

Glossary of Terms

ABS See *acrylonitrile butadiene styrene polymer*.

ABS nylon alloy Thermoplastic alloy of ABS and nylon suitable for injection molding. Has properties similar to ABS but considerably higher elongation at yield.

ABS polycarbonate alloy Thermoplastic alloy of ABS and polycarbonate suitable for injection molding and extrusion. Has properties similar to ABS. Used in automotive applications.

ABS polyurethane alloy Thermoplastic alloy of acrylonitrile butadiene styrene and polyurethane.

absolute density See *density*.

absolute gravity See *density*.

accelerator A chemical substance that accelerates chemical, photochemical, biochemical, etc. reaction or process, such as crosslinking or degradation of polymers, that is triggered and/or sustained by another substance, such as curing agent or catalyst, or environmental factor, such as heat, radiation or a microorganism. Also called promoter, cocatalyst.

acetal See *acetal resin*.

acetal resin Acetal resins are thermoplastics prepared either by homopolymerization of formaldehyde or its trimer, trioxane, or by copolymerization of trioxane with other monomers, such as ethylene oxide. Acetals have high impact strength, stiffness, and yield stress; low friction coefficient and gas and vapor permeability; good dimensional stability and dielectric properties; high fatigue strength; and good retention of properties at elevated temperatures. The homopolymer has higher heat deflection temperature but lower continuous use temperature than copolymers. All acetals have poor resistance to acids and homopolymers also show poor resistance to alkalis. Acetals are subject to UV degradation, are flammable, and are difficult to bond. Processed by injection and blow molding and extrusion. Used in mechanical parts such as gears and bearings, automotive parts such as window cranks and trim fasteners; appliances; pump housings, shower heads, and other plumbing applications; and electronics such as connectors. Also called POM, polyoxymethylene, polyformaldehyde, acetal.

acetone A volatile, colorless, highly flammable liquid with molecular formula CH_3COCH_3 . Acetone has autoignition temperature 537°C, mixes readily with water and some other solvents and is moderately toxic. Acetone dissolves most thermoplastics and some thermosets. Used as organic synthesis intermediate, e.g., in the manufacture of bisphenol A and antioxidants, as solvent in paints and acetate fiber spinning and for cleaning of electronic parts. Also called dimethyl ketone.

acrylate resin See *acrylic resin*.

acrylate styrene acrylonitrile polymer Acrylic rubber-modified thermoplastic having high outdoor weatherability, e.g., retention of color, gloss, and impact and tensile properties. The material offers high gloss, good heat and chemical resistance, great toughness and rigidity, and very good antistatic properties. It is compatible with other polymers such as PVC and polycarbonate and processable by (co)extrusion, thermoforming, injection molding, structural foam molding, and extrusion-blow molding.

Drying is necessary because the material is mildly hygroscopic. Used in building and construction, leisure and recreation, and automotive applications when there is a demand for good weatherability, e.g., commercial siding, exterior auto trim, outdoor furniture. Also called ASA, acrylonitrile styrene acrylate polymer, acrylic styrene acrylonitrile polymer.

acrylate styrene acrylonitrile polymer polyvinyl chloride alloy Thermoplastic alloy of an acrylate styrene acrylonitrile polymer with polyvinyl chloride.

acrylic epoxy resin See *vinyl ester resin*.

acrylic ethylene rubber See *ethylene acrylic rubber*.

acrylic resin The class of thermoplastics comprised of homopolymers and copolymers of alkyl (meth)acrylates. The most common monomers used are methyl and ethyl (meth)acrylates; the comonomers include other unsaturated monomers. The acrylic resins offer excellent optical clarity, weatherability and resistance to sunlight, outstanding surface hardness, good chemical resistance, rigidity, good impact strength, excellent dimensional stability, and low mold shrinkage. They have poor solvent resistance, are subject to stress cracking, are combustible, and have low flexibility and thermal stability. The acrylic resins can be cast in sheets, rods, or tubing; extruded into sheets or profiles; injection molded; thermoformed; and coated. The applications include transparent items such as lenses, automotive trim, household items, light fixtures, conformed coatings on printed circuit boards, and medical devices. Also called polyacrylate, acrylate resin.

acrylic resin polyvinyl chloride alloy A thermoplastic alloy of an acrylic resin and polyvinyl chloride.

acrylic styrene acrylonitrile polymer See *acrylate styrene acrylonitrile polymer*.

acrylonitrile butadiene rubber See *nitrile rubber*.

acrylonitrile butadiene styrene polymer ABS resins are thermoplastics comprised of a mixture of styrene-acrylonitrile copolymer (SAN) and SAN-grafted butadiene rubber. They have high impact resistance, toughness, rigidity and processability, but low dielectric strength, continuous service temperature, and elongation. Outdoor use requires protective coatings in some cases. Plating grades provide excellent adhesion to metals. Processed by extrusion, blow molding, thermoforming, calendaring and injection molding. Used in household appliances, tools, nonfood packaging, business machinery, interior automotive parts, extruded sheet, pipe and pipe fittings. Also called ABS.

acrylonitrile copolymer Acrylonitrile copolymers are thermoplastics prepared by copolymerization of acrylonitrile with minor amounts of other unsaturated monomers. The class of acrylonitrile copolymers include ASA, ABS, SAN, and nitrile resins. In a narrower sense the term acrylonitrile copolymers is often used to denote (high) nitrile (barrier) resins. These resins have good gas barrier properties, chemical resistance, and taste and odor retention properties. These resins have moderately high tensile properties and good impact properties when rubber modified or oriented. Processed by extrusion, injection molding, and thermoforming. Used mainly in food and nonfood packaging. FDA approved for direct contact with food with some limitations.

acrylonitrile methyl acrylate copolymer A thermoplastic polymer of acrylonitrile and methyl acrylate.

acrylonitrile rubber See *nitrile rubber*.

acrylonitrile styrene acrylate polymer See *acrylate styrene acrylonitrile polymer*.

activation energy An excess energy that must be added to an atomic or molecular system to allow a process, such as diffusion or chemical reaction, to proceed.

adherend A body held to another body, usually by an adhesive or solvent. A part or detail being prepared for bonding.

adhesion promoter A coating applied to a substrate prior to adhesive application, in order to improve adhesion of the material, such as a plastic. Also called primer.

adhesive A material, usually polymeric, capable of forming permanent or temporary surface bonds with another material as is or after processing such as curing. Used for bonding and joining. Many classes of adhesives include hot-melt, pressure-sensitive, contact, UV cured, emulsion, etc.

adhesive abrasion In adhesive bonding, a surface preparation technique in which the part surface is mechanically abraded in the presence of liquid adhesive. Abraded, adhesive-coated adherends are then mated, and adhesive is allowed to cure. It is speculated that abrasion in the presence of adhesive creates free radicals that react directly with the adhesive; when abrasion is performed in the absence of adhesive, the generated free radicals are scavenged by oxygen in air before adhesive is applied. Adhesive abrasion is commonly used on fluorocarbons; bond strengths of Teflon (PTFE) were increased about 700% using this technique.

adhesive bonding A method of joining two plastics or other materials in which an adhesive is applied to the part surfaces. Bonding occurs through mechanical or chemical interfacial forces between the adhesive and adherend and / or by molecular interlocking. Surface preparation of the adherends and curing of the adhesive may be required.

adhesive failure Failure of an adhesive bond at the adhesive-adherend interface. An example is an adhesive failure that leaves adhesive all on one adherend, with none on the other adherend. Adhesive failure is less desirable than cohesive failure because it is indicative of a joint with lower adhesive strength. See also *cohesive failure*.

