1100 7.6
PEEK 450 CA30	30% carbon fiber courtesy of Victrex, USA	150 1.0	200 1.4	450 3.1	250 1.7	450 3.1	950 6.6
Thermocomp LF-1006	30% glass fiber courtesy of LNP Engineering Plastics	100 0.7	250 1.7	550 3.8	400 2.8	500 3.5	1200 8.3
Lubricomp LCL-4033 EM	15% carbon fiber, 15% PTFE courtesy of LNP Engineering Plastics	100 0.7	400 2.8	300 2.1	250 1.7	500 3.5	900 6.2

NOTES: ■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

Adhesive Performance

Loctite 3105 and 3311, light curing acrylic adhesives, consistently achieved the highest bond strengths on PEEK. Depend 330, a two-part no-mix acrylic adhesive, achieved the second highest bond strengths followed by Prism 401, 4011 and Super Bonder 414, cyanoacrylate adhesives. Black Max 380, a rubber toughened cyanoacrylate adhesive, achieved the lowest bond strengths on PEEK.

Surface Treatments

Surface roughening caused either no effect or a statistically significant increase in the bond strengths achieved on PEEK. Prism Primer 770, used in conjunction with Prism 401, or 4011 with 7701, had no overall statistically significant effect on the bondability of PEEK. However, Prism Primer 770 and 7701 did result in a statistically significant increase in the bond strengths achieved on the PEEK 450 CA30 and Thermocomp LF-1006 grades.

Other Important Information

- PEEK is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polyetherimide (PEI)

thermoplastic 7 OTHER

Trade Names

• Ultem

Manufacturer

GE Plastics

General Description

Polyetherimide (PEI) is an amorphous thermoplastic which is based on repeating aromatic imide and ether units. PEI is known for its high strength and rigidity, especially under long-term heat exposure. The rigid aromatic imide units provide PEI with its high performance properties at elevated temperatures, while the ether linkages provide it with the chain flexibility necessary to have good melt flow and processability. Currently the largest area of growth for PEI is in metal replacement applications, mostly involving the replacement of aluminum and brass automotive parts. Specialty grades available include glass, mineral, and carbon reinforced, low wear and low friction, improved chemical resistance and PC/PEI blends, as well as commercial aircraft interior and medically rated grades. In 1994, the price of PEI ranged approximately from $8.00 to $10.00 per pound at truckload quantities.

General Properties

Polyetherimide is a high performance plastic which is well suited for extreme service environments. At room temperature its mechanical properties exceed those of most thermoplastics, and it displays an impressive retention of these properties at temperatures as high as 375°F (191°C). PEI also performs extremely well at elevated temperatures. For example, Ultem 1000 has a glass transition temperature of 419°F (215°C), heat deflection temperature at 264 psi (1.82 MPa) of 392°F (200°C), and continuous service temperature of 338°F (170°C). PEI exhibits excellent impact strength and ductility, but does display notch sensitivity when subjected to high stress rates. PEI has an exceptionally high flame resistance, and when it does burn, it generates very low levels of smoke. It is an excellent electrical insulator, has a low dissipation factor, a high volume resistivity, a high arc resistance, and is extraordinarily free of ionic contaminations. Not only does PEI have excellent hydrolytic stability, UV stability, and radiation resistance, but it is also extremely well suited for repeated steam, hot air, ethylene oxide gas and cold chemical sterilizations. PEI is resistant to a wide range of chemicals including alcohols, hydrocarbons, aqueous detergents and bleaches, strong acids, and mild bases.

Typical Properties of Polyetherimide

	American Engineering	SI
Processing temperature	600-750°F	316-399°C
Linear mold shrinkage	0.001-0.006 in/in	0.001-0.006 cm/cm
Melting point	400-450°F	204-232°C
Density	78.0-93.6 lb/ft^3	1.25-1.50 g/cm^3
Tensile strength, yield	14.9-26.6 lb/in^2 x 10^3	10.5-18.7 kg/cm^2 x 10^2
Tensile strength, break	12.1-25.9 lb/in^2 x 10^3	8.5-18.2 kg/cm^2 x 10^2
Elongation, break	1.5-5.3%	1.5-5.3%
Tensile modulus	3.3-18.0 lb/in^2 x 10^5	2.3-12.7 kg/cm^2 x 10^4
Flexural strength, yield	19.5-44.6 lb/in^2 x 10^3	13.7-31.4 kg/cm^2 x 10^2
Flexural modulus	4.0-18.4 lb/in^2 x 10^5	2.8-12.9 kg/cm^2 x 10^4
Compressive strength	20.0-26.0 lb/in^2 x 10^3	14.1-18.3 kg/cm^2 x 10^2
Izod notched, R.T.	0.8-1.6 ft-lb/in	4.1-8.7 kg cm/cm
Hardness	R115-R125 Rockwell	R115-R125 Rockwell
Thermal conductivity	1.6-5.1 BTU-in/hr-ft^2-°F	0.23-0.74 W/m-°K
Linear thermal expansion	0.6-1.9 in/in-°F x 10^{-5}	1.1-3.4 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	390-420°F	199-216°C
Deflection temp. @ 66 psi	400-440°F	204-227°C
Continuous service temp.	300-350°F	149-177°C
Dielectric strength	480-770 V/10^{-3} in	1.9-3.0 V/mm x 10^4
Dielectric constant @ 1MHz	3.0-3.8	3.0-3.8
Dissipation factor @ 1MHz	0.001-0.005	0.001-0.005
Water absorption, 24hr	0.12-0.25%	0.12-0.25%

Typical Applications

• Transportation — under-the-hood temperature sensors, fuel system and transmission components

• Electronics — thin wall connectors, chip carriers, burn-in sockets, printed wiring boards

• Medical — fittings, connectors

• Miscellaneous — computer disks, electrical tapes, flexible circuitry, explosion-proof electrical enclosures

ADHESIVE SHEAR STRENGTH

(psi)
(MPa)

Polyetherimide **Ultem courtesy of GE Plastics**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin grade 1010	3 rms	150 1.0	1350 9.3	300 2.1	1100 7.6	500 3.5	2250 15.5
Grade 1010 roughened	28 rms	1050 7.2	2450 16.9	2000 13.8	2000 13.8	800 5.5	2250 15.5
Grade 2100	10% glass reinforced	350 2.4	1050 7.2	500 3.5	900 6.2	700 4.8	1750 12.1
Grade 2400	40% glass reinforced	1150 7.9	1000 6.9	850 5.9	2150 14.8	1700 11.7	1300 9.0
Grade 3453	45% glass / silica reinforced	1300 9.0	1650 11.4	1350 9.3	2000 13.8	1500 10.3	1500 10.3
Grade 4001	unreinforced, with lubricant	150 1.0	650 4.5	300 2.1	700 4.8	550 3.8	>1800 Δ >12.4 Δ
Grade CRS5001	unreinforced, chemically resistant grade	450 3.1	1400 9.7	200 1.4	1050 7.2	700 4.8	1550 10.7
Grade 7801	25% Carbon reinforced	950 6.6	1250 8.6	1350 9.3	1850 12.8	750 5.2	1400 9.7
Grade LTX100A	PEI/PC blend injection molding grade	750 5.2	1400 9.7	650 4.5	1100 7.6	800 5.5	3550 24.5

NOTES: Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.
■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, and Loctite 3105 and 3311, light curing acrylic adhesives, normally achieved the highest bond strengths on the various grades of Ultem which were evaluated. However, the performance of each adhesive varied from grade to grade. Black Max 380, a rubber toughened cyanoacrylate adhesive, and Depend 330, a two-part no-mix acrylic adhesive, typically achieved the lowest bond strengths on PEI.

Surface Treatments

Surface roughening and plasma treatment both caused large, statistically significant increases in the bond strengths achieved on PEI. The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, caused a significant decrease in the bond strengths achieved on most of the grades of Ultem which were evaluated.

Other Important Information

- Good solvents for use with PEI are methylene chloride and n-methylpyrrolidone
- An accelerator may be necessary to speed the cure of cyanoacrylates on unfilled grades of PEI.
- PEI is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polyethersulfone (PES)

thermoplastic ♻ 7 OTHER

Trade Names

- Ultrason
- Victrex PES

Manufacturer

BASF
Victrex, USA

General Description

PES is an amorphous thermoplastic whose backbone is composed of alternating aromatic groups linked with alternating oxygen and sulfur dioxide groups. PES is primarily used for high temperature applications. Specialty grades available include glass, carbon, stainless steel, and fluorocarbon filled. In 1994, the price of PES ranged approximately from $5.25 to $6.50 per pound at truckload quantities.

General Properties

The most notable properties of PES are its transparency, good mechanical properties, and outstanding thermal stability–unfilled PES has a useful life of 4 to 5 years at 390°F (199°C) and approximately 20 years at 356°F (180°C). Moreover, the mechanical and electrical properties of PES show a low sensitivity to temperature change and load. In addition, the mechanical properties of PES at elevated temperatures can be significantly increased by annealing. PES has a low smoke emission and can withstand long-term exposure to both air and water at elevated temperatures. PES is chemically resistant to most inorganic chemicals, greases, aliphatic hydrocarbons, and both leaded and unleaded gasoline. However, PES is attacked by esters, ketones, methylene chloride, and polar aromatic solvents. The chemical resistance of PES is lessened by internal stress, but this can be alleviated by annealing the polymer. Typical of the polysulfone family, PES has a low resistance to weathering and is degraded by UV light, making unfilled PES inappropriate for outdoor use. The major disadvantage to adhesively joining PES is that PES is extremely sensitive to stress cracking. However, the addition of glass fillers, the use of adhesive accelerators, and/or annealing PES greatly increases its resistance to stress cracking.

Typical Properties of Polyethersulfone

	American Engineering	SI
Processing temperature	675-700°F	357-371°C
Linear mold shrinkage	0.001-0.006 in/in	0.001-0.006 cm/cm
Melting point	440-460°F	227-238°C
Density	91.8-99.9 lb/ft^3	1.47-1.60 g/cm^3
Tensile strength, yield	13.0-21.0 lb/in^2 x 10^3	9.1-14.8 kg/cm^2 x 10^2
Tensile strength, break	11.9-23.6 lb/in^2 x 10^3	8.4-16.6 kg/cm^2 x 10^2
Elongation, break	2.0-4.3%	2.0-4.3%
Tensile modulus	5.9-13.5 lb/in^2 x 10^5	4.1-9.5 kg/cm^2 x 10^4
Flexural strength, yield	17.9-29.5 lb/in^2 x 10^3	12.6-20.7 kg/cm^2 x 10^2
Flexural modulus	3.4-13.0 lb/in^2 x 10^5	2.4-9.1 kg/cm^2 x 10^4
Compressive strength	15.9-21.3 lb/in^2 x 10^3	11.2-15.0 kg/cm^2 x 10^2
Izod notched, R.T.	1.0-1.6 ft-lb/in	5.3-8.6 kg cm/cm
Hardness	R120-R123 Rockwell	R120-R123 Rockwell
Thermal conductivity	1.3-2.9 BTU-in/hr-ft^2-°F	0.19-0.42 W/m°-K
Linear thermal expansion	1.2-3.3 in/in-°F x 10^{-5}	2.2-5.9 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	400-460°F	204-238°C
Deflection temp. @ 66 psi	420-460°F	216-238°C
Continuous service temp.	350-390°F	177-199°C
Dielectric strength	370-600 V/10^{-3} in	1.5-2.4 V/mm x 10^4
Dielectric constant @ 1MHz	3.5-4.2	3.5-4.2
Dissipation factor @ 1MHz	0.006-0.010	0.006-0.010
Water absorption, 24 hr	0.29-0.41%	0.29-0.41%

Typical Applications

- Electrical — multipin connectors, coil formers, printed circuit boards
- Miscellaneous — radomes, pump housings, bearing cages, hot combs, medical trays

ADHESIVE SHEAR STRENGTH

(psi)
(MPa)

Polyethersulfone **Ultrason E2010 by BASF**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	5 rms	650 4.5	1600 11.0	150 1.0	950 6.6	250 1.7	3050 21.0
Roughened	24 rms	1850 12.8	1600 11.0	1100 7.6	1250 8.6	250 1.7	3050 21.0
Lubricant	9% Polymist F510	950 6.6	850 5.9	600 4.1	700 4.8	800 5.5	2350 16.2
Internal mold release	0.5% Mold Wiz 55PV	650 4.5	500 3.5	150 1.0	950 6.6	250 1.7	3800 26.2
Filler	17% 497 Fiberglass	1750 12.1	1600 11.0	1850 12.8	1900 13.1	1150 7.9	3050 21.0
Colorant	0.5% Yellow 55-21007	650 4.5	850 5.9	450 3.1	2950 20.3	550 3.8	3050 21.0
Polysulfone	Udel courtesy of Amoco Perf. Products	650 4.5	1600 11.0	150 1.0	700 4.8	900 6.2	3050 21.0

NOTES:
- (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.
- (pink) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Loctite 3105 and 3311, light curing acrylic adhesives, consistently achieved the highest bond strengths on PES. Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, and Black Max 380, a rubber toughened cyanoacrylate adhesive, typically achieved the second highest bond strengths on PES. However, the magnitude of the bond strengths achieved by the cyanoacrylate adhesives were inconsistent and followed no set trend throughout the various formulations. Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths on PES. The only statistically significant difference between the bondability of unfilled PES and polysulfone was that Depend 330 achieved higher, statistically significant bond strengths on the polysulfone than on the unfilled PES.

Surface Treatments

Surface roughening caused either no effect or a statistically significant increase in the bond strengths achieved on PES. The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, caused a statistically significant decrease in the bondability of both PES and polysulfone.

Other Important Information

- PES and polysulfone are extremely sensitive to stress cracking caused by exposure to uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately, and cyanoacrylate accelerators should be used whenever possible.
- PES and polysulfone are compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately.
- PES and polysulfone are incompatible with anaerobic adhesives.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polyethylene (LDPE, HDPE)

thermoplastic

HDPE LDPE

Trade Names	Manufacturer
• Aspun	Dow Plastics
• Attane	Dow Plastics
• Bapolene	Bamberger Polymers, Inc.
• Clysar	DuPont Company
• Dowlex	Dow Chemical Company
• Escorene	Exxon Chemical
• Fortiflex	Solvay Polymers
• Hostan GUR	Hoescht Celanese Corp.
• Marlex	Phillips 66 Co.
• Microthene	Quantum Chemical Co.
• Novapol	Novacor Chemicals
• Petrothene	Quantum Chemical
• Polyfort FLP	A. Schulman, Inc.
• Sclair	Novacor Chemicals
• Tuflin	Union Carbide Corp.
• Ultra-wear	Polymer Corporation

General Description

Polyethylene is a lightweight, semicrystalline thermoplastic produced by the liquid phase, free radical initiated polymerization of ethylene. The polymer is formed when the proper combination of pressure, temperature, and catalyst break open the double bonds within the ethylene molecules. The amount of branching within the bulk polymer and its density can be controlled by varying the reaction conditions. An increase in the density of polyethylene leads to an increase in its hardness, surface abrasion, tensile strength, modulus, thermal stability, chemical resistance, and surface gloss but diminishes toughness, clarity, flexibility, elongation, and stress cracking resistance. Specialty grades available include the four major density groups, namely I, II, III, and IV in order of increasing density, UV stabilized, flame retardant, antistatic, and grades with many different types of fillers. In 1994, the price of PE ranged approximately from $0.50 to $1.50 per pound at truckload quantities.

General Properties

Polyethylene is not a high performance plastic suited for extreme service environments, but rather an extremely versatile and inexpensive resin that has become one of the most popular of all plastics. Almost all of polyethylene's properties vary greatly with changes in density and molecular weight. Low density polyethylene has a relatively low strength and hardness, but is flexible, clear, impact, creep and stress-crack resistant, and can have an elongation comparable to some rubbers. High density polyethylene has significantly higher strength, hardness, abrasion and chemical resistance, but it sacrifices some of the properties in which low density polyethylene excels. Polyethylenes are not able to withstand high temperatures, but their chemical resistance is excellent for an inexpensive, non-engineering resin. They are not recommended for continuous use with hydrocarbons, some alcohols, and oxidizing acids, but they are resistant to phenols, ketones, esters, ethers, bases, salts, organic and inorganic acids.

Typical Properties of Polyethylene

	American Engineering	SI
Processing temperature	300-630°F	149-332°C
Linear mold shrinkage	0.017-0.050 in/in	0.017-0.050 cm/cm
Melting point	210-400°F	99-204°C
Density	56.2-58.1 lb/ft^3	0.90-0.93 g/cm^3
Tensile strength, yield	1.1-2.0 lb/in^2 x 10^3	0.8-1.4 kg/cm^2 x 10^2
Tensile strength, break	1.1-5.8 lb/in^2 x 10^3	0.8-4.1 kg/cm^2 x 10^2
Elongation, break	60.0-780.0%	60.0-780.0%
Tensile modulus	0.1-0.4 lb/in^2 x 10^5	0.1-0.3 kg/cm^2 x 10^4
Flexural strength, yield	-	-
Flexural modulus	0.2-0.5 lb/in^2 x 10^5	0.1-0.4 kg/cm^2 x 10^4
Compressive strength	-	-
Izod notched, R.T.	-	-
Hardness	D44-D55 Rockwell	D44-D55 Rockwell
Thermal conductivity	1.8-2.9 BTU-in/hr-ft^2-°F	0.26-0.42 W/m°-K
Linear thermal expansion	11.0-18.0 in/in-°F x 10^{-5}	19.8-32.4 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	-	-
Deflection temp. @ 66 psi	100-120°F	38-49°C
Continuous service temp.	-	-
Dielectric strength	475-900 V/10^{-3} in	1.9-3.5 V/mm x 10^4
Dielectric constant @ 1MHz	2.2-2.4	2.2-2.4
Dissipation factor @ 1MHz	0.0001-0.0005	0.0001-0.0005
Water absorption, 24 hr	-	-

Typical Applications

• Films	shrink bundling, drum and bag liners, ice bags, shipping sacks, cling wrap, snack packaging, diaper liners
• Packaging	food and shipping containers, milk, water, antifreeze, and household chemical containers, squeeze bottles
• Miscellaneous	pipe and chemical drum liners, electric cable jacketing, toys, portable sanitary facilities, commercial storage tanks, envelopes

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Low Density Polyethylene **722M produced by Dow Chemical**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	5 rms	<50 <0.3	150 1.0	500 3.5	150 1.0	150 1.0	350 2.4
Roughened	88 rms	<50 <0.3	150 1.0	500 3.5	150 1.0	150 1.0	350 2.4
Antioxidant	0.1% Irganox 1010	50 0.3	150 1.0	500 3.5	150 1.0	150 1.0	350 2.4
UV stabilizer	0.3% Cyasorb UV-531	100 0.7	100 0.7	200 1.4	150 1.0	200 1.4	150 1.0
Flame retardant	16% DER-83R 6% Antimony Oxide	100 0.7	150 1.0	500 3.5	150 1.0	150 1.0	100 0.7
Lubricant	1% Synpro 114-36	100 0.7	150 1.0	500 3.5	150 1.0	150 1.0	350 2.4
Filler	17% OmyaCarb F	100 0.7	150 1.0	500 3.5	300 2.1	200 1.4	350 2.4
Colorant	0.1% Watchung Red B RT4280	<50 <0.3	100 0.7	500 3.45	50 0.3	150 1.0	100 0.7
Antistatic	0.4% Armostat 375	<50 <0.3	600 4.1	500 3.5	750 5.2	150 1.0	200 1.4
High density polyethylene	courtesy of Compression Polymers	<50 <0.3	50 0.3	2000 13.8	50 0.3	150 1.0	100 0.7

NOTES:

- (grey box) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.
- (pink box) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, when used in conjunction with Prism Primer 770, or 4011 with 7701, achieved the highest bond strengths on both LDPE and HDPE. The second highest bond strengths were typically achieved by Loctite 3105 and 3311, light curing acrylic adhesives, but these bond strengths were not as consistent throughout the various formulations of LDPE. In addition, the untreated LDPE formulation containing the antistatic agent achieved higher bond strength than the LDPE treated with Prism Primer 770 or 7701 for three of the cyanoacrylate adhesives which were evaluated, namely Prism 401, 4011, and Super Bonder 414.

Surface Treatments

Prism primer 770, when used in conjunction with Prism 401, or 4011 with 7701, caused a statistically significant increase in the bond strengths achieved on all of the formulations of PE which were evaluated, with the exception of the formulation which contained an antistatic agent additive. Surface roughening caused no statistically significant effect on the bondability of LDPE.

Other Important Information

- Polyethylene is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polyethylene Terephthalate (PET)

thermoplastic PETE

Trade Names / Manufacturer

Trade Names	Manufacturer
• Cleartuf	Goodyear
• Ektar FB	Eastman Performance
• Impet	Hoechst Celanese
• Kodapak PET	Eastman Chemical Products
• Lumirror	Toray Industries
• Mylar	E.I. DuPont
• Petlon	Albis Corp.
• Petra	Allied-Signal Corp.
• Rynite	E.I. DuPont
• Selar	E.I. DuPont
• Tenite PET	Eastman Chemical Products
• Traytuf	Goodyear
• Valox	GE Plastics

General Description

Polyethylene terephthalate is produced by the condensation reaction of either dimethyl terephthalate (DMT) or purified terephthalic acid (PTA) with ethylene glycol. Recently, PET has been produced almost exclusively using PTA, while the addition of a secondary copolymerizing agent, such as cyclohexanedimethanol (CHDM) or isophthalic acid (IPA), has become common. These secondary copolymerizing agents are used to improve the clarity, toughness, and barrier properties of PET, which makes PET better suited for its primary market, blow molded carbonated soft drink containers. Specialty grades available include flame retardant, impact modified, and glass, mineral, carbon, PTFE, and mica filled. In 1994, the price of PET ranged approximately from $1.00 to $2.50 per pound at truckload quantities.

Typical Properties of Polyethylene Terephthalate

	American Engineering	SI
Processing temperature	500-580°F	260-304°C
Linear mold shrinkage	0.006-0.007 in/in	0.006-0.007 cm/cm
Melting point	470-500°F	243-260°C
Density	84.3-87.4 lb/ft^3	1.35-1.40 g/cm^3
Tensile strength, yield	5.5-13.0 lb/in^2 x 10^3	3.9-9.1 kg/cm^2 x 10^2
Tensile strength, break	7.0-10.5 lb/in^2 x 10^3	4.9-7.4 kg/cm^2 x 10^2
Elongation, break	85.0-160.0%	85.0-160.0%
Tensile modulus	4.0-5.5 lb/in^2 x 10^5	2.8-3.9 kg/cm^2 x 10^4
Flexural strength, yield	11.1-18.5 lb/in^2 x 10^3	7.8-13.0 kg/cm^2 x 10^2
Flexural modulus	1.3-2.6 lb/in^2 x 10^5	0.9-1.8 kg/cm^2 x 10^4
Compressive strength	14.0-18.3 lb/in^2 x 10^3	9.8-12.90 kg/cm^2 x 10^2
Izod notched, R.T.	0.3-4.2 ft-lb/in	1.6-22.7 kg cm/cm
Hardness	M94-M101 Rockwell	M94-M101 Rockwell
Thermal conductivity	1.0-1.7 BTU-in/hr-ft^2-°F	6.7-12.1 W/m-°K
Linear thermal expansion	0.8-5.0 in/in-°F x 10^{-5}	1.4-9.0 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	350-450°F	177-232°C
Deflection temp. @ 66 psi	-	-
Continuous service temp.	330-380°F	166-193°C
Dielectric strength	390-700 V/10^{-3} in	1.5-2.7 V/mm x 10^4
Dielectric constant @ 1MHz	2.9-3.2	2.9-3.2
Dissipation factor @ 1MHz	0.010-0.020	0.010-0.020
Water absorption, 24 hr	0.08-0.15%	0.08-0.15%

General Properties

For almost all injection molding applications of PET, the PET will be either glass or mineral filled. Reinforced PET is the stiffest of all commonly used thermoplastics, illustrated by the flexural modulus of glass filled PET ranging from 1.3 to 2.6 x 10^6 psi (0.9 to 1.8 x 10^5 kg/cm^2). Reinforced PET also has a high tensile strength, excellent heat resistance, outstanding weatherability, and minimal water absorption. Although reinforced PET only has moderate impact resistance (1.2 to 2.6 ft-lb/in), impact resistant grades are available which offer a notched izod impact strength of up to 4 ft-lb/in. Reinforced PET has a high dielectric strength, which remains constant or increases with temperature up to 300°F (149°C). PET is chemically resistant to most chemicals, over a wide range of temperatures, including motor fuels, oils, and hydrocarbon solvents. However, PET is not recommended for long-term use in water at temperatures above 122°F (50°C). Since PET is a condensation polymer, it can be depolymerized when recycling, resulting in the reclamation of pure raw materials, which can then be used to fabricate new products. In 1993, 41% of all U.S. PET sales were recycled.

Typical Applications

• Automotive	cowl vent grilles, sunroof rails, wiper blade supports
• Electrical	computer fans, fuse holders, insulated housings
• Packaging	soft drink containers, packaged food containers

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polyethylene Terephthalate **Resin T80 by Hoechst Celanese**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	7 rms	450 3.1	>3200^Δ >22.1^Δ	>1800^Δ >12.4^Δ	>2200^Δ >15.2^Δ	500 3.5	1150 7.9
Roughened	31 rms	200 1.4	900 6.2	700 4.8	950 6.6	500 3.5	1150 7.9
Impact modifier	17% Novalene 7300P	>250^Δ >1.7^Δ	>350^Δ >2.4^Δ	>250^Δ >1.7^Δ	>400^Δ >2.8^Δ	>150^Δ >1.0^Δ	>300^Δ >2.1^Δ
Flame retardant	15% PO-64P 4% Antimony Oxide	1550 10.7	>2150^Δ >14.8^Δ	600 4.14	>2200^Δ >15.2^Δ	850 5.9	1150 7.9
Lubricant	0.2% Zinc Stearate	750 5.2	>1800^Δ >12.4^Δ	>1800^Δ >12.4^Δ	>2200^Δ >15.2^Δ	500 3.5	1150 7.9
Internal mold release	0.5% Mold Wiz 33PA	800 5.5	>3200^Δ >22.1^Δ	>1800^Δ >12.4^Δ	>2200^Δ >15.2^Δ	500 3.5	1700 11.7
Filler	17% 3540 Fiberglass	800 5.5	2900 20.0	>3350^Δ >23.1	2200 15.2	800 5.5	1700 11.7
Colorant	0.5% Green 99-41042	1000 6.9	>2200^Δ >15.2^Δ	>1800^Δ >12.4^Δ	>2200^Δ >15.2^Δ	500 3.5	1150 7.9
Antistatic	1% Dehydat 8312	>1350^Δ >9.3^Δ	>1900^Δ >13.1^Δ	>1800^Δ >12.4^Δ	>1450^Δ >10.0^Δ	500 3.5	1150 7.9

NOTES:
Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.
▢ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.
▢ (red) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, 4011 and Super Bonder 414, cyanoacrylate adhesives, created bonds which were stronger than the PET substrate for most of the formulations tested. Loctite 3105 and 3311, light curing acrylic adhesives, consistently achieved the second highest bond strengths. Black Max 380, a rubber toughened cyanoacrylate adhesive, and Depend 330, a two-part no-mix adhesive, typically achieved the lowest bond strengths.

Surface Treatments

The overall effect of using Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, on PET could not be determined because most of the PET formulations evaluated achieved substrate failure for both the primed and unprimed PET. However, the use of Prism Primer 770 or 7701 did cause a statistically significant increase in the bondability of glass filled PET and a statistically significant decrease in the bondability of flame retarded PET. Surface roughening had no effect with the acrylic adhesives and a negative effect with the cyanoacrylate adhesives.

Other Important Information

- PET is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polyimide (PI)

thermoplastic

OTHER

Trade Names / Manufacturer

Trade Names	Manufacturer
• Envex	Rogers Corporation
• Kapton	E.I. DuPont
• Kinel	Rhone Poulenc, Inc.
• Matrimid	Ciba - Geigy
• Meldin	Furon
• NEW-TPI	Mitsui Toastu
• Vespel	E.I. DuPont

General Description

PI is an aromatic, linear polymer typically produced by a condensation reaction, such as polymerizing aromatic dianhydride and aromatic diamine. The polymer can then either be cast with solvent evaporation to form a thermoplastic, such as Kapton films, or precipitated to form a “pseudo-thermoplastic”, such as Vespel. This psuedo-thermoplastic is not a true thermoplastic because it thermally degrades before its glass transition temperature and it is not a true thermoset because it is not crosslinked. Specialty grades of PI include antistatic, thermally conductive, corona resistant, and glass, carbon, molybdenum disulfide, and PTFE filled. In 1994, the price of Vespel, which is sold as molded parts or machineable stock, ranged approximately from $225 to $365 for a 1/4" diameter, 38" long rod or $950 for a 10" by 10" by 1/8" plaque. In addition, the price of Kapton films ranged from $63 (5 mil thickness) to $687 (1/3 mil thickness) per pound.

Typical Properties of Polyimide

	American Engineering	Si
Processing temperature	350-465°F	177-241°C
Linear mold shrinkage	0.001-0.004 in/in	0.001-0.004 cm/cm
Melting point	–	-
Density	82.4-106.8 lb/ft^3	1.32-1.71 g/cm^3
Tensile strength, yield	4.7-12.6 lb/in^2 x 10^3	3.3-8.9 kg/cm^2 x 10^2
Tensile strength, break	x 10^{-5}2.8-16.0 lb/in^2 x 10^3	2.0-11.2 kg/cm^2 x 10^2
Elongation, break	0.5-10.0%	0.5-10.0%
Tensile modulus	1.5-3.7 lb/in^2 x 10^5	1.1-2.6 kg/cm^2 x 10^4
Flexural strength, yield	1.1-3.7lb/in^2 x 10^3	0.8-2.6 kg/cm^2 x 10^2
Flexural modulus	0.9-28.0 lb/in^2 x 10^5	0.6-19.7 kg/cm^2 x 10^4
Compressive strength	2.0-35.1 lb/in^2 x 10^3	1.4-24.7 kg/cm^2 x 10^2
Izod notched, R.T.	0.3-1.8 ft-lb/in	1.4-9.7 kg cm/cm
Hardness	M100-M125 Rockwell	M100-M125 Rockwell
Thermal conductivity	1.5-4.4 BTU-in/hr-ft^2-°F	0.22-0.63 W/m°-K
Linear thermal expansion	0.7-2.9 in/in-°F x 10^{-5}	1.3-5.2 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	460-660°F	238-349°C
Deflection temp. @ 66 psi	-	-
Continuous service temp.	480-550°F	249-288°C
Dielectric strength	200-700 V/10^{-3} in	0.8-2.7 V/mm x 10^4
Dielectric constant @ 1MHz	3.0-5.2	3.0-5.2
Dissipation factor @ 1MHz	0.001-0.010	0.001-0.010
Water absorption, 24 hr	0.27-0.97%	0.27-0.97%

General Properties

The most notable properties of PI are its solvent resistance, barrier properties, and performance at both high and low temperature extremes. For example, Kapton films have performed outstandingly in field applications at temperatures as low as -452°F (-269°C) and as high as 752°F (400°C). Moreover, unfilled PI has a glass transition temperature of 590°F (310°C), heat deflection temperatures up to 660°F (349°C), a maximum recommended continuous service temperature as high as 500°F (260°C), and can withstand short-term exposures at temperatures up to 700°F (371°C). PI naturally has an extremely low flammability, with a limiting oxygen index of 44 and a UL 94 flammability rating of V-0. PI also has good dielectric properties, which remain constant over a wide range of frequencies, good elongation (up to 10%), and good abrasion resistance. PI is chemically resistant to most organic solvents and dilute acids. However, PI is attacked by strong acids and bases, and is soluble in highly polar solvents. PI is very resistant to radiation, but long-term exposure to corona discharge or combinations of ultraviolet radiation, oxygen, and water have a negative effect on its mechanical and physical properties. The major disadvantages of PI are that it is very expensive, very difficult to process, and most types of PI have volatiles or contain solvents which must be vented during curing. A minor disadvantage of PI is that it is only available in dark colors.

Typical Applications

• Nuclear	valve seats, thermal and electrical insulators, x-ray fluorescent sample holders
• Fibers	flame retardant clothing and filters for hot/ corrosive liquids and gases
• Miscellaneous	washers, wear strips, compressor valves, ultrasonic transmitting components

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polyimide

Vespel, Kapton courtesy of DuPont Polymers

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Vespel SP-1	unfilled	1550 10.7	2200 15.2	350 2.4	1650 11.4	1150 7.9	800 5.5
Vespel SP-21	15% graphite	1400 9.7	2250 15.5	850 5.9	2350 16.2	550 3.8	1000 6.9
Vespel SP-22	40% graphite	550 3.8	850 5.9	400 2.8	1000 6.9	500 3.5	250 1.7
Vespel SP-211	15% graphite 10% PTFE	400 2.8	550 3.8	600 4.1	700 4.8	200 1.4	200 1.4
Kapton HN	5 mil thick 500 gauge film	>800[¥ψΔ] >5.5[¥ψΔ]	>800[ψΔ] >5.5[ψΔ]	650[ψ] 4.5[ψ]	>800[\ψΔ] >5.5[ψΔ]	>800[ψΔ] >5.5[ψΔ]	>800[ψΔ] >5.5[ψΔ]
Kapton HPP-ST	5 mil thick 500 gauge film	>800[¥ψΔ] >5.5[¥ψΔ]	>800[ψΔ] >5.5[ψΔ]	600[ψ] 4.1[ψ]	>800[\ψΔ] >5.5[ψΔ]	>800[ψΔ] >5.5[ψΔ]	>800[ψΔ] >5.5[ψΔ]
Kapton HPP-FST	5 mil thick 500 gauge film	>800[¥ψΔ] >5.5[¥ψΔ]	>800[ψΔ] >5.5[ψΔ]	450[ψ] 3.1[ψ]	>800[ψΔ] >5.5[ψΔ]	>800[ψΔ] >5.5[ψΔ]	>800[ψΔ] >5.5[ψΔ]

NOTES:
Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by
¥ = TAK PAK 7452 Accelerator was used in conjunction with Black Max 380.
ψ = The Kapton films were bonded to aluminum lap shears prior to evaluation.

Adhesive Performance

Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, achieved the highest bond strengths on the Vespel polyimide. Black Max 380, a rubber toughened cyanoacrylate adhesive, achieved the second highest bond strengths. Depend 330, a two-part no-mix acrylic adhesive, and Loctite 3105 and 3311, light curing acrylic adhesives, achieved the lowest bond strengths on Vespel. Black Max 380, Prism 401, 4011, Super Bonder 414, Depend 330, Loctite 3105 and 3311 all achieved substrate failure on the 5 mil (0.005 in) thick Kapton films.

Surface Treatments

The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, resulted in either no effect or a statisically significant decrease in the bondability of polyimide.

Other Important Information

- When bonding polyimide films, an accelerator may be necessary to speed the cure of cyanoacrylates.
- Polyimide is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polymethylpentene (PMP)

thermoplastic 7 OTHER

Trade Names

• TPX

Manufacturer

Mitsui Petrochemical

General Description

Polymethylpentene, a member of the polyolefin family, is manufactured by a catalytic polymerization of 4-methylpentene-1. PMP is known for its transparency and extremely low density. PMP is usually compounded with additives and comonomers to enhance its mechanical and optical properties. Specialty grades available include radiation resistant, as well as mica and glass filled. In 1994, the price of PMP ranged approximately from $6.50 to $7.00 per pound at truckload quantities.