adiabatic A process in which there is no gain or loss of heat from the system to the environment. For plastics, although not completely correct, it is used to describe a mode of extrusion in which no external heat is added to the extruder. Heat may be removed from the extruder by cooling in order to keep the output temperature of the melt passing through the extruder constant. Heat input in this process originates from the conversion of mechanical energy of the screw to thermal energy.

adipic acid hexanediamine polymer See *nylon 66*.

adsorption Retention of a substance molecule on the surface of a solid or liquid. Also called physical adsorption.

advanced styrenic resin See *styrenic resin*.

alpha cellulose See *cellulose*.

amideimide resin See *polyimide*.

amorphous nylon Amorphous nylons are transparent products that typically involve rings in copolymer chains. One amorphous nylon involves 2,4,4- and 2,2,4-trimethylhexamethylene diamine and terephthalic acid.

amplitude The maximum displacement of a particle measured from its equilibrium position.

annealing A process in which a material, such as plastic, metal, or glass, is heated then cooled slowly. In plastics and metals, it is used to reduce stresses formed during fabrication. The plastic is heated to a temperature at which the molecules have enough mobility to allow them to reorient to a configuration with less residual stress. Semicrystalline polymers are heated to a temperature at which retarded crystallization or recrystallization can occur.

antimony pentoxide (Sb_2O_5) A white or yellowish powder that melts at 450°C (842°F). Loses oxygen above 300°C (572°F). Soluble in strong bases, forming antimonates; slightly soluble in water; insoluble in acids except for concentrated hydrochloric acid. Derived by reaction of concentrated nitric acid with the metal or trioxide. Used as a flame retardant for textiles and in the preparation of antimonates and other antimony compounds. Also called antimonic anhydride, antimonic acid, stibic anhydride.

antimony trioxide (Sb_2O_3) A white, odorless, crystalline powder that melts at 655°C (1211°F). Soluble in concentrated hydrochloric and sulfuric acids and strong bases; insoluble in water. Amphoteric, a suspected carcinogen. Derived by reaction of ammonium hydroxide with antimony chloride, combustion of antimony in air, or directly from low-grade ores. Used in flameproofing textiles, paper, and plastics, especially polyvinyl chloride; glass decolorizer; paint pigments; staining of copper and iron; opacifying ceramics; and as a catalyst or intermediate in organic reactions. Also called antimony white, antimony oxide.

aramid See *polyarylamide*.

aromatic ester carbonate See *aromatic polyester estercarbonate*.

aromatic polyamide See *polyarylamide*.

aromatic polyester Aromatic polyesters are thermoplastics prepared by polycondensation of aromatic polyol with aromatic dicarboxylic acid or anhydride or by polycondensation of aromatic hydroxycarboxylic acid. They are tough, durable, heat resistant, and offer good dimensional stability, dielectric properties, UV-stability, and flame retardance. Chemical resistance of aromatic polyesters is somewhat lower than other engineering plastics. Processing is achieved by injection and blow molding, extrusion, and thermoforming. Thorough drying is required. Uses include automotive housings and trim, electrical wire jacketing, printed circuit boards, appliance enclosures. Also called polyarylate, ARP.

aromatic polyester estercarbonate A thermoplastic comprising block copolymer of an aromatic polyester with polycarbonate. It has increased heat distortion temperature, compared to general-purpose polycarbonate. Also called polyestercarbonate, aromatic polyestercarbonate, aromatic ester carbonate.

aromatic polyestercarbonate See *aromatic polyester estercarbonate*.

ARP See *aromatic polyester*.

ASA See *acrylate styrene acrylonitrile polymer*.

ASA PVC alloy Alloy of acrylic styrene acrylonitrile and polyvinyl chloride.

aseptic In food processing, a process or condition that renders a processed food product essentially free of microorganisms capable of growing in the food in unrefrigerated distribution and storage conditions. In aseptic food packaging, presterilized containers are filled with aseptic foods, then hermetically sealed in a commercially sterile atmosphere.

ASR See *styrenic resin*.

ASTM D1002 An American Society for Testing of Materials (ASTM) standard practice for testing the shear strength of rigid sheet material by tensile loading. Two sections of a rigid sheet material, usually 4 in. in length x 1 in. in width x 0.064 in. in thickness (101.6 x 25 x 1.62 mm) and having suitably treated surfaces, are overlapped 0.5 in. (12.7 mm) and adhesively bonded together in a 0.5 square inch contact area (323 mm²). Both ends are then clamped firmly into the jaws of a tensile testing machine, and the jaws are moved apart at a speed of 0.05 in./min. (1.3 mm/min.) until joint failure occurs. The failing load, in psi (MPa) and mode of failure (adhesive, cohesive, or mixed) is reported. This is the most commonly used shear test for metal-to-metal structural adhesives. Although it is useful for quality control and comparing different adhesives, failure strength values are not useful for engineering design due to the complex stress distribution pattern in the adhesive with this joint configuration. Also called the lap shear test. Also called lap shear test.

ASTM D1761 An American Society for Testing of Materials (ASTM) standard practice for testing the strength and performance of mechanical fasteners in wood. Withdrawal resistance of wood to nails, staples, and screws is measured by recording the maximum load of fasteners withdrawn at a uniform rate of speed by a testing machine. Resistance of nails, staples, and screws to lateral movement is tested by tensile loading. Strength and rigidity of timber joints fastened with bolts or other metal connectors is tested by measuring the deformation of the joint at various intervals of loading. Vertical load capacity and torsional moment capacity of joist hangers is tested by measuring the amount of slip under load.

ASTM D4501 An American Society for Testing of Materials (ASTM) standard practice for determining the shear strengths of adhesives used to bond rigid materials by the block shear method. Adhesively bonded blocks, plates, or disks, with flash and fillets removed on the loaded side, are mounted into the shear fixture of a testing machine (capacity not less than 44 kN (10,000lbf)). Test specimens can be any size within the limits of the shearing fixture capacity. The shear fixture is mounted into the testing machine in such a way that one adherend is engaged by the holding block and the other by the shearing tool. A crosshead speed of 1.26 mm/min. (0.05 in./min.) is used for testing. The maximum forces sustained by the specimen is recorded. This test is particularly applicable for testing bonds between ceramic, glass, magnet moldings, and plastic parts with one flat face in which machining is difficult or impractical.

average molecular weight See *molecular weight*.

bar A metric unit of measurement of pressure equal to 1.0E+06 dynes/cm² or 1.0E+05 pascals. It has a dimension of unit of force per unit of area. Used to denote the pressure of gases, vapors and liquids.

barrier material Materials such as plastic films, sheeting, wood laminates, particle board, paper, fabrics, etc. with low permeability to gases and vapors. Used in construction as water vapor insulation, food packaging, protective clothing, etc.

base resin melt index See *melt index*.

beading In joining plastics, bending an edge of a flat thermoplastic sheet, using roll(s) with or without heating, or flanging an end of a thermoplastic pipe, using mandrel with or without heating, to form a profile suitable for subsequent joining or assembly. In coating, heavy accumulation of a coating which occurs at the lower edge of a panel or other vertical surface as the result of excessive flowing.

bending strength See *flexural strength*.

benzene An aromatic hydrocarbon with six-atom carbon ring, C₆H₆. Highly toxic and flammable (autoignition point 562°C). A colorless or yellowish liquid under normal conditions (b.p. 80.1°C), soluble in many organic solvents such as ethanol, acetone, tetrachlorocarbon, etc. Used for synthesis of organic compounds.

bisphenol A epoxy resin See *epoxy resin*.

bisphenol A fumarate polyester See *bisphenol A polyester*.

bisphenol A polyester A thermoset unsaturated polyester based on bisphenol A and fumaric acid. Also called bisphenol A fumarate polyester.

black lead See *graphite filler*.

booster In ultrasonic welding, a mechanical transformer used to increase or decrease the amplitude of the horn.

boss A hollow or solid projection used for attachment and support of related components. Properly designed bosses and ribs can provide dimensional stability to the part, while reducing material usage and molding cycle time. In mechanical fastening, the hollow projection into which an insert or screw is driven. Solid bosses are also called studs.

breaking elongation See *elongation*.

bursting strength Bursting strength of a material, such as plastic film, is the minimum force per unit area or pressure required to produce rupture. The pressure is applied with a ram or a diaphragm at a controlled rate to a specified area of the material held rigidly and initially flat but free to bulge under the increasing pressure.

butadiene styrene block polymer See *styrene butadiene block copolymer*.

butadiene styrene methyl methacrylate polymer See *methyl methacrylate butadiene styrene terpolymer*.

Butanone 2- (CH₃COCH₂CH₃) A colorless liquid with an acetone-like odor. Soluble in benzene, alcohol, ether; partially soluble in water; miscible with oils. Its TLV is 200 ppm in air; it is toxic by

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inhalation and a dangerous fire risk. Explosive limit in air is 2-10%. Derived from sulfuric acid hydrolysis of mixed n-butylenes followed by distillation, by controlled oxidation of butane, or by fermentation. Used as a solvent in nitrocellulose coatings and vinyl films and in paint removers, cements and adhesives, manufacture of smokeless powder, cleaning fluids, and acrylic coatings. Used in printing, and as a reagent for organic synthesis. Also called methyl ethyl ketone, MEK, ethyl methyl ketone. Also called methyl ethyl ketone, MEK.

butt joint A type of edge joint in which the edge faces of the two parts are at right angles to the other faces of the part.

butt joint weld A weld in which the parts are joined using a butt joint.

C

CA See *cellulose acetate*.

CAB See *cellulose acetate butyrate*.

caprolactam pyrrolidone polymer See *nylon 46*.

carbon black Carbon black is a black colloidal carbon filler made by the partial combustion and/or thermal cracking of natural gas, oil, or another hydrocarbon. Depending upon the starting material and the method of manufacture, carbon black can be called acetylene black, channel black, furnace black, etc. For example, channel black is made by impinging gas flames against steel plates or channel irons, from which the deposit is scraped at intervals. The properties and the uses of each carbon black type can also vary. Thus, furnace black comes in high abrasion, fast extrusion, high modulus, general purpose, and semireinforcing grades among others. Carbon black is widely used as a filler and pigment in PVC, phenolic resins, and polyolefins. It increases the resistance to UV light and electrical conductivity and sometimes acts as a crosslinking agent. Also called colloidal carbon.

carbon fiber Carbon fibers are high-performance reinforcement consisting essentially of carbon. They are made by a variety of methods including pyrolysis of cellulosic (e.g., rayon) and acrylic fibers, burning-off binder from a pitch precursor, and growing single crystals (whiskers) via thermal cracking of hydrocarbon gas. The properties of carbon fibers depend on the morphology of carbon in them and are the highest for crystalline carbon (graphite). These properties include high modulus and tensile strength, high thermal stability, electrical conductivity, chemical resistance, wear resistance, and relatively low weight. Used as continuous or short fibers and in mats in autoclave and die molding, filament winding, injection molding, and pultrusion. Carbon fibers are used at a loading levels of 20-60 vol% or more in both thermosets and thermoplastics such as epoxy resins and ABS. Carbon fibers are often used in combination with other fibers such as glass fibers to make hybrid composites. The end products containing carbon fibers include wheel chairs, tennis racquets, auto parts, machine tools, and support structures in electronic equipment. Also called graphite fiber.

carbon filler Carbon fillers are a family of fillers based on carbon in various forms, such as carbon black and graphite. Used as a black pigment, to improve lubricity, and to increase electrical conductivity of plastics. Also called powdered carbon, carbon powder.

carbon graphite See *graphite filler*.

carbon powder See *carbon filler*.

carbon tetrachloride (CCl_4) A colorless liquid with a sweet odor. Miscible with alcohol, ether, chloroform, benzene, solvent naphtha, and most fixed and volatile oils; insoluble in water. Noncombustible. Boils at 76.74°C (170.13°F); freezes at -23°C (-9.4°F); vapor is 5.3 times heavier than air. Its TLV is 5 ppm in air; it is toxic by ingestion, inhalation, and skin absorption. Decomposes to phosgene at high temperatures. Derived by reaction of carbon disulfide and chlorine in the presence of iron or by chlorination of methane or higher hydrocarbons at 250 - 400°C (752°F). Purified by removal of sulfur chloride using caustic alkali, followed by rectification. Used in metal degreasing, chlorination of organic compounds, the production of semiconductors and solvents (fats, oils, rubber); as a refrigerant and agricultural fumigant. Also called tetrachloromethane, perchloromethane.

cast film Film produced by pouring or spreading resin solution or melt over a suitable temporary substrate, followed by curing via solvent evaporation or melt cooling and removing the cured film from the substrate.

CE See *cellulosic plastic*.

cellulose Cellulose is a natural carbohydrate polymer of high molecular weight comprised of long chains of D-glucose units joined together by beta-1,4-glucosidic bonds. It is derived from plants such as cotton and trees. It is used to produce cellulose esters and ethers, i.e., cellulosic plastics, but the largest use is in paper manufacture. Cellulose fillers in a narrow sense are usually made from wood pulp. In a broader sense they may include cotton lint, wood flour, lignin, wood chips, and various cellulosic waste such as cotton fiber rejects. Treating wood pulp with alkali results in a colorless filler used in thermosetting resins such as phenolic. Also called pulp, cellulose pulp, alpha cellulose.

cellulose acetate Thermoplastic ester of cellulose and acetic acid which is characterized by toughness, gloss, clarity, good processability, stiffness, hardness, good "feel", and dielectric properties. The disadvantages of this ester include poor resistance to solvents, alkaline materials, and fungi, high moisture pickup and permeability, rather low compressive strength, and flammability. It is processed by injection and blow molding and extrusion. The applications include telephone and appliance cases, automotive steering wheels, pens and pencils, tool handles, tubular containers, eyeglass frames, brushes, tapes, sheeting, and signs. Also called CA.

cellulose acetate butyrate Thermoplastic mixed ester of cellulose and acetic and butyric acids. Characterized by toughness, gloss, clarity, good processability, low temperature impact strength, dimensional stability, weatherability, good "feel", and dielectric properties. The disadvantages of this ester include poor resistance to solvents, alkaline materials, and fungi, high moisture pickup and permeability, rather low compressive strength, and flammability. It is processed by injection and blow molding and extrusion. The applications include telephone and appliance cases, automotive steering wheels, pens and pencils, tool handles, tubular containers, eyeglass frames, brushes, tapes, sheeting, and signs. Also called cellulose butyrate, CAB.

cellulose butyrate See *cellulose acetate butyrate*.

cellulose propionate Thermoplastic ester of cellulose and propionic acid which is characterized by toughness, gloss, clarity, good processability, low temperature impact strength, dimensional stability, weatherability, good "feel", and dielectric properties. The disadvantages of this ester include poor resistance to solvents, alkaline materials, and fungi, high moisture pickup and permeability, rather low compressive strength, and flammability. It is processed by injection and blow molding and extrusion. The

applications include telephone and appliance cases, automotive steering wheels, pens and pencils, tool handles, tubular containers, eyeglass frames, brushes, tapes, sheeting, and signs. Also called CP.