General Properties

Polymethylpentene is a highly transparent polyolefin with light-transmission values up to 90%. PMP also has a relatively high melting point of approximately 464°F (240°C), and it retains useful mechanical properties at temperatures as high as 401°F (205°C). Although PMP is degraded by sunlight and high-energy irradiation, there are grades available which can withstand medical irradiation sterilization. PMP has good electrical properties and chemical resistance, however, is attacked by strong oxidizing acids. Unfilled polymethylpentene has a specific gravity of 0.83, which makes it one of the lightest thermoplastic resins.

Typical Applications

- Medical — syringes, connector pieces, hollowware, disposable cuvettes
- Lighting — diffusers, lenses, reflectors
- Packaging — microwave and hot air oven containers, food trays, coated paper plates
- Miscellaneous — liquid level and flow indicators, fluid reservoirs, machine bearing oiler bottles

Typical Properties of Polymethylpentene

	American Engineering	SI
Processing temperature	550-600°F	288-316°C
Linear mold shrinkage	0.002-0.021 in/in	0.002-0.021 cm/cm
Melting point	450-465°F	232-241°C
Density	51.8-66.8 lb/ft^3	0.83-1.07 g/cm^3
Tensile strength, yield	2.1-3.4 lb/in^2 x 10^3	1.5-2.4 kg/cm^2 x 10^2
Tensile strength, break	3.1-6.0 lb/in^2 x 10^3	2.2-4.2 kg/cm^2 x 10^2
Elongation, break	1.0-120.0%	1.0-120.0%
Tensile modulus	0.7-6.2 lb/in^2 x 10^5	0.5-4.4 kg/cm^2 x 10^4
Flexural strength, yield	-	-
Flexural modulus	1.8-7.2 lb/in^2 x 10^5	1.3-5.1 kg/cm^2 x 10^4
Compressive strength	-	-
Izod notched, R.T.	0.5-23.0 ft-lb/in	2.7-124.2 kg cm/cm
Hardness	R35-R90 Rockwell	R35-R90 Rockwell
Thermal conductivity	-	-
Linear thermal expansion	6.0-7.0 in/in-°F x 10^{-5}	10.8-12.6 cm/cm-°C
Deflection temp. @ 264 psi	150-250°F	66-121°C
Deflection temp. @ 66 psi	180-250°F	82-121°C
Continuous service temp.	-	-
Dielectric strength	1650-1700 V/10^{-3} in	6.5-6.69 V/mm x 10^4
Dielectric constant @ 1MHz	2.0-2.2	2.0-2.2
Dissipation factor @ 1MHz	-	-
Water absorption, 24 hr	-	-

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polymethylpentene **TPX RT-18 produced by Mitsui Plastics**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	3 rms	<50 <0.3	150 1.0	>1900† >13.1†	250 1.7	100 0.7	200 1.4
Roughened	46 rms	100 0.7	500 3.5	1000 6.9	350 2.4	100 0.7	200 1.4
Antioxidant	0.08% Irganox 1010	<50 <0.3	50 0.3	>1900† >13.1†	100 0.7	<50 <0.3	200 1.4
UV stabilizer	0.1% Chimasorb 944	50 0.3	100 0.7	>1900† >13.1†	100 0.7	<50 <0.3	50 0.3
Filler	23% Mica	50 0.3	150 1.0	>1900† >13.1†	250 1.7	150 1.0	200 1.4
Antistatic	0.3% Armostat 475	<50 <0.3	150 1.0	>2100† >14.5†	250 1.7	<50 <0.3	200 1.4

NOTES:

† = Due to the **severe deformation** of the block shear specimens, testing was stopped before the actual bond strength achieved by the adhesive could be determined (the adhesive bond never failed).

■ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

■ (red) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, used in conjunction with Prism Primer 770, or 4011 with 7701, achieved the highest bond strengths on PMP, typically substrate failure. Prism 401, 4011 and Super Bonder 414, cyanoacrylate adhesives, and Loctite 3105 and 3311, light curing acrylic adhesives, achieved the second highest bond strengths. Black Max 380, a rubber toughened cyanoacrylate adhesive, and Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths.

Surface Treatments

The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, caused a dramatic, statistically significant increase in the bondability of PMP. Surface roughening also resulted in a statistically significant increase in the bond strengths achieved on PMP using cyanoacrylate adhesives, but had no statistically significant effect on acrylic adhesives.

Other Important Information

- PMP can be stress cracked by uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately.
- PMP is compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately.
- PMP is incompatible with anaerobic adhesives.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polyphenylene Oxide (PPO)

thermoplastic

Trade Names

• Noryl

Manufacturer

GE Plastics

General Description

PPO is produced by the oxidative coupling of 2,6-dimethyl phenol. The resulting polymer is oxygen linked and properly called poly (2,6-dimethyl phenyl) 1,4-ether. PPO has excellent thermal stability, flame retardance, impact strength, and electrical properties. PPO also has one of the lowest moisture absorption rates found in any engineering thermoplastic. Specialty grades available include graphite/nickel, glass, glass fiber, carbon fiber, and stainless steel filled. In 1994, the price of PPO ranged approximately from $ 2.00 to $3.50 per pound at truckload quantities.

General Properties

PPO is an engineering thermoplastic known for its excellent radiation resistance, oxidation resistance, thermal stability, and electrical properties. In addition, PPO also has outstanding dimensional stability, impact strength at low temperatures, and endurance. Because PPO homopolymer is very difficult to process, PPO is often copolymerized with styrene, or a combination of butadiene and styrene, which facilitates processing and makes a wide range of physical properties available. PPO is chemically resistant to aqueous solutions, acids, bases, and salt solutions, but only mildly compatible with oils and greases. PPO is soluble in trichloroethylene, toluene, and ethylene dichloride, and may be stress cracked by other halogenated solvents, esters, and ketones. Due to PPO's thermal stability and low moisture absorption, products made of PPO can be repeatedly steam sterilized without significant degradation and can also be metal-plated.

Typical Applications

- Telecommunications — television cabinetry, cable splice boxes, wire board frames
- Automotive — grilles, spoilers, wheel covers, fuse blocks
- Business Machines — personal computer, printer bases, video display terminals

Typical Properties of Polyphenylene Oxide

	American Engineering	SI Units
Processing temperature	450-575°F	232-302°C
Linear mold shrinkage	0.004-0.009 in/in	0.004-0.009 cm/cm
Melting point	415-500°F	213-260°C
Density	64.9-69.3 lb/ft^3	1.04-1.11 g/cm^3
Tensile strength, yield	4.6-10.1 lb/in^2 x 10^3	3.2-7.1 kg/cm^2 x 10^2
Tensile strength, break	4.1-9.7 lb/in^2 x 10^3	2.9-6.8 kg/cm^2 x 10^2
Elongation, break	4.4-85.0%	4.4-85.0%
Tensile modulus	2.9-3.8 lb/in^2 x 10^5	2.0-2.7 kg/cm^2 x 10^4
Flexural strength, yield	7.0-15.5 lb/in^2 x 10^3	4.9-10.9 kg/cm^2 x 10^2
Flexural modulus	2.6-3.6 lb/in^2 x 10^5	1.8-2.5 kg/cm^2 x 10^4
Compressive strength	7.3-16.6 lb/in^2 x 10^3	5.1-11.7 kg/cm^2 x 10^2
Izod notched, R.T.	1.5-8.3 ft-lb/in	8.1-44.8 kg cm/cm
Hardness	R115-R120 Rockwell	R115-R120 Rockwell
Thermal conductivity	0.9-1.5 BTU-in/hr-ft^2-°F	0.13-0.22 W/m°-K
Linear thermal expansion	2.9-4.4 in/in-°F x 10^{-5}	5.2-7.9 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	180-450°F	82-232°C
Deflection temp. @ 66 psi	200-450°F	93-232°C
Continuous service temp.	200-250°F	93-121°C
Dielectric strength	400-600 V/10^{-3} in	1.6-2.4 V/mm x 10^4
Dielectric constant @ 1MHz	2.0-2.8	2.0-2.8
Dissipation factor @ 1MHz	0.002-0.004	0.002-0.004
Water absorption, 24 hr	0.06-0.10%	0.06-0.10%

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polyphenylene Oxide **Noryl 731 produced by GE Plastics**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	7 rms	500 3.5	2500 17.2	1750 12.1	1600 11.0	300 2.07	950 6.6
Roughened	25 rms	500 3.5	2500 17.2	1750 12.1	1600 11.0	600 4.1	950 6.6
Lubricant	9% Polymist F5A	500 3.5	1150 7.9	1000 6.9	1000 6.9	300 2.1	950 6.6
Filler	9% 489 Fiberglass	500 3.5	2500 17.2	1750 12.1	1600 11.0	950 6.6	500 3.5
Antistatic	5% Larostat HTS-904	650 4.5	850 5.9	600 4.1	650 4.5	300 2.1	950 6.6

NOTES:
- ■ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.
- ■ (pink) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, achieved the highest bond strengths on PPO. Loctite 3105 and 3311, light curing acrylic adhesives, performed the third best. Black Max 380, a rubber toughened cyanoacrylate adhesive, and Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths. The addition of an antistatic agent or internal lubricant to PPO was found to cause a statistically significant decrease in the bond strengths achieved by the cyanoacrylate adhesives. However, the addition of antistatic agent was determined to cause a statistically significant increase in the bond strengths achieved by Black Max 380.

Surface Treatments

Prism Primer 770, when used in conjunction with Prism 401, or 4011 with 7701, caused a statistically significant decrease in the bond strengths achieved on PPO. Surface roughening caused a statistically significant increase in the bond strengths achieved by Depend 330, but had no statistically significant effect on any of the other adhesives evaluated.

Other Important Information

- PPO can be stress cracked by uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately.
- PPO is compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately.
- PPO is incompatible with anaerobic adhesives.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polyphenylene Sulfide (PPS)

thermoplastic

Trade Names	Manufacturer
• Fortron	Hoechst Celanese
• Hyvex	Ferro Corporation
• Ryton	Phillips 66 Co.
• Supec	GE Plastics
• Tedur	Miles Inc.

General Description

PPS is produced by reacting p-dichlorobenzene with sodium sulfide. The resulting polymer is a crystalline, aromatic polymer whose backbone is composed of benzene rings para-substituted with sulfur atoms. This molecular structure is highly crystalline and extremely stable, which results in the outstanding heat resistance, chemical resistance, and dimensional stability of PPS. Specialty grades available include ground and fibrous glass, mineral, and carbon filled. In 1994, the price of PPS ranged approximately from $ 2.25 to $ 5.75 per pound at truckload quantities.

General Properties

The most notable properties of PPS are its thermal stability, inherent flame resistance, and outstanding chemical resistance. PPS also has good mechanical properties which remain stable during both long and short-term exposure to high temperatures. Although the high tensile strength and flexural modulus associated with PPS decrease somewhat with increasing temperature, they level off at approximately 250°F (121°C), and moderately high mechanical properties are maintained up to 500°F (260°C). In addition, PPS also exhibits a significant increase in its elongation and toughness at elevated temperatures. Although PPS has a low impact strength, glass fibers can be added for applications requiring high impact strength and dielectric properties. Glass and mineral fillers are also used for electrical applications where a high arc resistance and low track rate are required. Although PPS is highly chemically resistant–virtually insoluble below 400°F (204°C)–it can be attacked by chlorinated hydrocarbons. PPS is difficult to process, because of the high melt temperatures required, but the extremely crystalline structure of PPS results in high quality molded parts which are uniform and reproducible.

Typical Properties of Polyphenylene Sulfide

	American Engineering	SI
Processing temperature	600-650°F	316-343°C
Linear mold shrinkage	0.001-0.003 in/in	0.001-0.003 cm/cm
Melting point	525-600°F	274-316°C
Density	81.2-124.9 lb/ft^3	1.30-2.00 g/cm^3
Tensile strength, yield	1.4-29.0 lb/in^2 x 10^3	1.0-20.4 kg/cm^2 x 10^2
Tensile strength, break	6.4-29.0 lb/in^2 x 10^3	4.5-20.4 kg/cm^2 x 10^2
Elongation, break	1.0-4.0%	1.0-4.0%
Tensile modulus	10.0-45.0 lb/in^2 x 10^5	7.0-31.6 kg/cm^2 x 10^4
Flexural strength, yield	6.0-40.0 lb/in^2 x 10^3	4.2-28.1 kg/cm^2 x 10^2
Flexural modulus	1.2-2.4 lb/in^2 x 10^5	0.8-16.9 kg/cm^2 x 10^4
Compressive strength	16.0-28.0 lb/in^2 x 10^3	11.2-19.7 kg/cm^2 x 10^2
Izod notched, R.T.	0.6-1.9 ft-lb/in	3.2-10.3 kg cm/cm
Hardness	R116-R123 Rockwell	R116-R123 Rockwell
Thermal conductivity	-	-
Linear thermal expansion	0.5-1.8 in/in-°F x 10^{-5}	0.9-3.2 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	300-550°F	149-288°C
Deflection temp. @ 66 psi	400-550°F	204-288°C
Continuous service temp.	300-450°F	149-232°C
Dielectric strength	280-510 V/10^{-3} in	1.1-2.0 V/mm x 10^4
Dielectric constant @ 1MHz	3.4-6.0	3.4-6.0
Dissipation factor @ 1MHz	0.003-0.010	0.003-0.010
Water absorption, 24 hr	0.010-0.060%	0.010-0.060%

Typical Applications

• Chemical Processing	submersible, centrifugal, vane, and gear-type pumps
• Mechanical	hydraulic components, bearings, cams, valves
• Small Appliance	hair dryers, small cooking appliances, range components

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polyphenylene Sulfide **Supec courtesy of GE Plastics**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Supec grade W331	30% glass reinforced PTFE filled 9 rms	100 0.7	150 1.0	400 2.8	250 1.7	150 1.0	550 3.8
Grade W331 roughened	24 rms	150 1.0 ■	500 3.5 ■	400 2.8	400 2.8 ■	350 2.4 ■	550 3.8
Grade G301T	30% glass reinforced	200 1.4	400 2.8	150 1.0	350 2.4	250 1.7	1200 8.3
Grade G401	40% glass reinforced	200 1.4	300 2.1	300 2.1	300 2.1	450 3.1	1100 7.6
Grade G323	65% glass/mineral filled	250 1.7	400 2.8	900 6.2	600 4.1	300 2.1	2050 14.1
Grade CTX530	30% glass reinforced PPS/PEI blend	150 1.0	250 1.7	400 2.8	400 2.8	200 1.4	900 6.2

NOTES: ■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

Adhesive Performance

Loctite 3105 and 3311, light curing acrylic adhesives, achieved the highest bond strengths on the grades of PPS evaluated. Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, achieved the second highest bond strengths. The lowest bond strengths were achieved by Depend 330, a two-part no-mix acrylic adhesive, and Black Max 380, a rubber toughened cyanoacrylate adhesive. Typically, Depend 330 achieved slightly higher bond strengths than Black Max 380.

Surface Treatments

Surface roughening caused a statistically significant increase in the bond strengths achieved by all the adhesives evaluated, with the exception of Loctite 3105 and 3311, both of which experienced no statistically significant change. The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, did not produce any statistically significant change in the bondability of PPS.

Other Important Information

- PPS is compatible with all Loctite adhesives, sealants, primers, activators, and accelerators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polypropylene (PP)

thermoplastic

PP

Trade Names / Manufacturer

Trade Names	Manufacturer
• Adpro	Genesis Polymers
• Astryn	Himont USA, Inc.
• Azdel	Azdel, Inc.
• Endura	PPG Industries, Inc.
• Fortilene	Solvay Polymers
• HiGlass	Himont USA, Inc.
• Marlex	Philips 66 Co.
• Moplen	Himont USA, Inc.
• Nortuff	Quantum Chemical
• Petrothene	Quantum Chemical
• Polyfort FPP	A. Schulman, Inc.
• Rexene PP	Rexene
• Tonen	Tonen Petrochem
• Unipol PP	Shell Chemical Co.
• Valtec	Himont USA, Inc.

General Description

PP is manufactured by the polymerization of gaseous PP monomer, in the presence of an organometallic catalyst, at low pressure. The key to PP's properties is its crystallinity, which is determined by the degree of organization of the methyl groups on the polymer's backbone. Syndiotactic PP is formed when the methyl groups alternate above and below the plane of the main polymer chain. On the other hand, isotactic PP is formed when the methyl groups all lie above (or below) the plane. Finally, atactic PP results when the methyl groups are randomly positioned. Specialty grades available include calcium carbonate, carbon, copper, glass, mica, mineral, and glass bead filled. In 1994, the price of PP ranged approximately from $1.50 to $10.50 per pound at truckload quantities.

Typical Properties of Polypropylene

	American Engineering	SI
Processing temperature	390-460°F	199-238°C
Linear mold shrinkage	0.011-0.020 in/in	0.011-0.020 cm/cm
Melting point	320-360°F	160-182°C°C
Density	56.2-56.8 lb/ft^3	0.90-0.91 g/cm^3
Tensile strength, yield	2.8-5.4 $lb/in^2 \times 10^3$	2.0-3.8 $kg/cm^2 \times 10^2$
Tensile strength, break	2.5-5.4 $lb/in^2 \times 10^3$	1.8-3.8 $kg/cm^2 \times 10^2$
Elongation, break	1.8-500%	1.8-500%
Tensile modulus	1.4-2.1 $lb/in^2 \times 10^5$	1.0-1.5 $kg/cm^2 \times 10^4$
Flexural strength, yield	3.7-7.5 $lb/in^2 \times 10^3$	2.6-5.3 $kg/cm^2 \times 10^2$
Flexural modulus	1.1-2.5 $lb/in^2 \times 10^5$	0.8-1.8 $kg/cm^2 \times 10^4$
Compressive strength	3.5-4.7 $lb/in^2 \times 10^3$	2.5-3.3 $kg/cm^2 \times 10^2$
Izod notched, R.T.	0.3-1.0 ft-lb/in	1.6-5.4 kg cm/cm
Hardness	R65-R105 Rockwell	R65-R105 Rockwell
Thermal conductivity	0.8-1.6 BTU-in/hr-ft^2-°F	0.12-0.23 W/m°-K
Linear thermal expansion	2.1-6.5 in/in-°F x 10^{-5}	3.8-11.7 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	140-300°F	60-149°C
Deflection temp. @ 66 psi	225-310°F	107-154°C
Continuous service temp.	200-250°F	90-121°C
Dielectric strength	580-990 V/10^{-3} in	2.3-3.9 V/mm x 10^4
Dielectric constant @ 1MHz	2.1-2.7	2.1-2.7
Dissipation factor @ 1MHz	0.0002-0.0005	0.0002-0.0005
Water absorption, 24 hr	0.01-0.03%	0.01-0.03%

General Properties

PP is known for its good mechanical properties, heat resistance, and chemical resistance. In addition, PP has the highest flexural modulus of the polyolefins, is among the lightest of the engineering thermoplastics (SG=0.90), and has excellent moisture resistance. One of the major disadvantages of PP is its poor impact strength at low temperatures. However, PP/elastomer blends are available with much improved impact resistance. PP's mechanical properties are very dependent on its degree of crystallinity. Isotactic PP is harder, stiffer, and has a higher tensile strength than atactic PP, while atactic PP exhibits better impact strength and elongation under stress. Random copolymers are produced by introducing small amounts of ethylene into the polymerization reactor and result in much improved clarity and toughness at the expense of stiffness. PP is chemically resistant to most substances including nonoxidizing inorganics, detergents, low-boiling hydrocarbons, and alcohols. Unfilled PP is flammable and degraded by UV light; however, flame retardant and UV stabilized grades are available.

Typical Applications

• Fibers	carpet backing, diaper coverstock, rope
• Packaging	packaging films, bottles, prescription vials
• Appliance	washer agitators, dishwasher components
• Miscellaneous	straws, luggage, syringes, toys, storage battery cases

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polypropylene

Profax 6323 produced by Himont

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	5 rms	50 0.3	50 0.3	>1950† >13.5†	50 0.3	200 1.4	100 0.7
Roughened	26 rms	50 0.3	550 3.8	1300 9.0	300 2.1	200 1.4	450 3.1
Antioxidant	0.1% Irganox 1010 0.3% Cyanox STDP	50 0.3	250 1.7	>1950† >13.5†	50 0.3	200 1.4	100 0.7
UV stabilizer	0.5% Cyasorb UV 531	50 0.3	50 0.3	>1950† >13.5†	50 0.3	200 1.4	100 0.7
Impact modifier	9% Novalene EPDM	50 0.3	150 1.0	>1650† >11.4†	200 1.4	200 1.4	100 0.7
Flame retardant	9% PE-68 4% Antimony oxide	50 0.3	50 0.3	>1950† >13.5†	50 0.3	200 1.4	250 1.7
Smoke suppressant	13% Firebrake ZB	50 0.3	50 0.3	>1950† >13.5†	50 0.3	200 1.4	100 0.7
Lubricant	0.1% Calcium stearate 24-26	50 0.3	50 0.3	>1950† >13.5†	50 0.3	200 1.4	100 0.7
Filler	20% Cimpact 600 Talc	50 0.3	50 0.3	>1950† >13.5†	100 0.7	200 1.4	100 0.7
Colorant	0.1% Watchung Red RT-428-D	50 0.3	50 0.3	>1950† >13.5†	50 0.3	200 1.4	100 0.7
Antistatic	0.2% Armostat 475	50 0.3	200 1.4	>1950† >13.5†	200 1.4	200 1.4	100 0.7

NOTES:

† = Due to the **severe deformation** of the block shear specimens, testing was stopped before the actual bond strength achieved by the adhesive could be determined (the adhesive bond never failed).

■ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

■ (pink) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, used in conjunction with Prism Primer 770, or 4011 with 7701, achieved the highest bond strengths on PP, typically substrate failure. Black Max 380, a rubber toughened cyanoacrylate adhesive, Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, Depend 330, a two-part no-mix acrylic adhesive, and Loctite 3105 and 3311, light curing acrylic adhesives, all performed poorly on unprimed, unabraded PP.

Surface Treatments

The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, resulted in a dramatic, statistically significant increase in the bond strengths achieved on PP, typically substrate failure. Surface roughening resulted in either no effect or a statistically significant increase in the bond strengths achieved on PP.

Other Important Information

- Polypropylene is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polystyrene (PS)

thermoplastic

Trade Names	Manufacturer
• Dylark	ARCO Chemical
• Esbrite	Sumitomo Chemical
• Kaofulex	Kaofu Chemical
• Polyrex	Chi Mei Industrial
• Polysar	Novacor Chemicals
• Styron	Dow Chemical
• Styronol	Allied Resinous

General Description

The types of polystyrene commercially available can be broken down into three main categories, namely crystal, impact (HIPS), and expandable polystyrene (EPS). Crystal polystyrene is an amorphous polymer produced by the polymerization of styrene monomer at elevated temperatures. It is a rigid, glossy material, with superior clarity, but is limited by poor impact resistance. For applications requiring higher impact resistance, impact polystyrene is used. Impact polystyrene is produced by blending polybutadiene rubber with the polystyrene monomer prior to polymerization. Polystyrene also finds widespread use as "styrofoam". Styrofoam is predominately produced using expandable polystyrene (EPS) beads. EPS beads are polystyrene beads which contain a blowing agent. When heated, the blowing agent vaporizes, expanding the polystyrene and forming a low density foam. Specialty grades available include ignition resistant, glass fiber, silicone, and calcium carbonate filled. In 1994, the price of PS ranged from $0.50 to $1.25 per pound at truckload quantities.

Typical Properties of Polystyrene

	American Engineering	SI
Processing temperature	300-500°F	149-260°C
Linear mold shrinkage	0.002-0.008 in/in	0.002-0.008 cm/cm
Melting point	212-45°F	100-241°C
Density	63.7-66.2 lb/ft^3	1.02-1.06 g/cm^3
Tensile strength, yield	2.4-6.2 lb/in^2 x 10^3	1.7-4.4 kg/cm^2 x 10^2
Tensile strength, break	2.7-7.6 lb/in^2 x 10^3	1.9-5.3 kg/cm^2 x 10^2
Elongation, break	2.0-80.0%	2.0-80.0%
Tensile modulus	2.2-4.8 lb/in^2 x 10^5	1.5-3.4 kg/cm^2 x 10^4
Flexural strength, yield	4.3-13.0 lb/in^2 x 10^3	3.0-9.1 kg/cm^2 x 10^2
Flexural modulus	2.0-4.8 lb/in^2 x 10^5	1.4-3.4 kg/cm^2 x 10^4
Compressive strength	7.0-12.0 lb/in^2 x 10^3	4.9-8.4 kg/cm^2 x 10^2
Izod notched, R.T.	0.2-2.2 ft-lb/in	1.1-11.9 kg cm/cm
Hardness	M50-M100 Rockwell	M50-M100 Rockwell
Thermal conductivity	1.4-3.0 BTU-in/hr-ft^2-°F	0.20-0.43 W/m°-K
Linear thermal expansion	3.7-8.4 in/in-°F x 10^{-5}	6.7-15.1 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	150-275°F	66-135°C
Deflection temp. @ 66 psi	170-275°F	77-135°C
Continuous service temp.	-	-
Dielectric strength	300-575 V/10^{-3} in	1.2-2.3 V/mm x 10^4
Dielectric constant @ 1MHz	2.5-2.6	2.5-2.6
Dissipation factor @ 1MHz	0.0001-0.0010	0.0001-0.0010
Water absorption, 24 hr	0.05-0.10%	0.05-0.10%

General Properties

Polystyrene is known for its optical clarity, rigidity, and ability to be processed by all thermoplastic processes. Flexural modulii as high as approximately 500,000 psi (35,000 kg/cm^2), a tensile strength of 8,000 psi, and an elongation generally between 3% and 5% are typical of crystal polystyrene. However, the impact resistance of crystal polystyrene is very low, usually between 0.3 to 0.5 ft-lb/in. Impact resistant grades are available with elongations of up to 50%, and notched izod impact strengths as high as 5 ft-lb/in, but the optical clarity and tensile strength decrease. Crystal grades of polystyrene transmit up to 90% of visible light, but are susceptible to weathering and ultraviolet light degradation. Protective coatings or UV stabilizers are recommended for outdoor applications. In general, polystyrene has poor solvent resistance and is attacked by hydrocarbons, phenols, ketones, esters, ethers, and some acids. Due to its low melting point, polystyrene is not recommended for use in high temperature applications. Polystyrene is a good insulator and has a low dielectric loss factor.

Typical Applications

• Packaging	processed food and produce containers, foam for meat and produce trays
• Construction	window moldings and frames, doors and door frames, footing profiles, structural foam sections for insulating walls
• Household	styrofoam plates, toys, food containers, television housings
• Medical	labware, diagnostic equipment, tissue culture flasks, vacuum canisters

ADHESIVE SHEAR STRENGTH

(psi)
(MPa)

Polystyrene **XC2245-HIY-9100 by Huntsman**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	4 rms	450 3.1	1350 9.3	>1750Δ >12.1Δ	500 3.5	350 2.4	1350 9.3
Roughened	32 rms	750 5.2	>800Δ >5.5Δ	750 5.2	800 5.5	350 2.4	1350 9.3
Antioxidant	0.06% Irganox 245 0.02% Irganox 1076	450 3.1	>1450Δ >10.0Δ	>3300Δ >22.8Δ	1250 8.6	350 2.4	1350 9.3
UV stabilizer	0.31% Tinuvin 328 0.31% Tinuvin 770	450 3.1	1350 9.3	>1750Δ >12.1Δ	500 3.5	350 2.4	500 3.5
Impact modifier	15% Kraton D1101	900 6.2	>2100Δ >14.5Δ	>1750Δ >12.1	>2300Δ >15.9Δ	150 1.0	>2000Δ >13.8Δ
Flame retardant	4% Saytex HBCD-SF 1% Antimony Oxide	450 3.1	750 5.2	>1750Δ >12.1Δ	>850Δ >5.9Δ	50 0.3	1350 9.3
Lubricant	0.5% Zinc Stearate	450 3.1	>1200Δ >8.3Δ	>1750Δ >12.1Δ	500 3.5	50 0.3	1350 9.3
Colorant	4% CP204230	450 3.1	450 3.1	1500 10.3	500 3.5	350 2.4	1000 6.9

NOTES:
Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.
■ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.
■ (pink) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, when used in conjunction with Prism Primer 770, or 4011 with 7701, achieved the highest bond strengths on PS, typically substrate failure. Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, and Loctite 3105 and 3311, light curing acrylic adhesives, normally achieved the second highest bond strengths. Black Max 380, a rubber toughened cyanoacrylate adhesive, and Depend 330, a two-part no-mix acrylic adhesive, achieved the lowest bond strengths. The addition of an impact modifier additive increased the bondability of PS with cyanoacrylate and light curing acrylic adhesives.

Surface Treatments

The use of Prism Primer 770, when used in conjunction with Prism 401, or 4011 with 7701, caused a statistically significant increase in the bondability of all the formulations of PS evaluated, except for the roughened PS, where Prism Primer 770 or 7701 caused a statistically significant decrease in its bondability. Surface roughening caused a statistically significant increase in the bond strengths achieved on unprimed PS when using cyanoacrylate adhesives, but had no statistically significant effect when using acrylic adhesives.

Other Important Information

- Polystyrene is compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately.
- Polystyrene is incompatible with anaerobic adhesives.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polyurethane (PU)

thermoplastic

Trade Names	Manufacturer
• Bayflex	Miles Inc.
• Estane	B. F. Goodrich Chemical
• Isoplast	Dow Chemical
• Mor-Thane	Morton
• Neuthane	New England Urethane
• Pellethane	Dow Chemical
• Tecoflex	Thermedics Inc.
• Tecothane	Thermedics Inc.
• Texin	Miles Inc.

General Description

Polyurethanes are produced by the condensation reaction of an isocyanate and a material with a hydroxyl functionality, such as a polyol. PU can have the chemical structure of either a thermoplastic or thermoset and can have the physical structure of a rigid solid, a soft elastomer, or a foam. The chemical composition of PU can also vary widely, depending on the specific polyol and isocyanate bearing species which are reacted to form the PU. The many different chemical structures and physical forms possible for PU make it a versatile, widely used polymer. Specialty grades available include flame retardant, clay, silica, and glass filled. In 1994, the price of PU ranged approximately from $2.50 to $6.50 per pound at truckload quantities.

General Properties

The major benefits offered by PU are that it retains its high impact strength at low temperatures, it is readily foamable, and it is resistant to abrasion, tear propagation, ozone, oxidation, fungus, and humidity. Although thermoplastic PU is attacked by steam, fuels, ketones, esters, and strong acids and bases, it is resistant to aliphatic hydrocarbons and dilute acids and bases. The highest recommended use temperature of thermoplastic PU is approximately 220°F (104°C), rendering it inappropriate for most high temperature applications. Furthermore, thermoplastic PU has poor weatherability stemming from its poor resistance to UV degradation. Since PU can be painted with flexible PU paints without pretreatment, it has found use in many automotive exterior parts.

Typical Properties of Polyurethane

	American Engineering	SI
Processing temperature	385-450°F	196-232°C
Linear mold shrinkage	0.004-0.014 in/in	0.004-0.014 cm/cm
Melting point	400-450°F	204-232°C
Density	69.9-77.4 lb/ft^3	1.12-1.24 g/cm^3
Tensile strength, yield	4.9-35.0 lb/in^2 x 10^3	3.4-24.6 kg/cm^2 x 10^2
Tensile strength, break	4.9-35.0 lb/in^2 x 10^3	3.4-24.6 kg/cm^2 x 10^2
Elongation, break	100.0-500.0%	100.0-500.0%
Tensile modulus	0.6-45.0 lb/in^2 x 10^5	0.4-31.6 kg/cm^2 x 10^4
Flexural strength, yield	6.0-60.0 lb/in^2 x 10^3	4.2-42.2 kg/cm^2 x 10^2
Flexural modulus	0.1-0.4 lb/in^2 x 10^5	0.0-0.2 kg/cm^2 x 10^4
Compressive strength	1.2-29.5 lb/in^2 x 10^3	0.8-20.7 kg/cm^2 x 10^2
Izod notched, R.T.	1.5 ft-lb/in-no break	8.1-0.0 kg cm/cm
Hardness	A55-A95 Rockwell	A55-A95 Rockwell
Thermal conductivity	1.7-2.3 BTU-in/hr-ft^2-°F	0.25-0.33 W/m°-K
Linear thermal expansion	1.8-8.4 in/in-°F x 10^{-5}	3.2-15.1 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	100-330°F	38-166°C
Deflection temp. @ 66 psi	115-370°F	46-188°C
Continuous service temp.	180-220°F	82-104°C
Dielectric strength	430-730 V/10^{-3} in	1.7-2.9 V/mm x 10^4
Dielectric constant @ 1MHz	4.4-5.1	4.4-5.1
Dissipation factor @ 1MHz	0.060-0.100	0.060-0.100
Water absorption, 24 hr	0.10-0.60%	0.10-0.60%

Typical Applications

• Automotive	facias, padding, seats, gaskets, body panels, bumpers
• Medical	implantable devices, tubing, blood bags, dialysis membrane
• Machinery	bearings, nuts, wheels, seals, tubing
• Consumer	furniture padding, mattress goods, roller skate wheels, athletic shoes

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polyurethane **Pellethane 2363-55D produced by Dow Chemical**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin (shore D)	14 rms	200 1.4	350 2.4	1400 9.7	300 2.1	350 2.4	1150 7.9
Roughened	167 rms	350 2.4	1350 9.3	1950 13.5	1300 9.0	1500 10.3	1700 11.7
UV stabilizer	1% Tinuvin 328	100 0.7	200 1.4	950 6.6	150 1.0	350 2.4	750 5.2
Flame retardant	15% BT-93 2% Antimony Oxide	200 1.4	450 3.1	>1850† >12.8†	600 4.1	>1400† >9.7†	>1350† >9.3†
Plasticizer	13% TP-95	50 0.3	150 1.0	>750† >5.2†	150 1.0	200 1.4	450 3.1
Lubricant #1	0.5% Mold Wiz INT-33PA	200 1.4	800 5.5	>2150† >14.8†	700 4.8	900 6.2	>1800† >12.4†
Lubricant #2	0.5% FS1235 Silicone	450 3.1	>2250† >15.5†	>2900† >20.0†	1250 8.6	>2650† >18.3†	>2350† >16.2†
Unfilled resin (shore A)	Estane 58630 B.F Goodrich	200 1.4	>850† >5.9†	>1300† >9.0†	550 3.8	450 3.1	800 5.5

NOTES: † = Due to the **severe deformation** of the block shear specimens, testing was stopped before the actual bond strength achieved by the adhesive could be determined (the adhesive bond never failed).

■ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

■ (pink) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, used in conjunction with Prism Primer 770, or 4011 with 7701, created bonds which were stronger than the substrate for most of the polyurethane formulations which were evaluated. Typically, the adhesives which achieved the second highest bond strengths were Loctite 3105 and 3311, light curing acrylic adhesives, followed by Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, and Depend 330, a two-part no-mix acrylic adhesive. Black Max 380, a rubber toughened cyanoacrylate adhesive, consistently achieved the lowest bond strengths on polyurethane.

Surface Treatments

The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, resulted in a large, statistically significant increase in the bond strengths achieved on polyurethane. Surface roughening also resulted in a statistically significant increase in the bond strengths achieved on polyurethane for all the adhesives which were evaluated.