cellulose pulp See *cellulose*.

cellulosic See *cellulosic plastic*.

cellulosic plastic A class of thermoplastics consisting of cellulose esters and ethers. The most important esters are acetates, including mixed esters, and nitrates. The most important ethers are ethyl and carboxymethyl. The cellulosic plastics are characterized by toughness, gloss, clarity, and good processability. In addition, the acetates exhibit good stiffness and hardness, the butyrates and propionates show increased weatherability, low temperature impact strength, and dimensional stability, and all esters have good "feel" and dielectric properties. The disadvantages of the esters include poor resistance to solvents, alkaline materials, and fungi, high moisture pickup and permeability, rather low compressive strength, and flammability. They are processed by injection and blow molding and extrusion. The applications include telephone and appliance cases, automotive steering wheels, pens and pencils, tool handles, tubular containers, eyeglass frames, brushes, tapes, sheeting, and signs. Also called cellulosic, CE.

chain scission Breaking of the chainlike molecule of a polymer as a result of chemical, photochemical, etc. reaction such as thermal degradation or photolysis.

chamfer A beveled edge or corner; to bevel a sharp edge.

chemical saturation Absence of double or triple bonds in a chain organic molecule such as that of most polymers, usually between carbon atoms. Saturation makes the molecule less reactive and polymers less susceptible to degradation and crosslinking.

chemical unsaturation Presence of double or triple bonds in a chain organic molecule such as that of some polymers, usually between carbon atoms. Unsaturation makes the molecule more reactive, especially in free-radical addition reactions such as addition polymerization, and polymers more susceptible to degradation, crosslinking and chemical modification.

chlorendic polyester A thermoset unsaturated polyester based on chlorendic anhydride.

chlorinated polyvinyl chloride Thermoplastics produced by post-chlorination of PVC to increase glass temperature and heat deflection under load. Have high chemical resistance, rigidity, flame retardance, tensile strength, and weatherability. Processed by extrusion, injection molding, casting, and calendaring. Used in hot and cold water piping and fittings, chemical liquid piping, automotive parts, waste disposal devices, outdoor applications, and glazing beads. Also called PVD, CPVC.

chloroprene rubber See *neoprene rubber*.

chlorosulfonated PE rubber See *chlorosulfonated polyethylene rubber*.

chlorosulfonated polyethylene rubber Chlorosulfonated polyethylene rubbers are thermosetting elastomers that contain between 20 and 40% chlorine and approximately 1 to 2% sulfur. They provide resistance to ozone and oxygen attack under sunlight and UV radiation conditions. They are also resistant to deterioration due to heat, chemicals, and solvents. The most common applications for these elastomers are hose, tubing, and sheet goods, soles and heels, life boats and jackets, and windbreakers. Also called CSPE rubber, CSM, chlorosulfonated PE rubber.

chopped glass fiber Chopped glass fibers have lengths from 1/8 to 1/2 in. and are made by chopping glass strands containing 8 120 filaments. The individual fibers are bonded together within strands so that they can remain in bundles after chopping. Used widely in bulk molding compounds; and compression, transfer, and injection molding. Also called short glass fiber, medium glass fiber, chopped strand.

chopped strand See *chopped glass fiber*.

chromic acid etching In adhesive bonding, a surface preparation technique in which chromic acid is used to introduce oxygenated reactive molecular groups, such as hydroxyl, carbonyl, carboxylic, and hydrogen sulfite, to the part surface and to form root-like cavities as sites for mechanical interlocking. Commonly used for polyolefins, ABS, polystyrene, polyphenyleneoxide, and acetals.

cobalt naphthenate A brown, amorphous powder or bluish-red solid of indefinite composition. Soluble in alcohol, ether, oils; insoluble in water. Combustible. Derived from reaction of cobaltous hydroxide or cobaltous acetate with naphthenic acids. Used as catalyst in bonding rubber to steel and other metals and as a paint and varnish drier. Also called cobaltous naphthenate.

cobalt-60 One of the unstable isotopes of Co used widely as a source of gamma radiation.

cocatalyst See *accelerator*.

coextruded film A film made by coextrusion of 2 or more different or similar plastics through a single die with two or more orifices arranged so that the extrudates merge and weld together into a laminar film before cooling. Each ply of coextruded film imparts a desired property, such as impermeability or resistance to some environment and heat-sealability, usually unattainable with a single material.

cohesive failure Failure of an adhesive bond that occurs within the adhesive, leaving adhesive present on both adherends. Optimum failure is 100% cohesive failure, when both shear areas are completely covered. See also *adhesive failure*.

colloidal carbon See *carbon black*.

conditioning Process of bringing the material or apparatus to a certain condition, e.g., moisture content or temperature, prior to further processing, treatment, etc. Also called conditioning cycle.

conditioning cycle See *conditioning*.

conduction In heat transfer, migration of energy due to a temperature gradient. Heat energy is transferred by the movement of molecules at hotter or colder temperatures, with different degrees of thermal motion, into colder or hotter regions, respectively. See also *radiation convection*.

contact adhesive An adhesive that will adhere to itself on contact. When applied to both adherends, it forms a bond after drying, without sustained pressure on the adherends. Composed of neoprene or, less commonly, nitrile elastomers. See also *pressure sensitive adhesive*.

continuous glass fiber Continuous glass fibers are strands of filaments (roving) made by melt drawing from various grades of glass. Can be twisted. Used in sheet molding compounds, sprayup lamination, pultrusion, and filament winding. Continuous glass fibers provide fast wetout, even tension, and abrasion resistance during processing. Also called long glass fiber, continuous strand roving, continuous roving, continuous glass roving.

continuous glass roving See *continuous glass fiber*.

continuous roving See *continuous glass fiber*.

continuous strand roving See *continuous glass fiber*.

convection The mass movement of particles arising from the movement of a streaming fluid due to difference in a physical property such as density, temperature, etc. Mass movement due to a temperature difference results in heat transfer, as in the upward movement of a warm air current. See also *radiation conduction*.

copolyester See *polyester*.

copolyester thermoplastic rubber See *polyester thermoplastic elastomer*.

copolyester TPE See *polyester thermoplastic elastomer*.

corona discharge treatment In adhesive bonding, a surface preparation technique in which a high electric potential is discharged by ionizing the surrounding gas, usually air. The gas reacts with the plastic, roughening the surface to provide sites for mechanical interlocking and introducing reactive sites on the surface. Functional groups such as carbonyls, hydroxyls, hydroperoxides, aldehydes, ethers, esters, carboxylic acids, and unsaturated bonds have been proposed as reactive sites. Commonly used for polyolefins, corona discharge increases wettability and surface reactivity. In processing plastics, treating the surface of an inert plastic such as polyolefin with corona discharge to increase its affinity to inks, adhesives or coatings. Plastic films are passed over a grounded metal cylinder with a pointed high-voltage electrode above it to produce the discharge. The discharge oxidizes the surface, making it more receptive to finishing. Also called corona treatment. See also *plasma arc treatment*.

corona treatment See *corona discharge treatment*.

Coulombic friction The opposing force that occurs when two dry surfaces are rubbed together, as in vibration and spin welding. Also called external friction. See also *internal friction*.

coupler In ultrasonic welding, a booster that does not affect the amplitude of the horn. Its gain ratio is 1:1.

CP See *cellulose propionate*.