Other Important Information

- Polyurethane can be stress cracked by uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately.
- Polyurethane is compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately.
- Polyurethane is incompatible with anaerobic adhesives.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Polyvinyl Chloride (PVC)

thermoplastic

Trade Names / Manufacturer

Trade Names	Manufacturer
• Alpha	Dexter Plastics
• Fiberloc	B. F. Goodrich
• Geon	B. F. Goodrich
• Novablend	Novatec Plastics
• Polyvin	A. Schulman
• Quirvil	Rukmianca SpA
• Superkleen	Alpha Chemical
• Tenneco	Rimtech Corp.
• Unichem	Colorite Plastics
• Vythene	Alpha Chemical

General Description

Polyvinyl chloride, the most widely used of the vinyl resins, is formed via the free radical polymerization of vinyl chloride monomer. Unmodified PVC is a hard, brittle, glass-like material which is unsuitable for most engineering applications. However, the addition of plasticizers, such as dioctyl phthalate (DOP), give PVC sufficient flexibility to be used for many applications. PVC is one of the most economical and versatile plastics in use today. It has become a very popular construction material, with major applications including piping and home siding. Specialty grades available include impact modified, filled, pigmented, and flame retarded. In 1994, the prices of PVC ranged approximately from $0.50 to $1.50 per pound at truckload quantities.

General Properties

Polyvinyl chloride offers good physical properties at a fraction of the cost of some of the more expensive engineering resins. A wide variety of fillers and additives are commonly used with PVC to tailor its characteristics to meet the needs of the end user. PVC is resistant to water, weathering, and corrosion, has a high strength-to-weight ratio, and is a good electrical and thermal insulator. Most grades of PVC are non-flammable and receive a UL94 rating of V-0. With a maximum recommended continuous service temperature no higher than 220°F (104°C), PVC is not recommended for high temperature applications. It has good resistance to alcohols, mild acids and bases, and salts, but is attacked by halogenated hydrocarbons, phenols, ketones, esters, and ethers. PVC is easily processed by a wide variety of thermoplastic methods, however, stabilizers must be added to scavenge the HCl released during high temperature processing which could degrade the resin.

Typical Properties of Polyvinyl Chloride

	American Engineering	SI
Processing temperature	315-410°F	157-210°C
Linear mold shrinkage	0.001-0.005 in/in	0.001-0.005 cm/cm
Melting point	270-405°F	132-207°C
Density	72.4-91.8 lb/ft^3	1.16-1.47 g/cm^3
Tensile strength, yield	1.3-7.4 lb/in^2 x 10^3	0.9-5.2 kg/cm^2 x 10^2
Tensile strength, break	1.1-7.4 lb/in^2 x 10^3	0.8-5.2 kg/cm^2 x 10^2
Elongation, break	5.0-500.0%	5.0-500.0%
Tensile modulus	2.7-4.5 lb/in^2 x 10^5	1.9-3.2 kg/cm^2 x 10^4
Flexural strength, yield	10.7-12.0 lb/in^2 x 10^3	7.5-8.4 kg/cm^2 x 10^2
Flexural modulus	3.0-5.4 lb/in^2 x 10^5	2.1-3.8 kg/cm^2 x 10^4
Compressive strength	6.5-10.1 lb/in^2 x 10^3	4.6-7.1 kg/cm^2 x 10^2
Izod notched, R.T.	0.3-17.6 ft-lb/in	1.6-95.0 kg cm/cm
Hardness	A50-A95 Rockwell	A50-A95 Rockwell
Thermal conductivity	1.0-1.3 BTU-in/hr-ft^2-°F	0.14-0.19 W/m°-K
Linear thermal expansion	3.6-7.3 in/in-°F x 10^{-5}	6.5-13.1 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	100-311°F	38-155°C
Deflection temp. @ 66 psi	113-311°F	45-155°C
Continuous service temp.	130-220°F	54-104°C
Dielectric strength	350-725 V/10^{-3} in	1.4-2.8 V/mm x 10^4
Dielectric constant @ 1MHz	3.9-5.2	3.9-5.2
Dissipation factor @ 1MHz	0.019-0.090	0.019-0.090
Water absorption, 24 hr	0.08-0.60%	0.08-0.60%

Typical Applications

- **Construction** — water supply, agricultural irrigation and chemical processing piping, siding, window sashes, gutters, interior moldings, flooring
- **Packaging** — films for food wrap, bottles, food containers
- **Consumer goods** — furniture parts, wall coverings, upholstery, sporting goods, toys
- **Medical** — tubing, blood and solution bags, dialysis devices, connectors

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polyvinyl Chloride **Oxychem 160 produced by Occidental Chemical**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	3 rms	>1600Δ >11.0Δ	>3650Δ >25.2Δ	>2850Δ >19.7Δ	>2900Δ >20.0Δ	>2650Δ >18.3Δ	>2550Δ >17.6Δ
Roughened	27 rms	>1600Δ >11.0Δ	>1850Δ >12.8Δ	>1400Δ >9.7Δ	>2900Δ >20.0Δ	>1550Δ >10.7Δ	>2550Δ >17.6Δ
UV stabilizer	1% UV-531	>1600Δ >11.0Δ	>2800Δ >19.3Δ	>1400Δ >9.7Δ	>2900Δ >20.0Δ	>1850Δ >12.8Δ	>2550Δ >17.6Δ
Impact modifier	7% Paraloid BTA753	>1100Δ >7.6Δ	>4300Δ >29.7Δ	>3650Δ >25.2Δ	>2900Δ >20.0Δ	1050 7.24	>3000Δ >20.7Δ
Flame retardant	0.3% Antimony Oxide	>1600Δ >11.0Δ	>3050Δ >21.0Δ	>2850Δ >19.7Δ	>2900Δ >20.0Δ	>2050Δ >14.1Δ	>2550Δ >17.6Δ
Smoke suppressant	0.3% Ammonium Octamolybdate	1250 8.6	>3650Δ >25.2Δ	>2850Δ >19.7Δ	>2900Δ >20.0Δ	>1800Δ >12.4Δ	>2550Δ >17.6Δ
Lubricant	1% Calcium Stearate 24-46	>1600Δ >11.0Δ	>3650Δ >25.2Δ	>2850Δ >19.7Δ	>2900Δ >20.0Δ	>1900Δ >13.1Δ	>2550Δ >17.6Δ
Filler	9% OmyaCarb F	>1600Δ >11.0Δ	>4250Δ >29.3Δ	>1750Δ >12.1Δ	>4400Δ >30.3Δ	>2650Δ >18.3Δ	>3150Δ >21.7Δ
Plasticizer	5% Drapex 6.8	>1600Δ >11.0Δ	>2250Δ >15.5Δ	>1550Δ >10.7Δ	>2900Δ >20.0Δ	>1500Δ >10.3Δ	>2550Δ >17.6Δ
Colorant	0.5% FD&C Blue #1	>1600Δ >11.0Δ	>3650Δ >25.2Δ	>2850Δ >19.7Δ	>2900Δ >20.0Δ	>1050Δ >7.24Δ	>2550Δ >17.6Δ
Antistatic	1.5% Markstat AL48	>1600Δ >11.0Δ	>3650Δ >25.2Δ	>1200Δ >8.3Δ	>2900Δ >20.0Δ	>900Δ >6.2Δ	>2550Δ >17.6Δ

NOTES:

Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.

■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Black Max 380, a rubber toughened cyanoacrylate adhesive, Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, Depend 330, a two-part no-mix adhesive, and Loctite 3105 and 3311, light curing adhesives, all created bonds which were stronger than the rigid PVC substrate for most of the formulations tested. However, Black Max 380 and Depend 330 typically achieved substrate failure at much lower bond strengths than Prism 401, 4011, Super Bonder 414, Loctite 3105, and 3311.

Surface Treatments

Surface roughening and/or the use of Prism Primer 770 or 7701 resulted in either no statistically significant effect or in the rigid PVC failing at a statistically significant lower bond strength than the untreated PVC.

Other Important Information

- PVC can be stress cracked by uncured cyanoacrylate adhesives, so any excess adhesive should be removed from the surface immediately.
- PVC is compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface of the PVC immediately.
- PVC is incompatible with anaerobic adhesives
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Styrene-Acrylonitrile (SAN)

thermoplastic 7 OTHER

Trade Names / Manufacturer

- Luran — BASF
- Lustran — Monsanto
- Styvex — Ferro Corp.
- Suprel — Vista Chemical Co.
- Tyril — Dow Chemical

General Description

SAN is a high performance polymer of the styrene family, which is formed via the copolymerization of styrene and acrylonitrile monomers. The general properties of SAN are similar to polystyrene, but the addition of the polar acrylonitrile group adds superior chemical resistance, high temperature performance, and toughness. Typical of copolymers, the properties of SAN can be varied by changing the molecular weight and composition. An increase in the acrylonitrile content will improve the resin's physical properties but will make processing more difficult and decrease transparency. SAN can be used as a color carrier for other thermoplastics and as an additive to improve the flow characteristics of ABS, PVC, and some other resins. Specialty grades available include those with UV stabilizers, elastomers, glass fibers, and flow aids. In 1994, the price ranged approximately from $1.00 to $1.50 per pound at truckload quantities.

General Properties

The major benefits of SAN are its stiffness, strength, and clarity. However, like polystyrene, SAN has a low impact strength, typically 0.3 to 1.2 ft-lb/in. The use of reinforcing fillers, such as glass fiber, can be used to increase this impact strength, as well as the heat resistance, hardness, and modulus of SAN. The continuous service temperature of SAN is dependent on the load and specific chemical environment which it will be exposed to, normally varying between 120°F (49°C) and 180°F (82°C). SAN plastics are chemically resistant to aliphatic hydrocarbons, battery acids, bases, and most detergents. However, they are attacked by aromatic and chlorinated hydrocarbons, ketones, and esters.

Typical Properties of Styrene-Acrylonitrile

	American Engineering	SI Units
Processing temperature	415-515°F	213-268°C
Linear mold shrinkage	0.001-0.005 in/in	0.001-0.005 cm/cm
Melting point	212-480°F	100-249°C
Density	65.6-87.4 lb/ft^3	1.05-1.40 g/cm^3
Tensile strength, yield	9.3-17.0 lb/in^2 x 10^3	6.5-12.0 kg/cm^2 x 10^2
Tensile strength, break	8.3-17.6 lb/in^2 x 10^3	5.8-12.4 kg/cm^2 x 10^2
Elongation, break	0.9-3.1%	0.9-3.1%
Tensile modulus	4.5-15.1 lb/in^2 x 10^5	3.2-10.6 kg/cm^2 x 10^4
Flexural strength, yield	12.9-22.8 lb/in^2 x 10^3	9.1-16.0 kg/cm^2 x 10^2
Flexural modulus	4.5-15.0 lb/in^2 x 10^5	3.2-10.5 kg/cm^2 x 10^4
Compressive strength	12.5-23.2 lb/in^2 x 10^3	8.8-16.3 kg/cm^2 x 10^2
Izod notched, R.T.	0.3-1.2 ft-lb/in	1.6-6.5 kg cm/cm
Hardness	M80-M98 Rockwell	M80-M98 Rockwell
Thermal conductivity	1.4-2.2 BTU-in/hr-ft^2-°F	0.20-0.32 W/m-°K
Linear thermal expansion	1.5-3.8 in/in-°F x 10^{-5}	2.7-6.8 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	185-226°F	85-108°C
Deflection temp. @ 66 psi	210-235°F	99-113°C
Continuous service temp.	120-180°F	49-82°C
Dielectric strength	490-520 V/10^{-3} in	1.9-2.0 V/mm x 10^4
Dielectric constant @ 1MHz	2.7-3.7	2.7-3.7
Dissipation factor @ 1MHz	0.008-0.010	0.008-0.010
Water absorption, 24 hr	0.08-0.26%	0.08-0.26%

Typical Applications

- **Appliances** — knobs, refrigerator compartments, blender and mixer bowls
- **Electronics** — cassette cases, meter lenses, tape windows
- **Medical** — syringe components, blood aspirators, dialyzer housings
- **Packaging** — cosmetic containers, closures, bottles, jars
- **Miscellaneous** — safety glazing, battery cases, typewriter keys, pen and pencil barrels

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Styrene-Acrylonitrile **Lustran 31 produced by Monsanto**

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Unfilled resin	3 rms	500 3.5	>3800Δ >26.2Δ	450 3.1	>3650Δ >25.2Δ	800 5.5	2800 19.3
Roughened	18 rm	>850Δ >5.9Δ	>3800Δ >26.2Δ	1150 7.9	>3650Δ >25.2Δ	800 5.5	>2900Δ >20.0Δ
UV stabilizer	0.31% Tinuvin 770 0.31% Tinuvin 328	>2050Δ >14.1Δ	>3800Δ >26.2Δ	450 3.1	>5950Δ >41.0Δ	>1200Δ >8.3Δ	2800 19.3
Flame retardant	4% Saytex HBCD-SF 1% Antimony Oxide	500 3.5	1850 12.8	>1000Δ >6.9Δ	1550 10.7	800 5.5	>2800Δ >19.3Δ
Impact modifier	29% Paraloid EXL3330	1000 6.9	>3800Δ >26.2Δ	>1450Δ >10.0Δ	>3650Δ >25.2Δ	>1100Δ >7.6Δ	2800 19.3
Lubricant	0.1% Calcium Stearate 24-46	500 3.5	>3800Δ >26.2Δ	>750Δ >5.2Δ	>3650Δ >25.2Δ	800 5.5	2800 19.3
Internal mold release	5% Mold Wiz INT-33PA	750 5.2	>3800Δ >26.2Δ	450 3.1	>3650Δ >25.2Δ	800 5.5	1750 12.1
Glass filler	17% Glass Type 3540	500 3.5	>3800Δ >26.2Δ	450 3.1	>4550Δ >31.4Δ	800 5.5	2800 19.3
Colorant	1% OmniColor Fuschia	500 3.5	>3800Δ >26.2Δ	1400 9.7	>3650Δ >25.2Δ	>900Δ >6.2Δ	2800 19.3
Antistatic	3% Armostat 550	>1850Δ >12.8Δ	>3800Δ >26.2Δ	450 3.1	>3650Δ >25.2Δ	800 5.5	>3000Δ >20.7Δ

NOTES:
- Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.
- ■ (grey) = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.
- ■ (red) = The addition of the indicated additive (or surface roughening) caused a statistically significant **decrease** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, created bonds stronger than the SAN substrate for all the formulations which were evaluated, with the exception of the formulation containing the flame retardant additive. Loctite 3105 and 3311, light curing acrylic adhesives, achieved the second highest bond strengths. Depend 330, a two-part no-mix acrylic adhesive, and Black Max 380, a rubber toughened cyanoacrylate adhesive, achieved the lowest bond strengths.

Surface Treatments

Surface roughening caused either no effect or a statistically significant increase in the bond strengths achieved on SAN. The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, caused a statistically significant decrease in the bond strengths achieved on SAN for all the formulations which were evaluated.

Other Important Information

- SAN is compatible with acrylic adhesives, but can be attacked by their activators before the adhesive has cured. Any excess activator should be removed from the surface immediately.
- SAN is incompatible with anaerobic adhesives.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Vinyl Ester

thermoset

Trade Names	Manufacturer
• Acpol	Cook Composites
• Corezyn	Interplastic Corp.
• Corrolite	Reichhold Chemical
• Derakane	Dow Chemical
• Hetron	Ashland Chemical Co.
• Nupol	Cook Composites
• Polycor	Industrial Dielectrics

General Description

Vinyl esters are unsaturated esters of epoxy resins which are usually glass filled to increase their rigidity and decrease their mold shrinkage. Such fiber reinforced plastics (FRP) are usually formed by curing the vinyl ester in layers with variously configurated sheets of glass. The glass sheets typically used are surfacing veils, chopped strands, chopped strand mats, woven rovings, biaxial mats, continuous strands, unidirectional mats and/or a combination of these. Other specialty grades available include UV absorbing, pigmented, and flame retardant grades. In 1994, the price of vinyl esters ranged approximately from $1.50 to $2.00 per pound at truckload quantities.

General Properties

Vinyl esters are known for their outstanding resistance to corrosion and a wide range of chemicals. Vinyl esters also have high impact strengths, good elongations (3-10%), and high weight to strength ratios (SG = 1.1 to 1.3). The properties of vinyl ester resins are extremely versatile, and properties can be tailored to specific applications by modifying the base resin and the composite glass fiber structure. For example, by adding an elastomer to the bisphenol A backbone, the tensile elongation, impact resistance, and abrasion resistance of vinyl esters are greatly increased. The addition of an epoxy novolac resin to its backbone results in superior oxidation, heat, and solvent resistance. The ignition resistance of vinyl esters is greatly improved by adding bromated resins to the polymer's backbone and/or by adding antimony oxide. Unfilled vinyl esters are slow burning and have low smoke emission. Vinyl esters are excellent electrical and thermal insulators and have outstanding resistance to thermal aging. Vinyl esters are chemically resistant to a wide variety of chemicals, including acids, alkalies, halogenated organics, caustics, and solvents.

Typical Properties of Vinyl Ester

	American Engineering	SI
Processing temperature	250-300°F	121-149°C
Linear mold shrinkage	0.0005-0.0010 in/in	0.0005-0.0010 cm/cm
Melting point	-	-
Density	64.3-71.2 lb/ft^3	1.03-1.14 g/cm^3
Tensile strength, yield	9.1-12.6 lb/in^2 x 10^3	6.4-8.9 kg/cm^2 x 10^2
Tensile strength, break	9.9-12.1 lb/in^2 x 10^3	7.0-8.5 kg/cm^2 x 10^2
Elongation, break	3.4-5.5%	3.4-5.5%
Tensile modulus	4.4-5.2 lb/in^2 x 10^5	3.1-3.7 kg/cm^2 x 10^4
Flexural strength, yield	16.0-21.9 lb/in^2 x 10^3	11.2-15.4 kg/cm^2 x 10^2
Flexural modulus	4.4-5.7 lb/in^2 x 10^5	3.1-4.0 kg/cm^2 x 10^4
Compressive strength	16.5-42.0 lb/in^2 x 10^3	11.6-29.5 kg/cm^2 x 10^2
Izod notched, R.T.	0.4-0.6 ft-lb/in	2.2-3.2 kg cm/cm
Hardness	M110-M115 Rockwell	M110-M115 Rockwell
Thermal conductivity	-	-
Linear thermal expansion	1.8-2.1 in/in-°F x 10^{-5}	3.2-3.8 cm/cm-°C x 10^{-5}
Deflection temp. @ 264 psi	200-428°F	93-220°C
Deflection temp. @ 66 psi	-	-
Continuous service temp.	-	-
Dielectric strength	400-470 V/10^{-3} in	1.6-1.8 V/mm x 10^4
Dielectric constant @ 1MHz	2.8-3.5	2.8-3.5
Dissipation factor @ 1MHz	0.002-0.020	0.002-0.020
Water absorption, 24 hr	0.10-0.30%	0.10-0.30%

Typical Applications

• Chemical Equipment tanks	Adsorption towers, process vessels, storage piping, hood scrubbers
• Miscellaneous	Sheet-molding compounds, electrical equipment, flooring, fans

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Vinyl Ester

Loctite Industrial Adhesive		Black Max 380 Rubber Toughened Cyanoacrylate	PRISM 401 Surface Insensitive Cyanoacrylate	PRISM 401/ PRISM Primer 770 Polyolefin Primer for Cyanoacrylates	Super Bonder 414 General-Purpose Cyanoacrylate	Depend 330 Two-Part No-Mix Acrylic	3105 Light Cure Acrylic
Loctite Medical Device Adhesive		--	PRISM 4011 Surface Insensitive Cyanoacrylate	PRISM 4011/ PRISM Primer 7701 Polyolefin Primer for Cyanoacrylates	--	--	3311 Light Cure Acrylic
Derakane 411-45	Vinyl Ester resin with C-glass veil 15 rms courtesy of Dow	950 6.6	1900 13.1	800 5.5	1950 13.5	400 2.8	1950 13.5
411-45 roughened	Vinyl Ester resin with C-glass veil 27 rms	1950 ■ 13.5 ■	1900 13.1	800 5.5	1950 13.5	1000 ■ 6.9 ■	1950 13.5
Derakane 470-36	High Temperature/Corrosion Resistant Grade with C-glass veil	550 3.8	>2200Δ >15.2Δ	650 4.5	>2450Δ >16.9Δ	350 2.4	1500 10.3
C-695 Black 229	20-30% glass fiber mineral filled courtesy of American Cyanamid	>1650Δ >11.4Δ	>2100Δ >14.5Δ	750 5.2	>1850Δ >12.8Δ	600 4.1	1750 12.1

NOTES: Δ = The force applied to the test specimens exceeded the strength of the material resulting in **substrate failure** before the actual bond strength achieved by the adhesive could be determined.

■ = The addition of the indicated additive (or surface roughening) caused a statistically significant **increase** in the bond strength within 95% confidence limits.

Adhesive Performance

Prism 401, 4011, and Super Bonder 414, cyanoacrylate adhesives, Loctite 3105 and 3311, light curing acrylic adhesives, achieved the highest bond strengths on the grades of vinyl ester which were evaluated. Black Max 380, a rubber toughened cyanoacrylate adhesive, consistently achieved the second highest bond strengths, followed by Depend 330, a two-part no-mix acrylic adhesive.

Surface Treatments

Surface roughening caused either no effect or a statistically significant increase in the bond strengths achieved on vinyl ester. The use of Prism Primer 770, in conjunction with Prism 401, or 4011 with 7701, caused a statistically significant decrease in the bondability of all the grades of vinyl ester which were evaluated.

Other Important Information

- Vinyl ester is compatible with all Loctite adhesives, sealants, primers, and activators.
- Surface cleaners: isopropyl alcohol, Loctite ODC Free Cleaner 7070.

Stress Cracking Resistance of Various Plastics

	Cyanoacrylates	Acrylics
Acrylonitrile-Butadiene-Styrene (ABS)	**2**	**2**
Acetal	**1**	**1**
Acrylic (PMMA)	**2**	**2**
Acrylic-Styrene-Acrylonitrile (ASA)	**1**	**2**
Allylic Ester (DAP, DAIP)	**1**	**1**
Cellulosic (CAP)	**2**	**2**
Epoxy	**1**	**1**
Fluoropolymers (PTFE, FEP, PFA, ETFE)	**1**	**1**
Ionomer	**2**	**2**
Liquid Crystal Polymer (LCP)	**1**	**1**
Phenolic	**1**	**1**
Polyamide (Nylon)	**1**	**1**
Polybutylene terephthalate (PBT)	**1**	**1**
Polycarbonate (PC)	**2**	**2**
Polyester, Thermoset	**1**	**1**
Polyetheretherketone (PEEK)	**1**	**1**
Polyetherimide (PEI)	**1**	**1**
Polyethersulfone (PES)	**2**	**2**
Polyethylene (PE)	**1**	**1**
Polyethylene terephthalate (PET)	**1**	**1**
Polyimide (PI)	**1**	**1**
Polymethylpentene (PMP)	**1**	**1**
Polyphenylene oxide (PPO)	**2**	**2**
Polyphenylene sulfide (PPS)	**1**	**1**
Polypropylene (PP)	**1**	**1**
Polystyrene (PS)	**1**	**2**
Polyurethane (PU)	**2**	**2**
Polyvinyl chloride (PVC)	**2**	**2**
Styrene-Acryonitrile (SAN)	**1**	**2**
Vinyl ester	**1**	**1**

Legend 1 = Normally Compatible
2 = OK for Tested Applications

Surface Treatments

Adhesive Abrading

Adhesive abrading is performed by abrading the plastic's surface in the presence of liquid adhesive. Two of the abraded, adhesive-coated adherends are then mated, and the adhesive is allowed to cure. This increases the bond strengths achieved on Teflon (PTFE) by approximately 700 percent. It is speculated that when abrasion is carried out in the presence of the adhesive, free radicals are created which react directly with the adhesive. This does not normally occur because the free radicals are scavenged by the oxygen present in air, or decay, before the adhesive is applied.

Common uses: fluorocarbons

Chromic Acid Etching

Chromic acid etching increases the bondability of a plastic by introducing reactive sites, such as hydroxyl, carbonyl, carboxylic acid, and $-SO_3H$ groups, to the plastic's surface and forming root-like cavities which provide sites for mechanical interlocking. The effects of this treatment vary from substrate to substrate. For example, increasing the etch time and temperature increases only the etch depth when etching polypropylene. On the other hand, both the degree of oxidation and etch depth increase with time for polyethylene.

Common uses: polyolefins, ABS, polystyrene, polyphenyloxide, acetals

Corona Discharge

In a corona discharge process, the plastic is exposed to a corona discharge, usually in the presence of air and at atmospheric pressure. This roughens the surface, which provides sites for mechanical interlocking, and introduces reactive sites on the plastic's surface, consequently increasing the wettability and reactivity of the surface. The reactive functionalities which are theorized to be introduced to the surface may include, but are not proven to be, carbonyl, hydroxyl, hydroperoxide, aldehyde, ether, ester, and carboxylic acid groups, as well as unsaturated bonds.

Common uses: polyolefins

Flame Treatment

Flame treatment increases the bondability of a plastic by oxidizing the surface through brief exposure to flame. The oxidation proceeds by a free radical mechanism, accompanied by chain scissions and some crosslinking. The functionalities introduced by oxidation are hydroxyl, carbonyl, carboxyl, and amide groups with a typical oxidation depth of approximately 4 to 9 nanometers. The improved bondability results from increased wettability, due to increased surface energy, and interfacial diffusivity, caused by chain scissions.

Common uses: polyolefins, polyacetals, polyethylene terephthalate

Iodine Treatment

Iodine treatment increases the bond strengths achieved on a substrate by altering the surface crystallinity from alpha form (where the N-H groups lie parallel to the surface) to beta form (where the N-H groups stand perpendicular to the surface). The surface remains relatively smooth after treatment, so it is believed that increased chemical reactivity, rather than mechanical interlocking is the mechanism for improved adhesion.

Common uses: nylon

Plasma Treatment

Plasma treatment increases the bondability of a substrate by bombarding the substrate surface with ions of a gas, such as Ar_2, He_2, N_2, and O_2, at low pressure. Several mechanisms have been proposed to explain the enhanced bondability created by plasma treating. For example, plasma treatment is hypothesized to crosslink the substrate's surface, which strengthens the joint boundary and prevents a thin layer of substrate from peeling off. In addition, the surface oxidation caused by plasma treatment is thought to introduce reactive functionalities which then increase the surface's reactivity and wettability. Another theory attributes plasma treatment's effectiveness to an increased interfacial diffusion which is created by chain scissions in the substrate's surface. Chain scissions increase the interfacial diffusion by lowering the surface viscosity and increasing the molecular mobility of the plastic's surface.

Common uses: polyolefins, polyesters, many more

Primers

Primers typically consist of a reactive chemical species dispersed in a solvent. To use the primer, the solution is brushed or sprayed onto the substrate surface. The carrier solvent is then allowed to flash off, leaving the active species behind. Depending on the type of primer, the surface may be ready to bond immediately, as in the case of polyolefin primers for cyanoacrylates, or may require time to react with atmospheric moisture before the application of the adhesive. Primers that must react with atmospheric moisture include silane and isocyanate-based primers which are typically used for silicone and polyurethane-based adhesives, respectively. Surface primers generally improve substrate bondablility by acting as a chemical bridge between the substrate and the adhesive. Typically, the reactive species in a primer will be multifunctional, with one set of reactive groups that will preferentially react with the substrate surface, and additional groups that will have a high affinity for the adhesive.

Common uses: acetals, fluoropolymers, polybutylene, terephthalate, polyolefins, polyurethane, silicone

Sodium Treatment

Sodium treatment is carried out by immersing the substrate in an aggressive etching solution containing either a sodium-naphthalene complex dissolved in tetrahydrofuran or a sodium-ammonia complex dissolved in ammonia. The etching process results in the dissolution of the amorphous regions of the substrate's surface, consequently increasing the substrate's surface roughness and potential for mechanical interlocking. Moreover, sodium treatment introduces unsaturated bonds, carbonyl groups, and carboxyl groups to the substrate's surface, which increases the substrate's reactivity and wettability. Due to carbonaceous residue which results from the defluorination of the surface, sodium treatment darkens the surface to an approximate depth of 1 micrometer. The on-part life of the treatment is very long (years), however, heating and UV exposure rapidly degrade the treated surface. Major disadvantages of using sodium treatments are that extended exposure to the solution will result in a substantial degradation of the substrate's surface, the etchants are highly hazardous, and that the solution degrades very rapidly in the presence of oxygen.

Common uses: fluorocarbons

Surface Grafting

Surface grafting is accomplished by grafting a chemical species to the substrate's surface which increases the substrate's bondability. For example, polyethylene can be exposed to gamma radiation in the presence of vinyl acetate monomer, which then becomes chemically grafted to the polyethylene surface.

Common uses: vinylic compounds on polyolefins

Surface Roughening

Surface roughening is a simple, low cost method of increasing the bondability of many plastics. Surface roughening increases the bondability by dramatically increasing the number of mechanical interlocking sites.

Common uses: effective for many plastics

Thermal Treatment

Thermal treatment increases the bondability of plastics by exposing the plastic to a blast of hot air (approximately 500°C), which oxidizes the surface. This mainly introduces carbonyl, carboxyl, and amide groups to the surface, but some hydroperoxide groups are also formed. Very similar to flame treatments, this process also utilizes a free radical mechanism accompanied by chain scission and some crosslinking. The improved bondability results from increased wettability, due to the introduction of polar groups, and interfacial diffusivity, caused by chain scissions.

Common uses: polyolefins

Transcrystalline Growth

Transcrystalline growth improves bondability of a plastic by molding adherends against a high energy metallic substrate that induces trancrystalline growth in the plastic's surface regions. The metallic substrate induces the formation of crystallites at the plastic's surface and results in rod-like or columnar spherulites that form inward from the interface. This is thought to strengthen the surface by driving low molecular weight material into the interior. In addition, some metallic substrates may oxidize the plastic's surface, resulting in a substantial increase in the reactivity and wettability of the plastic's surface. The effectiveness of this treatment is dependent on such molding conditions as the cooling rate and mold surface.

Common uses: polyolefins, polyamides, polyurethanes

UV Exposure

UV exposure increases the bondability of plastics by irradiating them with high intensity UV light. However, the effectiveness of UV exposure is very dependent on the wavelength of light being used. For example, light with a wavelength of 184 nm will crosslink the surface of polyethylene, while light at 253.7 nm will not. UV irradiation causes chain scissions, crosslinking, and oxidation of the polymer's surface, even in inert gases. Many different mechanisms describing why UV exposure increases the bondability of plastics have been proposed, including: increasing the wettability; strengthening the plastic's boundary layer through crosslinking; and inducing hydrogen bonding. The predominant view is that the bondability is improved by the formation of polymeric scission products, which promote interfacial flow, interdiffusion, and polar interactions.

Common Uses: polyolefins

Adhesive Joint Design

Introduction

In this section, the terms and concepts related to joint design are divided into three categories which include:

- Types of Joints
- Joint Stress Distribution
- Design Guidelines

Before looking at different types of joints, a few terms need to be explained.

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

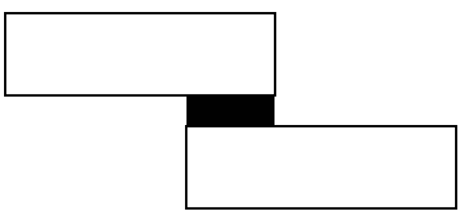
Joint Geometry: Joint geometry refers to the general shape of an adhesive bond. Is the shape of the bond long and narrow, short and wide, thick or thin?

Types of Joints

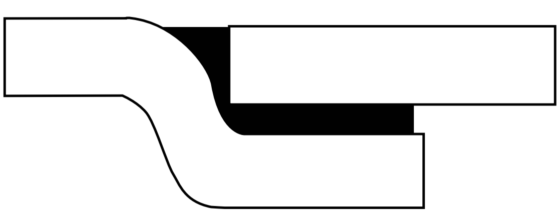
The specific types of joints which will be examined in this section include:

- Lap/Overlap
- Joggle Lap
- Butt Joint
- Scarf Joint
- Strap/Double Strap
- Cylindrical

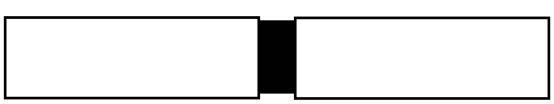
Lap/Overlap Joint: A lap joint, also called an overlap joint, is formed by placing one substrate partially over another substrate.



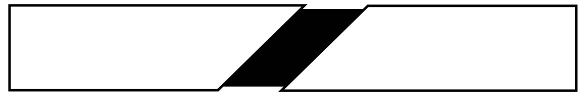
Joggle Lap Joint: The joggle lap joint is an offset joint and is very similar to the lap joint.



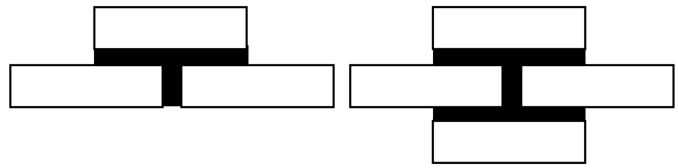
Butt Joint: A butt joint is formed by bonding two objects end to end.



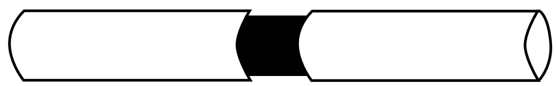
Scarf Joint: A scarf joint is an angular butt joint. Cutting the joint at an angle increases the surface area.



Strap Joint (Single or Double): A strap joint is a combination overlap joint with a butt joint.



Cylindrical Joint: A cylindrical joint uses a butt joint to join two cylindrical objects.



Joint Stress Distribution

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

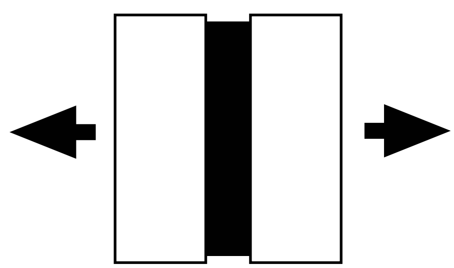
Stress: Usually expressed as Newtons per square meter (N/M^2), which is equivalent to a Pascal (Pa.) In the English system, stress is normally expressed in pounds per square inch (psi).

Types of Stresses

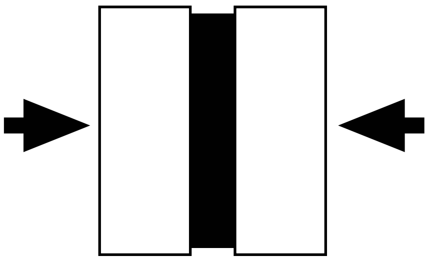
There are several types of stresses commonly found in adhesive bonds which include:

- Tensile
- Compressive
- Shear
- Cleavage
- Peel

Tensile Stress: A tensile stress tends to pull an object apart. The stress also tends to elongate an object.

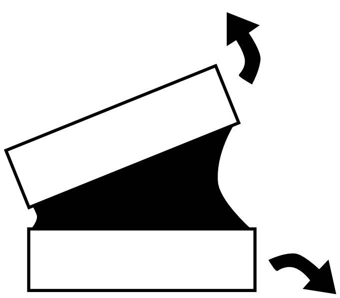


Compressive Stress: A compressive stress, on the other hand, tends to squeeze an object together.