CPVC See *chlorinated polyvinyl chloride*.

cracking Appearance of external and/or internal cracks in the material as a result of stress that exceeds the strength of the material. The stress can be external and/or internal and can be caused by a variety of adverse conditions: structural defects, impact, aging, corrosion, etc. or a combination thereof. Also called resistance to cracking, grazing, cracking resistance. See also *crazing*.

cracking resistance See *cracking*.

crazing Appearance of thin cracks on the surface or minute frost-like internal cracks in materials such as plastic as a result of residual stress, impact, temperature changes, degradation, etc. See also *cracking*

creep Time-dependent increase in strain in material, occurring under stress.

crosslinked PE See *crosslinked polyethylene*.

crosslinked polyethylene Polyethylene thermoplastic partially crosslinked by irradiation or by the use of chemical additives such

as peroxides to improve tensile strength, dielectric properties and impact strength over a wider range of temperatures. Also called crosslinked PE.

crosslinking Reaction or formation of covalent bonds between chain-like polymer molecules or between polymer molecules and low-molecular compounds such as carbon black fillers. As a result of crosslinking polymers, such as thermosetting resins, may become hard and infusible. Crosslinking is induced by heat, UV or electron-beam radiation, oxidation, etc. Crosslinking can be achieved either between polymer molecules alone as in unsaturated polyesters or with the help of multifunctional crosslinking agents such as diamines that react with functional side groups of the polymers. Crosslinking can be catalyzed by the presence of transition metal complexes, thiols and other compounds.

crystal polystyrene See *general purpose polystyrene*.

crystal PS See *general purpose polystyrene*.

crystalline melting point The temperature of melting of the crystalline phase of a crystalline polymer. It is higher than the temperature of melting of the surrounding amorphous phase.

CSM See *chlorosulfonated polyethylene rubber*.

CSPE rubber See *chlorosulfonated polyethylene rubber*.

CTFE See *polychlorotrifluoroethylene*.

curing A process of hardening or solidification involving crosslinking, oxidizing, and / or polymerization (addition or condensation).

cianoacrylate In adhesive bonding, a highly reactive class of adhesives that cures rapidly at room temperature with trace amounts of moisture as catalysts to form high strength bonds with plastics and metals.

cyclohexane (C₆H₁₂) A colorless liquid with a pungent odor. Molecular structure is an alicyclic hydrocarbon that can exist in two conformations, the "boat" and "chair", depending on bond angles between carbon atoms. Soluble in alcohol, acetone, benzene; insoluble in water. Boils at 807°C (1485°F); freezes at 6.3°C (43°F). Its autoignition temperature is 473°F (145°C). It is a dangerous fire risk; flammable limit in air is 1.3 - 8.4%. Its TLV is 300 ppm in air; it is moderately toxic by inhalation and skin contact. Derived from crude petroleum or by catalytic hydrogenation of benzene. Used in the production of nylon, in the extraction of essential oils; as a solvent for cellulose ethers, fats, oils, crude rubber, bitumens, resins, waxes; in organic synthesis; as a paint and varnish remover and in glass substitutes. Also called hexamethylene, hexanaphthene, hexahydrobenzene.

cyclohexanone (C₆H₁₀O) Cyclohexanone is an oily, water-white to pale yellow liquid with a slight odor of peppermint and acetone. Soluble in organic solvents such as alcohols and ethers, slightly soluble in water. It has an autoignition temperature of 420°C (788°F). Its TLV is 25 ppm in air; it is toxic by inhalation and skin contact. Derived by passing cyclohexanol over copper with air at 138°C (280°F) or by oxidation of cyclohexanol with chromic acid or oxide. Used in the preparation of adipic acid, caprolactam, polyvinyl chloride and its copolymers, and methacrylate ester polymers, and for metal degreasing. Used in wood stains, paint and varnish removers, spot removers, polishes, natural and synthetic resins, lube oil, and other products. Also called pimelic ketone, keto-hexamethylene.

D

DAIP See *diallyl phthalate resin*.

damping In part assembly, to mechanically limit the amplitude of vibration in the parts being assembled.

DAP See *diallyl phthalate resin*.

dart impact energy The mean energy of a free-falling dart that will cause 50% failures after 50 tests to a specimen directly stricken by the dart. The energy is calculated by multiplying dart mass, gravitational acceleration and drop height. Also called falling dart impact strength, dart impact strength.

dart impact strength See *dart impact energy*.

deflection temperature under load See *heat deflection temperature*.

degradation Loss or undesirable change in properties as a result of aging, chemical reactions, wear, use, exposure, etc. The properties include color, size, strength, etc. See also *degradation*.

density The mass of any substance (gas, liquid or solid) per unit volume at specified temperature and pressure. The density is called absolute when measured under standard conditions, e.g., 760 mmHg pressure and 0°C temperature. **Note:** For plastics- the weight in air per volume of impermeable portion of the material measured at 23°C according to ASTM D792. Also called mass density, absolute gravity, absolute density.

diallyl isophthalate See *diallyl phthalate resin*.

diallyl isophthalate resin See *diallyl phthalate resin*.

diallyl meta phthalate See *diallyl meta phthalate resin*.

diallyl meta phthalate resin Diallyl phthalates are thermoset resins comprising diallyl phthalate prepolymer. Sometimes supplied as a monomer. These resins show excellent moisture resistance, high service temperatures, good retention of electric properties under high temperature and humidity, dimensional stability, chemical resistance (except for phenols and oxidizing acids), and good mechanical strength. The disadvantages include high cost and shrinkage during curing. Cured by peroxide catalysts. Processed by injection, compression, and transfer molding. Used in glass fiber-reinforced plastic articles such as tubing and in the manufacture of automotive distribution caps, electronic connectors, and transformer cases. Also called diallyl meta phthalate.

diallyl ortho phthalate See *diallyl ortho phthalate resin*.

diallyl ortho phthalate resin Diallyl phthalates are thermoset resins comprising diallyl phthalate prepolymer. Sometimes supplied as a monomer. These resins show excellent moisture resistance, high service temperatures, good retention of electric properties under high temperature and humidity, dimensional stability, chemical resistance (except for phenols and oxidizing acids), and good mechanical strength. The disadvantages include high cost and shrinkage during curing. Cured by peroxide catalysts. Processed by injection, compression, and transfer molding. Used in glass fiber-reinforced plastic articles such as tubing and in the manufacture of automotive distribution caps, electronic connectors, and transformer cases. Also called diallyl ortho phthalate.

diallyl phthalate See *diallyl phthalate resin*.

diallyl phthalate resin Thermoset resins comprised of diallyl (iso)phthalate prepolymer. Sometimes supplied as a monomer.

These resins show excellent moisture resistance, high service temperatures, good retention of electric properties under high temperature and humidity, dimensional stability, chemical resistance (except for phenols and oxidizing acids), and good mechanical strength. The disadvantages include high cost and shrinkage during curing. Cured by peroxide catalysts. Processed by injection, compression, and transfer molding. Used in glass fiber-reinforced plastic articles such as tubing and in the manufacture of automotive distribution caps, electronic connectors, and transformer cases. Also called PDAP, diallyl phthalate, diallyl isophthalate resin, diallyl isophthalate, DAP, DAIP.

diaphragming Part flexing that can cause stress, fracturing, or undesirable melting of thin-sectioned, flat parts. Also called "oil-canning", which describes the way the plastic part bends up and down when subjected to ultrasonic energy.

dichloroethylene 1,2 (ClCH₂CHCl) A colorless liquid with a pleasant odor. Exists as cis and trans stereoisomers. Soluble in most organic solvents; slightly soluble in water. Trans isomer boils at 47 - 49°C (116 - 120°F); cis isomer boils at 58 - 60°C (136 - 140°F) and freezes at -80°C (-112°F). Its TLV is 200 ppm in air; it is toxic by ingestion, inhalation, and skin contact and is an irritant and narcotic at high concentrations. Flammable; a dangerous fire hazard. Used as a solvent for organic compounds and in organic synthesis; in dye extraction, perfumes, lacquers, and thermoplastics. Also called sym-dichloroethylene, acetylene dichloride, dichloroacetylene.