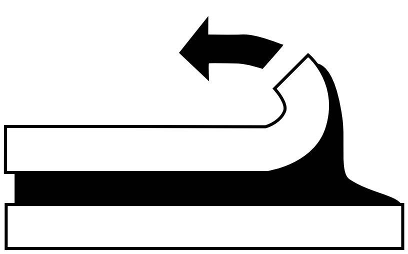


Shear Stress: A shear stress results in two surfaces sliding over one another

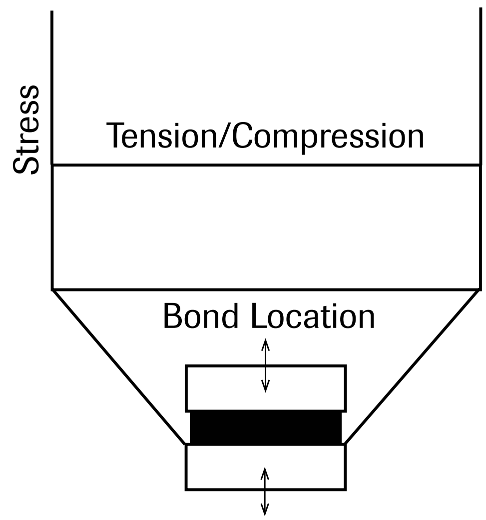
Cleavage Stress: A cleavage stress occurs when a joint is being opened at one end.



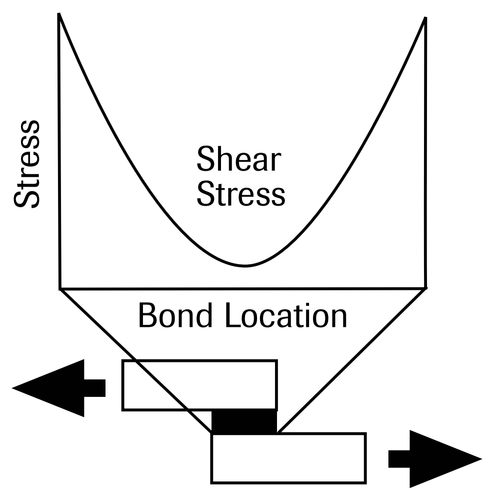
Peel Stress: A peel stress occurs when a flexible substrate is being lifted or peeled from the other substrate.



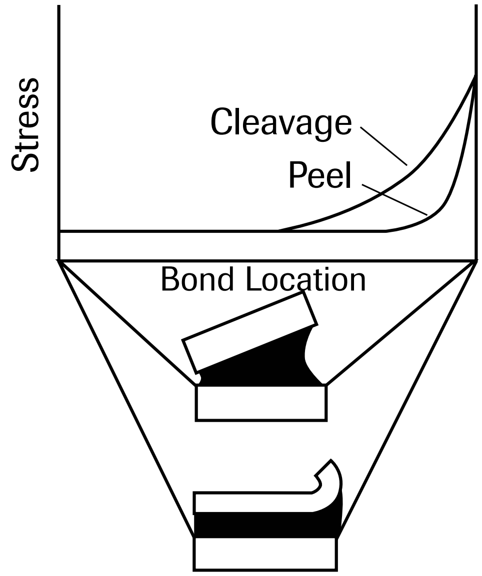
Tension and Compression Stress Distribution: When a bond experiences either a tensile or a compressive stress, the joint stress distribution is illustrated as a straight line. The stress is evenly distributed across the entire bond.



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 does the middle of the bond.



Cleavage and Peel Stress Distribution: When a cleavage or a 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 which is under an applied force. There are several design guidelines which should be considered when designing an adhesive joint.

- Maximize Shear/Minimize Peel and Cleavage
  Note from the stress distribution curve for cleavage and peel, 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.

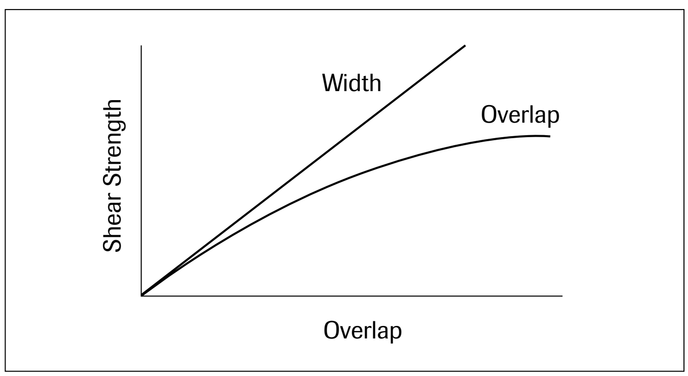
- Maximize Compression/Minimize Tensile
  Note from the stress distribution curve for compression and tension, that stress was uniformly distributed across the bond. In most adhesive films, the compressive strength is greater than the tensile strength. An adhesive joint which is feeling a compressive force is less likely to fail than a joint undergoing tension.

- Joint Width More Important Than Overlap
  Note from the shear stress distribution curve, that the ends of the bond resist a greater amount of stress than does the middle of the bond. If the width of the bond is increased, the bond area at each end also increases; the overall result is 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.

  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.

Bond Shear Strength Width vs Overlap
As a general rule, increase the joint width rather than the overlap area.



Processor Rules for Good Adhesive Assembly

Richard Thompson, Senior product engineer

There's more to reliable adhesive assembly than picking the right adhesive. Processors with assembly operations will boost their quality batting average by understanding all the ground rules.

Today's new and better plastic materials offer plastic-parts assemblers many opportunities to produce more reliable and durable products, often at lower cost. These new materials call for techniques that differ greatly from those used with traditional materials.

Assemblers must understand that plastics, compared to traditional materials, such as metals, have lower tensile strength, are usually more flexible, have higher coefficients of expansion, and often are harder to adhere to. These differences greatly influence the way joints are designed and adhesives are selected.

Why plastic fails before joint

The lower tensile strengths of plastics make it common to create bonded joints that are stronger than the plastic itself. Consider a joint between two strips of plastic 1 in. wide x 1/8 in. thick, as illustrated. Because of the large joint overlap, the substrate will fail before the bond. The same overall assembly strength could be achieved with an overlap of only 0.58 in.

This situation shows why adhesive manufacturers often report "substrate failure" in a table of bonding strengths on plastics. Most of the standard test methods were originally designed for metals and have no instructions for adjusting the bond area used according to the tensile strength of the material.

Flex modulus stresses joints

With an elastic modulus of about 300,000 psi, a typical unreinforced plastic part is over 100 times more flexible than steel for identically-shaped components. In designing lap joints, this added flexibility means that more bending and differential shearing will occur in the bonded joint as the assembly is placed under load.

This flexibility leads to increased stress concentration near the ends of the overlap. However, the stress ratios of plastic overlap joints are far greater than those of steel joints (see table). These concentrations can lead to joint failure at relatively low loads.

The disadvantages of these high stress concentrations can be reduced effectively in many cases by careful selection of the other joint design parameters. Most important among these are: the elastic modulus of the adhesive, length of the overlap, and thickness of the bondline between the two substrates (see drawing).

A lower modulus adhesive reduces stress concen-trations by accommodating the relative motion of the two sub-strates with greater shear compliance (see table). The extreme case is when a rubbery adhesive isused. Such an adhesive is so flexible that shear deformations can be accommodated without creating significant stress concen-trations. But an adhesive this flexible may not be able to accommodate the structural

Effects of bondline gap

Bondline gap in.	Stress ratio max.
0.001	18.40
0.002	13.00
0.005	8.31
0.010	5.93
0.020	4.25
0.040	3.06

Effects of substrate modulus

Material	Modulus psi	Stress ratio
Steel	30,700,000	1.69
Glass-filled plastic	1,000,000	7.77
Unfilled plastic	300,000	13.03

Effects of joint overlap

Overlap length, in.	Stress ratio max.
1,000	22.50
0.500	13.00
0.250	7.17
0.125	3.78

Effects of adhesive modulus

Adhesive Modulus psi	Stress ratio max.
300,000	22.40
100,000	13.03
50,000	9.27
20,000	5.93
200	1.13

Constants for tables

Adhesive modulus	= 100,000 psi
Overlap	= 0.5 in.
Bond line	= 0.002 in.
Load	= 100 lbs.
Substrate thickness	= 0.125 in.
Substrate modulus	= 300,000 psi

loads on an actual assembly without excessive deformation.

Shortening bond overlaps reduces both the bending and the differential shearing effects which are present in lap joints (see table). If larger bond areas are needed to carry the load, it is better to increase bond width rather than bond overlap. Increased width adds very little to stress distribution in the bond.

Thicker bondlines make the joint more compliant to shear stress. The extra thickness spreads the shear strain over a larger dimension, resulting in less unit strain on the adhesive and, therefore, less stress concentration (see table). This is similar to using a lower modulus adhesive; a more compliant joint results in both cases.

By using a combination of the methods described previously, stress concentrations in plastic lap joints can be reduced to levels comparable to those in steel joints. For example, a joint made with an adhesive having a modulus of 20,000 psi, and overlap of 0.25 in. and a bondline thickness of 0.010 in. would have a maximum stress factor of 1.64. This compares favorably with the value for a typical bonded steel joint.

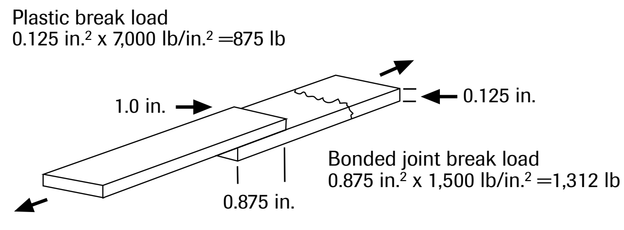
Good wet out gives good bond

Good wetting of the substrate surface is essential for developing reliable bonds, Adhesives that do not wet the surface will not spread out and fill substrate surface irregularities.

Wetting occurs when the surface tension of the liquid adhesive is lower than the critical surface tension of the substrates being bonded. If this condition is not met, the liquid does not spread, but forms a round droplet on the surface, like water beads up on a newly-waxed car.

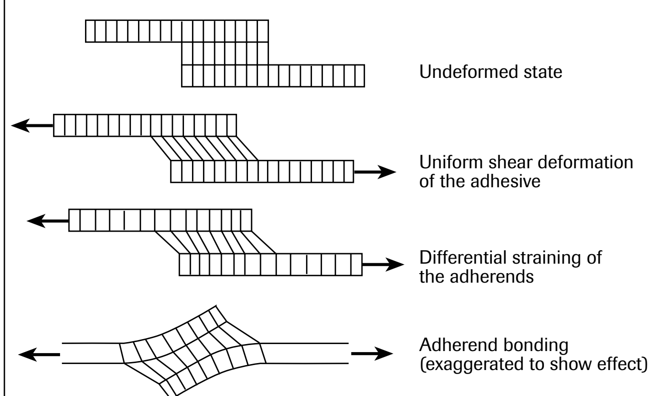
Wetting of plastic surfaces is much more complex than wetting clean metal surfaces. Plastics and adhesives are both polymeric materials and thus have similar physical properties, including wetting tensions. Plastic bonded joints do not have the large difference between the critical surface tension of the substrate and that of the adhesive, which insures wetting for metals. In addition, many plastics have notoriously low critical wetting tensions. Polyethylene (PE) and polypropylene (PP), with critical surface tensions of 31 and 29 dynes/cm respectively, present serious wetting challenges for most adhesives. Other plastics such as polystyrene (PS) and polyvinyl chloride (PVC) have higher critical surface tensions and present less of a problem.

Plastic fails before bond when large overlaps are used

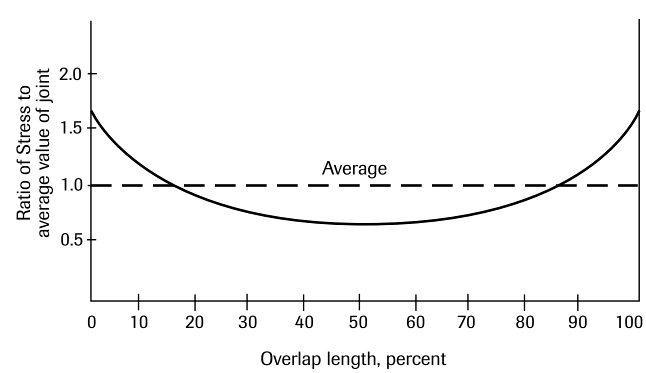


- Plastic breaks at 875 lb
- Same overall assembly strength achieved with only 0.58 in. overlap

Bonded tensile lap-shear specimens



Stress concentrations near ends of overlap joints



When poor wetting occurs, there are methods to treat the surface for better bonding. One of these is simply cleaning and abrading the surface. The most common procedure is a solvent wipe, followed by abrasion and then a final solvent wipe. The solvent selected should not craze or soften the plastic. Grit blasting is the most effective abrasion method, although using aluminum oxide cloth also works well. Sandpaper should not be used because it often contains lubricants to assist in finishing wood. The final solvent rinse removes residue from abrasion.

Using cleaning and abrasion first insures that wetting problems are not caused by surface contamination. Another potential benefit is that removing the surface layer of plastic may expose material with better wetting characteristics due to a different crystalline microstructure.

Flame treatment is often used to change the surface characteristics of plastics. It involves passing the surface of the plastic through the oxidizing portion of a natural gas flame. The surface is rapidly melted and quenched by the process; some oxidation of the surface may occur at the same time. Exposure to the flame is only a few seconds.

Flame treatment is widely used for PE and PP, but has also been applied to other plastics, including thermoplastic polyester, polyacetal, and polyphenylene sulfide. Specially designed gas burners are available for this process, but butane torches can be used for laboratory trials.

Chemical surface treatments have often been used to improve the bonding of plastics. The most common involve strong oxidating agents such as chromic acid to etch the surface. While often effective, these methods are difficult to justify economically due to the cost of maintaining tanks and chemical solutions.

Polytetrafluoroethylene (PTFE) and other fluoropolymers are often treated with etching solutions based on dispersions of metallic sodium in organic solvents. This method dramatically improves surface wetting characteristics, and the plastic can readily be bonded using a wide range of adhesives. In some cases, PTFE pretreated in this way can be purchased.

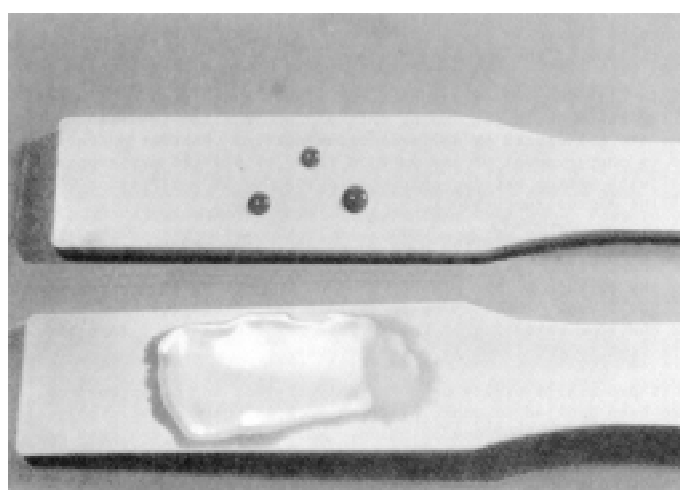
Plasma surface treatment is a relatively new technology for improving wetting on plastic surfaces. In this process, parts are exposed to ionized gases generated by radio frequency energy in a sealed chamber under extremely low pressures. By selecting appropriate gases and exposure conditions, the surface can be cleaned, etched, or chemically activated. Results include significant differences in surface wetting (see photo), and a two to threefold increase in bond shear strength.

Because plasma treatment involves a closed and evacuated chamber, the process is excellent for treating large numbers of small, high-value parts at one time. It is harder to economically justify for larger parts since fewer can be treated in the same cycle.

Visual observation is often enough to determine if wetting is adequate, but it is sometimes desirable to measure the value. One test is the ASTM D2578, "Wetting Tension of Polyethylene and Polypropylene firms." This method uses a series of test liquids with known surface tensions to determine the level required to just wet the surface. The critical wetting tension of a surface is approximated by the surface tension of the fluid selected. Although this method is intended for PE and PP, the same type of procedure can be used on other plastics.

Adhesive/plastic fit is a must

When bonding metals and other inorganic materials, the issue of adhesive-substrate compatibility seldom arises. Cases of damage to these materials are few, and generally are the result of some unusual interactions. However, when bonding plastics, care must be taken to avoid stress cracking, which can occur when incompatible adhesives are applied to the surface of a stressed plastic part.



Plasma treatment improves adhesive wetting on plastic surfaces. At top, liquid adhesive beads on PP surface before plasma treatment. Liquid spreads easily after treatment, bottom.

Softening and weakening of the surface occur, leading to the formation of cracks. Liquid adhesive may penetrate into the crack causing further damage. Eventually, the crack may propagate through the entire part and cause failure.

Following are some guidelines that will help to minimize the potential for stress cracking:

- Work with parts that are in a low stress condition. Molded-in stresses can be reduced by modifying the molding cycle or annealing parts after molding.
- Use the minimum quantity of adhesive required and cure it as quickly as possible, cleaning up any excess adhesive at once. Cured adhesive will not cause cracking.
- Use only cleaning solvents/primers compatible with the plastics.
- Do not use anaerobic threadlocking compounds with crack-susceptible plastics. Uncured adhesive outside the threaded joint combined with high stresses caused by the threads almost guarantees stress cracking will occur.
- When in doubt, consult adhesive suppliers.

Expansion rate must be similar

When materials with different coefficients of thermal expansion (CTE) are joined, shear stresses result when the assembly is heated or cooled. With plastics, extreme differences can occur. For example, a sheet of G-10 epoxy glass laminate with a CTE of $5x10^{-6}$ in./in./F bonded to acrylic with a CTE of $60x10^{-6}$ will result in rapid stress increases due to the twelvefold difference in expansion rate.

If expansion problems cannot be solved by revising material selections, using thicker bondlines and more flexible adhesives can help reduce problems. However, a thin film of adhesive between two components is only a small part of the total assembled joint, and as such, it is incapable of restraining or accommodating large relative motions between substrates.

By taking into consideration the differences between plastics, and the compatibility of various adhesives, product assemblers can produce bonded joints that improve product performance while reducing manufacturing costs.

Coefficient of Thermal Expansion for various materials

Material	**Thermal Expansion 10^{-6} in./in./F**
Polyethylene	167
Cellulose acetate	90
Acrylic	60
Polypropylene	58
Thermoplastic polyester (PBT)	53
Nylon	50
Styrene	48
Acetal	45
Polycarbonate	38
Polysulfone	31
Polyphenylene sulfide	30
30% glass-filled nylon	25
Phenolic	23
Zinc	15
Aluminum	13
Copper	12
40% glass-filled polycarbonate	9
Steel	7
Glass	5
Graphite	2

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Test Methodology

Determining The Experimental Matrix

The Selection of Adhesives

It was desired to evaluate the families of adhesives which are best suited for bonding plastics. These adhesive families were identified as ethyl cyanoacrylates, light curing acrylics, and two-part no-mix acrylics. The ethyl cyanoacrylate family was further broken down into rubber toughened, surface insensitive, and general-purpose cyanoacrylate adhesives, as well as surface insensitive cyanoacrylates used in conjunction with polyolefin primers. From each of these categories, an adhesive was then selected which was believed to be representative of the performance of that family of adhesives when bonding plastics. The adhesives which were selected are tabulated below:

Adhesive	Adhesive Description
Black Max 380	Rubber-toughened ethyl cyanoacrylate adhesive
Prism 401, Prism 4011	Surface insensitive ethyl cyanoacrylate adhesives
Prism 401/ Prism Primer 770 and 4011/7701	Surface insensitive ethyl cyanoacrylates used in conjunction with polyolefin primers
Superbonder 414	General-purpose ethyl cyanoacrylate
Depend 330	Two-part no-mix acrylic adhesive
Loctite 3105, 3311	Light curing acrylic adhesives

The Selection of Plastics

The various types of plastics which are currently available were surveyed, and thirty of the most commonly used plastic types were selected for testing. The specific formulations of these plastics which were evaluated were chosen in one of the two following ways:

<u>Specialty Formulations</u>

Seventeen of the thirty materials were compounded specifically to determine the effect different additives and fillers had on the bondability of the base resin using the following procedure:

1. A grade of the plastic which had no fillers or additives was selected and tested for bond strength performance with the aforementioned adhesives.
2. The most common additives and fillers used with each plastic were identified.
3. A separate formulation of the plastic was compounded with a high fill level of each of the identified common additives and fillers.
4. Adhesive bond strength evaluations were performed on the various formulations which were compounded.
5. The results were analyzed to determine if the filler or additive resulted in a statistically significant change in the bondability of the plastic from the unfilled resin within 95% confidence limits.

<u>Commercially Available Grades</u>

For thirteen of the thirty plastics, commercially available grades were selected to represent each major category available for that plastic. For example, when testing ionomer, grades were evaluated which represented each of the major cation types. Moreover, while evaluating phenolics, a grade was selected to represent each of the end use applications, such as general-purpose, glass filled, heat resistant, and electric grades.

Determining The Test Method

The lap shear test method ASTM D1002 is typically used to determine adhesive shear strengths. However, because it was designed for use with metals, it has several serious limitations when evaluating plastics. For example, because plastics have much lower tensile strength than metals, the plastic lap shear specimens are much more likely to experience substrate failure than the metal lap shear specimens. This makes the comparative analysis of different adhesives on a plastic very difficult because many of the adhesives will achieve substrate failure, rendering it impossible to identify the adhesive best suited for that material. Another major disadvantage to using the lap shear test method is that because plastics have much lower modulii than metals, they deform more during testing, which introduces peel and cleavage forces on the joint. Consequently, the lower the modulus of the plastic, the more it will deform under load, and the less representative the experimental shear strength will be of the actual shear strength which should have been achieved on that material.

Due to these limitations, a block shear test method (ASTM D4501) was chosen. Since block shear testing places the load on a thicker section of the test specimen, the specimen can withstand higher loads before experiencing substrate failure. In, addition, due to the geometry of the test specimens and the block shear fixture, peel and cleavage forces in the joint are minimized.

Limitations

While the bond strengths in this guide give a good indication of the typical bond strengths that can be achieved with many plastics, as well as the effect of many fillers and additives, they also face several limitations. For example, while the additives and fillers were selected because they were believed to be representative of the most commonly used additives and fillers, there are many types of each additive and filler produced by many different companies, and different types of the same additive or filler may not have the same effect on the bondability of a material. In addition, the additives and fillers were tested individually in this guide, so the effect of interactions between these different fillers and additives on the bondability of materials could not be gauged.

Another consideration that must be kept in mind when using this data to select an adhesive/plastic combination is how well the block shear test method will reflect the stresses that an adhesively bonded joint will see in "real world" applications. Adhesively bonded joints are designed to maximize tensile and compressive stresses, and to minimize peel and cleavage stresses, so the magnitude of the former two are generally much larger than the latter two. Thus, the shear strength of an adhesive is generally most critical to adhesive joint performance, but since all joints experience some peel and cleavage stresses, their effects should not be disregarded.

Finally, selecting the best adhesive for a given application involves more than selecting the adhesive which provides the highest bond strength. Other factors such as speed of cure, environmental resistance, thermal resistance, suitability for automation, and price will play a large role in determining the optimum adhesive system for a given application. It is suggested that the reader refer to the chapters which explain the properties of the various adhesives in greater detail before choosing the best adhesive for an application.

Although there are some limitations to the degree the information provided in this guide can be extrapolated, the data contained here should be invaluable in helping the end user quickly make comparative evaluations of the bond strengths that various adhesive/plastic combinations provide. Once the most promising combinations of adhesives and plastics have been identified, it is important that testing be performed on assemblies to insure that they will meet or exceed all performance requirements.

Test Methods

Substrate Preparation

1. Substrates were cut into 1" by 1" by 0.125" block shear test specimens.
2. All bonding surfaces were cleaned with isopropyl alcohol.

Adhesive Application and Cure Method

<u>Cyanoacrylates (Black Max 380, Prism 401, Prism 4011, Superbonder 414)</u>

1. Adhesive was applied in an even film to one test specimen.
2. A second test specimen was mated to the first with a 0.5" overlap (bond area = 0.5 in^2).
3. The block shear assembly was clamped with two Brink and Cotton No. 1 clamps.
4. The bonded assembly was allowed to cure at ambient conditions for 1 week before testing.

<u>Cyanoacrylates with Polyolefin Primers (Prism 401 and Polyolefin Primer 770, or 4011 with 7701)</u>

1. Polyolefin primer was brushed onto each bonding surface.
2. The polyolefin primer's carrier solvent was allowed to flash off.
3. Adhesive was applied in an even film to one substrate.
4. The second test specimen was mated to the first with a 0.5" overlap (bond area = 0.5 in^2).
5. The block shear assembly was clamped with two Brink and Cotton No. 1 clamps.
6. The bonded assembly was allowed to cure at ambient conditions for 1 week before testing.

<u>Two-Part No-Mix Acrylic (Depend 330)</u>

1. Activator 7387 was sprayed on one test specimen.
2. The activator's carrier solvent was allowed to flash off for more than two minutes.
3. Depend 330 was applied in an even film to a second test specimen.
4. Within 30 minutes, the second test specimen was mated to the first with a 0.5" overlap (bond area= 0.5 in^2).
5. The block shear assembly was clamped with two Brink and Cotton No. 1 clamps.
6. The bonded assembly was allowed to cure at ambient conditions for one week before testing.

<u>Light Cure Acrylics (Loctite 3105 and 3311)</u>

1. Adhesive was applied in an even film to one test specimen.
2. A UV transparent, medical polycarbonate 1" by 1" by 0.125" test specimen was cleaned with isopropyl alcohol.
3. The second test specimen was mated to the first with a 0.5" overlap (bond area = 0.5 in^2).
4. The block shear assembly was irradiated (through the polycarbonate) in an ultraviolet light source for

30 seconds to cure the adhesive. The ultraviolet light source used was a Fusion UV Curing System, equipped with an H-bulb having an irradiance of approximately 100 mW/cm^2 @ 365 nm.

5. The assembly was left at ambient conditions for one week prior to testing.

Block Shear Test Method

1. Assemblies were tested on an Instron 4204 mechanical properties tester, equipped with a 50 kN load cell, and a pull speed of 0.05"/minute.
2. Five replicates of each assembly were tested.

Surface Roughness

1. The test specimens were manually abraded using a 3M Heavy-Duty Stripping Pad.
2. The surface roughness was determined using a Surfanalyzer 4000 with a traverse distance of 0.03 in and a traverse speed of 0.01 in/second.

Glossary

Compressive Strength (ASTM D695)
"Test Method for Compressive Properties of Rigid Plastics"

Continuous Service Temperature
The recommended continuous service temperature is an estimate of the highest temperature a plastic can continuously withstand over the life of an application. It is usually reported by the manufacturer and can be derived from the melting point, deflection temperature, and temperature at which a material's properties begin to severely diminish.

Deflection Temperature @ 66 psi (ASTM D648)
"Test Method for Deflection Temperature of Plastics Under Load"

Deflection Temperature @ 264 psi (ASTM D648)
"Test Method for Deflection Temperature of Plastics Under Load"

Density (ASTM D792)
"Test Method for Specific Gravity and Density of Plastics by Displacement"

Dielectric Constant (ASTM D150)
"Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials"

Dielectric Strength (ASTM D149)
"Test Methods for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies"

Dissipation Factor (ASTM D150)
"Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials"

Elongation, Break (ASTM D638)
"Test Method for Tensile Properties of Plastics"

Flexural Modulus (ASTM D790)
"Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials"

Flexural Strength, Yield (ASTM D790)
"Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials"

Hardness (ASTM D785)
"Test Method for Rockwell Hardness of Plastic and Electrical Insulating Materials"
(ASTM D2240)
"Test Method for Rubber Property Durometer Hardness"

Linear Mold Shrinkage (ASTM D955)
"Test Method for Measuring Shrinkage from Mold Dimensions of Molded Plastics"

Linear Thermal Expansion (ASTM D696)
"Test Method for Coefficient of Linear Thermal Expansion of Plastics"

Melting Point (ASTM D789)
"Test Method for Determination of Relative Viscosity, Melting Point, and Moisture Content of Polyamide"
(ASTM D2117)
"Test Method for Melting Point of Semicrystalline Polymers by the Hot Stage Microscopy Method"

Notched Izod Impact Strength, R.T. (ASTM D256)
"Test Method for Impact Resistance of Plastics and Electrical Insulating Materials"

Processing Temperature
is the average processing temperature recommended by manufacturers for commonly used processing methods.

Tensile Modulus (ASTM D638)
"Test Method for Tensile Properties of Plastics"

Tensile Strength, Break (ASTM D638)
"Test Method for Tensile Properties of Plastics"

Tensile Strength, Yield (ASTM D638)
"Test Method for Tensile Properties of Plastics"

Thermal Conductivity (ASTM C177)
"Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus"

Thermoplastics
Thermoplastics are distinguished by their ability to be softened and reshaped through the application of heat and pressure. They can be processed in this manner because, unlike thermosets, they are made up of polymeric chains which are not joined by covalent bonds (crosslinks).

Thermosets
Thermosets are plastics whose polymeric chains are joined by covalent bonds (crosslinks) to form a three-dimensional network. Due to the formation of this three-dimensional network, thermoset resins cannot be softened or reshaped through the application of heat or pressure.

Water Absorption (ASTM D570)
"Test Method for Water Absorption of Plastics"

Index Of Trade Names

Trade Name	Plastic Type	Manufacturer	Page Number
Eccogel	Epoxy	Emerson & Cuming	24
Eccoseal	Epoxy	Emerson & Cuming	24
Ektar FB	Polyester (PET)	Eastman Performance	50
Elastopreg	Polypropylene	BASF	60
Eltex	PE, PP	Solvay & Cie	48, 60
Empee PE	Polyethylene	Monmouth Plastics	48
Endura	PE, PP	PPG Industries	48, 60
Envex	Polyimide	Rogers Corporation	52
Epolite	Epoxy	Hexcel Corporation	24
EPON	Epoxy	Shell Chemical Company	24
Epoxylite	Epoxy	Epoxylite Corporation	24
Ertalon	Polyamide (Nylon)	ERTA Inc.	34
Esbrite	Polystyrene	Sumitomo Chemical	62
Escorene	PE, PP	Exxon Chemical	48, 60
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Ferrex	Polypropylene	Ferro Corporation	60
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Fiberloc	PVC	B. F. Goodrich	66
Fluon	PTFE	ICA Americas Inc.	26
Formion	Ionomer	A. Schulman	28
Fortiflex	Polyethylene	Solvay Polymers	48
Fortilene	Polypropylene	Solvay Polymers	60
Fortron	PPS	Hoechst Celanese	58
Fusabond	Polypropylene	DuPont Canada	60
Geloy	ASA	GE Plastics	16
Geon	PVC	B. F. Goodrich	66
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Granlar	Polyester (LCP)	Granmont Inc.	30
Grilamid	Polyamide (Nylon)	EMS	34
Grilon	Polyamide (Nylon)	EMS	34
Halar	ECTFE	Ausimont USA, Inc.	26
Halon	ETFE	Ausimont USA, Inc.	26
Haysite	Polyester, thermoset	Haysite Reinforced Plastics	40
Hetron	Vinyl ester	Ashland Chemical Company	70
Hi-Zex	Polyethylene	Mitsui Petrochemical	48
HiGlass	Polypropylene	Himont USA, Inc.	60
Hostaflon	PTFE	Hoechst Celanese	26
Hostan GUR	Polyethylene	Hoechst Celanese	48
HX Series	Polyester (LCP)	E.I. DuPont	30
Hyflon	PFA	Ausimont USA, Inc.	26
Hyvex	PPS	Ferro Corporation	58
Impet	Polyester (PET)	Hoechst Celanese	50
Insultruc	Polyester, thermoset	Industrial Dielectrics	40
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Jet	Polyester, thermoset	Jet Moulding	40
Kaofulex	Polystyrene	Kaofu Chemical	62
Kapton	Polyimide	E.I. DuPont	52
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Kemlex	Acetal	Ferro Corporation	12
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Trade Name	Plastic Type	Manufacturer	Page Number
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Surlyn	Ionomer	E.I. DuPont	28
Tactix	Epoxy	Dow Chemical	24
Taitalac	ABS	Taita Chemical Company	18
Technyl	Polyamide (Nylon)	Rhone Poulenc, Inc.	34
Tecoflex	Polyurethane	Thermedics Inc.	64
Tecolite	Phenolic	Toshiba Chemical Products	32
Tecothane	Polyurethane	Thermedics Inc.	64
Tedur	PPS	Miles Inc.	58
Teflon	PTFE, FEP, PFA	E.I. DuPont	26
Tefzel	ETFE	E.I. DuPont	26
Tenac	Acetal	Asahi Chemical	12
Tenite	Cellulosic, PE, PP	Eastman Chemical Products	22, 48, 60
Tenite PET	Polyester (PET)	Eastman Chemical Products	50
Tenneco	PVC	Rimtech Corporation	66
Terblend	ASA	BASF	16
Texalon	Polyamide (Nylon)	Texapol Corporation	34
Texin	Polyurethane	Miles Inc.	64
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Toyolac	ABS	Toray Industries	18
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Traytuf	Polyester (PET)	Goodyear	50
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Tyril	SAN	Dow Chemical	68
Ultem	Polyetherimide	GE Plastics	44
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Ultraform	Acetal	BASF	12
Ultramid	Polyamide (Nylon)	BASF	34
Ultrason	Polyethersulfone	BASF	46
Ultra-wear	Polyethylene	Polymer Corporation	48
Unichem	PVC	Colorite Plastics	66
Unipol PP	Polypropylene	Shell Chemical Company	60
Unival	Polyethylene	Union Carbide	48
Valox	Polyester (PBT, PET)	GE Plastics	36, 50
Valtec	Polypropylene	Himont USA, Inc.	60
Vectra	Polyester (LCP)	Hoechst Celanese	30
Vekton	Polyamide (Nylon)	Norton Performance	34
Verton	Polyamide (Nylon)	LNP Engineering	34
Vespel	Polyimide	E.I. DuPont	52
Vestamid	Polyamide (Nylon)	Huls America	34
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Victrex PES	Polyethersulfone	Victrex, USA	46
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Vybex	Polyester (PBT)	Ferro Corporation	36
Vydyne	Polyamide (Nylon)	Monsanto Chemical	34
Vythene	PVC	Alpha Chemical	66
Wellamid	Polyamide (Nylon)	Wellman, Inc.	34
Xydar	Polyester (LCP)	Amoco Perform. Products	30
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Zemid	Polyethylene	DuPont Canada	48
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Disclaimer

The information contained herein is intended to be used solely as an indicator of the bondability of the evaluated plastics. The information is believed to be accurate, and is well suited for comparative analysis, however, the testing was performed using a limited number of adhesive lots, plastic lots, and replicates. Consequently, this makes the information contained herein inappropriate for specification purposes.

Suggestions concerning the compatibility of plastics with adhesives is based on test data and general knowledge concerning the chemical resistance of plastics. All thermoplastics have the potential to stress crack when exposed to uncured adhesive depending on the exposure time, part geometry, stresses, and plastic composition variables. Consequently, it is important that the end user evaluate the suitability of the adhesive in their process to insure that the adhesive does not detrimentally affect the performance of the plastic.

Suggestions for surface cleaners to be evaluated are based on test data and general information concerning the chemical resistance of the plastics. The chemical resistance of plastics can be affected by the exposure time, temperature, stress levels, and plastic composition variables. Consequently, it is important that the end user evaluate the suitablility of the cleaning solvent in their process to insure that the solvent does not detrimentally affect the performance of the plastic.

Loctite can not assume responsibility for the results obtained by others over whose methods we have no control. It is the user's responsiblity to determine suitability for the user's purpose of any production method mentioned herein and to adopt such precautions as may be advisable for the protection of property and of persons against any hazards that may be involved in the handling and use thereof.

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Formerly called "*How to Bond Plastics*"