dichloromethane (CH₂Cl₂) A colorless, volatile liquid with an odor of ether. Boils at 40.1°C (104.2°F); freezes at -97°C (-143°F). Soluble in alcohol, ether; slightly soluble in water. Nonflammable and nonexplosive in air. It is a carcinogen and narcotic; its TLV is 100 ppm in air. Derived from the chlorination of methyl chloride, followed by distillation. Used as a refrigerant; in nonflammable paint removers; in plastics processing and solvent extraction; as a blowing agent in foams and an aerosol propellant; in solvent degreasing; and as a solvent in organic synthesis. Also called methylene dichloride, methylene chloride. Also called methylene chloride.

dicyandiamide (NH₂C(NH)(NHCN)) White crystals that are stable when dry. Soluble in liquid ammonia; partly soluble in hot water. Melts at 207 - 209°C (405 - 408°F). Not flammable. Derived from polymerization of cyanamide in the presence of bases. Used as a catalyst for epoxy resins, a stabilizer in detergents, a modifier in starch products, a thinner in oil-well drilling muds; in organic reactions, fertilizers, pharmaceuticals, dyestuffs, case-hardening preparations, soldering compounds; and many other uses. Also called cyanoguanidine.

dielectric dissipation factor The ratio of the power dissipated in a dielectric to the product of the effective voltage and the current; or the cotangent of the dielectric phase angle; or the tangent of dielectric loss angle. **Note:** For plastics measured according to ASTM D150. Also called tan delta, permittivity loss factor, dissipation factor, dielectric loss tangent.

dielectric loss tangent See *dielectric dissipation factor*.

differential scanning calorimetry DSC is a technique in which the energy absorbed or produced is measured by monitoring the difference in energy input into the substance and a reference material as a function of temperature. Absorption of energy produces an endotherm; production of energy results in an exotherm. May be applied to processes involving an energy change, such as melting, crystallization, resin curing, and loss of solvents, or to processes involving a change in heat capacity, such as the glass transition.

dimethyl ketone See *acetone*.

direct contact hot tool welding A form of heated tool welding in which the thermoplastic parts are pressed directly against the hot tool or plate. Part surfaces are heated until the melting or glass transition is reached. The hot tool is then removed, and the parts are pressed together until cooled. The hot tool can be coated with polytetrafluoroethylene to reduce melt sticking. See also heated tool welding, hot tool welding.

dissipation factor See *dielectric dissipation factor*.

dissolving capacity See *solubility*.

DMF See *N,N-dimethylformamide*.

dodecanedioic acid hexamethylenediamine polymer See *nylon 612*.

driving torque In mechanical fastening, the force necessary to drive a self-tapping screw into a pilot hole. Lower values are optimal.

drop dart impact strength See *falling weight impact energy*.

drop weight impact strength See *falling weight impact energy*.

durability See *stability*.

durometer hardness Indentation hardness of a material as determined by either the depth of an indentation made with an indenter under specified load or the indenter load required to produce a specified indentation depth. The tool used to measure indentation hardness of polymeric materials is called a durometer, e.g., Shore-type durometer.

E

EA rubber See *ethylene acrylic rubber*.

EAR See *ethylene acrylic rubber*.

ECTFE See *ethylene chlorotrifluoroethylene copolymer*.

elasticity constant See *modulus of elasticity*.

electrofusion welding A technique used for joining thermoplastic pipes or liners, in which electricity is applied to a heating element surrounded by a thermoplastic material. The heat produced causes the thermoplastic material and the thermoplastic on the surface of the pipes to melt and flow together, forming a weld. Commonly used for joining polyethylene pipes.

electromagnetic radiation Waves of electric charges propagated through space by oscillating electromagnetic fields and associated energy.

electromagnetic welding See *induction welding*.

electron beam See *electron beam radiation*.

electron beam radiation Ionizing radiation propagated by electrons that move forward in a narrow stream with approximately equal velocity. Also called electron beam.

Elmendorf tear strength The resistance of flexible plastic film or sheeting to tear propagation. It is measured, according to ASTM D1922, as the average force, in grams, required to propagate

tearing from a precut slit through a specified length, using an Elmendorf-type pendulum tester and 2 specimens, a rectangular type and one with a constant radius testing length.

elongation The increase in gauge length of a specimen in tension, measured at or after the fracture, depending on the viscoelastic properties of the material. **Note:** Elongation is usually expressed as a percentage of the original gage length. Also called ultimate elongation, tensile elongation, breaking elongation.

EMAC See *ethylene methyl acrylate copolymer*.

embrittlement A condition of low ductility in metals resulting from chemical or physical damage. Also called metal embrittlement.

energy director A triangular shaped bead of plastic that is molded into one of the parts to be joined. Used in ultrasonic welding, it concentrates ultrasonic energy at the point, resulting in rapid heat buildup and melting.

environmental stress cracking Cracking or crazing that occurs in a thermoplastic material subjected to stress or strain in the presence of particular chemicals or weather conditions or as a result of aging. Also called ESC.

EP See *epoxy resin*.

EPDM See *EPDM rubber*.

EPDM rubber Ethylene propylene-diene terpolymer (EPDM) rubbers are produced from ethylene, propylene, and smaller amounts of a nonconjugated diene such as hexadiene. They are vulcanized using sulfur. Typical properties include excellent resistance to oxygen, ozone, light, high and low temperatures, acids, alkalies, and oils. They may be used in other elastomers as impact modifiers and also to improve heat and ozone resistance. Typical uses include weather stripping, auto parts, cable insulation, conveyor belts, garden and industrial hoses, and appliance tubing. EPDM rubbers have been proposed as potential substitutes for natural rubber in tires. Also called ethylene propylene diene monomer rubber, EPDM.

EPE bead See *polyethylene*.

EPM See *ethylene propene rubber*.

epoxides Organic compounds containing three-membered cyclic group(s) in which two carbon atoms are linked with an oxygen atom as in an ether. This group is called an epoxy group and is quite reactive, allowing the use of epoxides as intermediates in preparation of certain fluorocarbons and cellulose derivatives and as monomers in preparation of epoxy resins.

epoxy See *epoxy resin*.

epoxy resin Epoxy resins is a family of thermoset polyethers containing crosslinkable glycidyl groups. The largest group of epoxy resins is prepared by polymerization of bisphenol A and epichlorohydrin. These resins have a wide viscosity range, depending on their molecular weight, and are cured at room or elevated temperatures with catalyzed polyamines and/or anhydrides. Aliphatic and cycloaliphatic epoxy resins are produced by peroxidation of olefins with peracetic acid or epoxidation of polyols with epichlorohydrin. Novolak epoxy resins are prepared by reacting novolak phenolic resins with epichlorohydrin. Vinyl ester or acrylic epoxy resins are prepared by treating epoxy resins with unsaturated carboxylic acids such as acrylic acid. There are other specialty type epoxy resins such as halogenated epoxy and phenoxy resins. Bisphenol A epoxy resins exhibit excellent adhesion and very low shrinkage during curing. Additionally, cured novolak and cycloaliphatic resins have good

UV stability and dielectric properties, while cured vinyl ester resins show high strength and chemical resistance and brominated epoxy resins show fire retardant properties. Some epoxy resins have poor oxidative stability. Processed by injection, compression, transfer, and structural foam molding, casting, coating, and lamination. Widely used as protective coatings, adhesives, potting compounds, and binders in laminates, flooring, civil engineering, electrical and electronic products. Also called epoxy, EP, bisphenol A epoxy resin.

epoxyethane See *ethylene oxide*.

EPP bead See *polypropylene*.

EPR See *ethylene propene rubber*.

EPS bead See *polystyrene*.

ESC See *environmental stress cracking*.

etching In adhesive and solvent bonding, a process used to prepare plastic surfaces for bonding. Exposure of the plastic parts to a reactive chemical, such as chromic acid, or to an electrical discharge results in oxidation of the surface and an increase in surface roughness by removal of surface material.

ETFE See *ethylene tetrafluoroethylene copolymer*.

ethane An alkane (saturated aliphatic hydrocarbon) with 2 carbon atoms, CH_3CH_3 . A colorless, odorless, flammable gas. Relatively inactive chemically. Obtained from natural gas. Used in petrochemical synthesis and as fuel.

ethanol See *ethyl alcohol*.

ethene See *ethylene*.

ethyl acetate An ethyl ester of acetic acid, $\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3$. A colorless, fragrant, flammable liquid. Autoignition temperature 426°C . Toxic by inhalation and skin absorption. Derived by catalytic esterification of acetic acid with ethanol. Used as solvent in coatings and plastics, organic synthesis, artificial flavors, pharmaceuticals.

ethyl alcohol An aliphatic alcohol, $\text{CH}_3\text{CH}_2\text{OH}$. A colorless, volatile, flammable liquid. Autoignition point is 422°C . Toxic by ingestion. Derived by catalytic hydration of ethylene, fermentation of biomass such as grain, or enzymatic hydrolysis of cellulose. Used as automotive fuel additive, in alcoholic beverages, as solvent for resins and oils, in organic synthesis, cleaning compositions, cosmetics, antifreeze, and antiseptic. Also called ethanol.

ethylene An alkene (unsaturated aliphatic hydrocarbon) with two carbon atoms, $\text{CH}_2=\text{CH}_2$. A colorless, highly flammable gas with sweet odor. Autoignition point 543°C . Derived by thermal cracking of hydrocarbon gases or from gas synthesis. Used as monomer in polymer synthesis, refrigerant, and anesthetic. Also called ethene.

ethylene acrylic rubber A thermosetting elastomer comprising a polymer of ethylene and acrylic ester. It is used in applications requiring a tough rubber with good low temperature properties and resistance to deterioration due to heat, oil, and water. Used for automotive, heavy equipment, and industrial parts. Also called EAR, EA rubber, acrylic ethylene rubber.

ethylene alcohol See *ethylene glycol*.

ethylene chlorohydrin ($\text{C}_2\text{H}_5\text{ClO}$) Ethylene chlorohydrin, $\text{ClCH}_2\text{CH}_2\text{OH}$, is a colorless liquid easily soluble in most organic liquids and water. It has an autoignition temperature of 797°F and is a moderate fire hazard. Derived by reaction of hydrochlorous acid with ethylene. It is a strong irritant, deadly via inhalation, skin absorption, etc. with TLV of 1 ppm in air. Penetrates through rubber gloves. Used as a solvent for cellulose derivatives, intermediate in organic synthesis (e.g., for ethylene oxide) and sprouting activator. **Note:** Hydrolysis of ethylene oxide during sterilization can result in the formation of ethylene chlorohydrin and its residual presence in sterilized goods. Also called glycol chlorohydrin.

ethylene chlorotrifluoroethylene copolymer Thermoplastic alternating copolymer of ethylene and chlorotrifluoroethylene in a predominantly 1:1 ratio. Its strength, creep resistance, and wear resistance are significantly greater than those of other fluoropolymers. It has good dielectric properties and very high chemical resistance at room and elevated temperatures, and resists ignition and flame propagation. The service temperatures range from the cryogenic region to 330°F . The processing is carried out by molding, extrusion, rotomolding, and powder coating. The applications include wire and cable insulation, column packings, pump components, filter housings, tubing, linings, braided sleeving, and release films. Also called ECTFE.

ethylene glycol ($\text{C}_2\text{H}_6\text{O}_2$) Ethylene glycol, $\text{CH}_2\text{OHCH}_2\text{OH}$, is a colorless heavy liquid soluble in polar organic solvents such as alcohols and water. It has an autoignition temperature of 775°F . Its TLV is 50 ppm and it is toxic by ingestion and inhalation. Derived by air oxidation of ethylene followed by hydration of resultant ethylene oxide, from gas synthesis, by oxirane process, etc. Used as coolant and antifreeze, as a monomer for the production of polyesters, solvent additive, foam stabilizer, brake fluids and many other products. **Note:** Hydrolysis of ethylene oxide during sterilization can result in the formation of ethylene glycol and its residual presence in sterilized goods. Also called glycol, ethylene alcohol.

ethylene methyl acrylate copolymer Thermoplastic resins prepared by high-pressure polymerization of ethylene and <40% methyl acrylate. The resins are characterized by good dielectric properties, toughness, thermal stability, and resistance to environmental stress cracking. They also have good processibility in LDPE equipment. They exhibit high compatibility with other polyolefins and permit high levels of filling. Optical properties deteriorate with increasing content of acrylate. Processed by blown film extrusion, extrusion, blow molding, and injection molding. Uses include coatings, heat-sealable film, disposable gloves, and antiseptic packaging. Meet FDA requirements for food packaging. Also called methyl acrylate ethylene polymer, EMAC.

ethylene oxide ($\text{C}_2\text{H}_4\text{O}$) The simplest, unsubstituted, saturated epoxide with molecular formula CH_2OCH_2 . Ethylene oxide is a colorless gas at room temperature with autoignition temperature of 805°F . It is an eye and skin irritant and a suspected human carcinogen. Its TLV is 1ppm in air. It is dangerous fire and explosion hazard. Ethylene oxide is derived by catalytic oxidation of ethylene or by alkaline hydrolysis of ethylene chlorohydrin. It is used in manufacture of ethylene glycol and other important chemicals such as polyethylene oxide surfactants, and as sterilant, fumigant and rocket propellant. Also called oxirane, methylene oxide, ETO, epoxyethane.

ethylene polymers Ethylene polymers include ethylene homopolymers and copolymers with other unsaturated monomers, most importantly olefins such as propylene and polar substances such as vinyl acetate. The properties and uses of ethylene polymers depend on the molecular structure and weight.

ethylene propene rubber Ethylene propylene rubbers (EPR) are elastomers prepared by stereospecific polymerization of ethylene with propylene. The properties of EPR are similar to those of natural rubber. Used as impact modifiers for plastics and in tires. Also called ethylene propylene rubber, EPR, EPM.

ethylene propylene diene monomer rubber See *EPDM rubber*.

ethylene propylene rubber See *ethylene propene rubber*.

ethylene propylene terpolymer A polymer consisting of ethylene, propylene and one component not identified.

ethylene tetrafluoroethylene copolymer Thermoplastic comprised of an alternating copolymer of ethylene and tetrafluoroethylene. Has high impact resistance and good abrasion resistance, chemical resistance, weatherability, and electrical properties, approaching those of fully fluorinated polymers. Retains mechanical properties from cryogenic temperatures to 356°F. Can be molded, extruded, and powder coated. Used in tubing, cable and wire products, valves, pump parts, wraps, and tower packing in aerospace and chemical equipment applications. Also called ETFE.

ethylene vinyl alcohol copolymer EVOH resins are thermoplastics prepared by hydrolysis of ethylene-vinyl acetate copolymers. The resins have excellent gas and vapor barrier properties, high mechanical strength, gloss, elasticity, weatherability, and resistance to solvents and oils. The clarity, surface hardness, and abrasion resistance of EVOH resins are high. They absorb moisture which affects their performance as vapor barriers. The processibility of the resins improves and the absorption of moisture decreases with increasing content of ethylene. Processed by (co)extrusion, coating, blow molding, thermoforming, and film techniques. Used mainly as packaging films and container liners for food and nonfood items. Also called EVOH. Also called EAA

ethylene-acrylic acid copolymer A flexible thermoplastic with water and chemical resistance and barrier properties similar to those of low-density polyethylene and enhanced adhesion, optics, toughness, and hot tack properties, compared to the latter. Contains 3-20% acrylic acid, with density and adhesion to polar substrates increasing with increasing acrylic acid content. FDA-approved for direct contact with food. Processed by extrusion, blow and film methods and extrusion molding, and extrusion coating. Used in rubberlike small parts like pipe caps, hoses, gaskets, gloves, hospital sheeting, diaper liners, and packaging film.

ETO See *ethylene oxide*.

EVOH See *ethylene vinyl alcohol copolymer*.

expandable polyethylene bead See *polyethylene*.

expandable polypropylene bead See *polypropylene*.

expandable polystyrene bead See *polystyrene*.

extenders Relatively inexpensive resin, plasticizer or filler such as carbonate used to reduce cost and/or to improve processing of plastics, rubbers or nonmetallic coatings.

extrusion welding A joining process in which molten thermoplastic material is extruded into a groove in a preheated seam. The extruded thermoplastic material fills the groove and cools, welding the two parts together. Commonly used for joining membranes and pipes with thermoplastic liners.

F

falling dart impact strength See *dart impact energy*.

falling weight impact energy The mean energy of a free-falling dart or weight (tip) that will cause 50% failures after 50 tests to a directly or indirectly stricken specimen. The energy is calculated by multiplying dart mass, gravitational acceleration and drop height. Also called falling weight impact strength, drop weight impact strength, drop dart impact strength.

falling weight impact strength See *falling weight impact energy*.

far field Refers to the distance that ultrasonic energy is transmitted from the horn to the joint interface in ultrasonic welding. Far field welding occurs when the joint is more than 0.25 in. (6.4 mm) from the point at which the horn contacts the part. See also *near field*.

FEP See *fluorinated ethylene propylene copolymer*.

ferromagnetic material Materials such as stainless steel and iron, in which the magnetic moments or dipoles of atoms exhibit a high degree of alignment parallel to each other in the presence of a magnetic field. This alignment is in opposition to the usual tendency of atoms to orient in random directions due to thermal motion. Used in induction welding.

fireproofing agent See *flame retardant*.

fixture In part assembly, a device used to align and support the parts during assembly. Also called a nest. Also called nest.

flame retardant A substance that reduces the flammability of materials such as plastics or textiles in which it is incorporated. There are inorganic flame retardants such as antimony trioxide (Sb_2O_3) and organic flame retardants such as brominated polyols. The mechanisms of flame retardation vary depending on the nature of material and flame retardant. For example, some flame retardants yield a substantial volume of coke on burning, which prevents oxygen from reaching inside the material and blocks further combustion. Also called fireproofing agent.

flame treatment In adhesive bonding, a surface preparation technique in which the plastic is briefly exposed to a flame. Flame treatment oxidizes the surface through a free radical mechanism, introducing hydroxyl, carbonyl, carboxyl, and amide functional groups to a depth of ~4 - 6 nm, and produces chain scissions and some crosslinking. Commonly used for polyolefins, polyacetals, and polyethylene terephthalate, flame treatment increases wettability and interfacial diffusivity.

flash In welding thermoplastics, molten plastic that seeps out of the joint area during the welding process. In molding, surplus plastic attached to the molding along the parting line. Flash must usually be removed before parts are considered to be finished.

flexural properties Properties describing the reaction of physical systems to flexural stress and strain.

flexural strength The maximum stress in the extreme fiber of a specimen loaded to failure in bending. **Note:** Flexural strength is calculated as a function of load, support span and specimen geometry. Also called modulus of rupture, bending strength.

flexural stress The maximum fiber stress in a specimen at a given strain in a bending test. The maximum fiber stress is a function of load, support span, and specimen width and depth. It depends on the method of load application relative to the supports and on the

specimen geometry. It has to be calculated. **Note:** Flexural stress is calculated as a function of load at a given strain or at failure, support span and specimen geometry.

fluorinated ethylene propylene copolymer Thermoplastic copolymer of tetrafluoroethylene and hexafluoropropylene. It has decreased tensile strength, wear resistance, and creep resistance, but good weatherability, low dielectric constant, low flammability, low friction coefficient, and high chemical resistance. The material is useful up to 400°F; above this temperature FEP decomposes, releasing toxic products. The relatively low melt viscosity of FEP allows processing by conventional molding, extrusion, and powder coating. Uses include linings for chemical apparatus and pipes, containers, bearings, films, coatings, electric wires and cables. Also called FEP.

fluoro rubber See *fluoroelastomer*.

fluorocarbon resin See *fluoropolymer*.

fluoroelastomer Fluoroelastomers are a class of synthetic elastomers designed for demanding service applications. They possess excellent resistance to corrosive fluids and other chemicals, as well as to high temperatures. Typical applications include automotive fuel line hoses, o-rings, shaft seals, engine oil and coolant seals, and carburetor fuel pumps. Fluoroelastomers may be used as additives for polyolefins to improve extrusion properties. Also called fluoro rubber.

fluorohydrocarbon resin See *fluoropolymer*.

fluoroplastic See *fluoropolymer*.

fluoropolymer Thermoplastics comprised of mostly polyolefins that have all or some of the hydrogen atoms replaced by fluorine. Characterized by excellent chemical resistance, antifriction properties, thermal stability, antiadhesive properties, low flammability, and weatherability. The disadvantages include low creep resistance and strength and insufficient ease in processing. The properties of fluoropolymers depend on the content of fluorine. The processing is achieved by extrusion and molding. The uses are chemical apparatus, bearings, films, coatings, and containers. Also called polyfluorohydrocarbon, polyfluorocarbon, fluoroplastic, fluorohydrocarbon resin, fluorocarbon resin.

fluorosilicone Synthetic polymers that are partly organic and partly inorganic. Their backbone is made up of alternating silicon and oxygen atoms with trifluoropropyl pendant groups. Most fluorosilicones are rubbers. Also called fluorosiloxane.

fluorosiloxane See *fluorosilicone*.

FMQ See *methylfluorosilicone*.

formula weight See *molecular weight*.

Fourier transform infrared spectroscopy FTIR is a spectroscopic technique in which a sample is irradiated with electromagnetic energy from the infrared region of the electromagnetic spectrum (wavelength ~0.7 to 500 μm). The sample is irradiated with all infrared wavelengths simultaneously, and mathematical manipulation of the Fourier transform is used to produce the absorption spectrum or "fingerprint" of the material. Molecular absorptions in the infrared region are due to rotational and vibrational motion in molecular bonds, such as stretching and bending. FTIR is commonly used for the identification of plastics, additives, and coatings.

fractional melt index resin Thermoplastics having a low melt index of <1. These resins have higher molecular weights and are harder to extrude because of lower rate and greater force

requirements compared to the lower molecular weight resins. They are mainly used for heavy duty applications such as pipe.

free surface energy See *surface tension*.

frequency The number of cycles completed by a periodic quantity in a unit time.

friction welding A welding method for thermoplastics in which friction provides the heat necessary to melt the parts at the joint interface. Friction welding methods include spin welding and vibration welding.

G

gain In ultrasonic welding, the ratio of output amplitude to input amplitude of a horn or booster. See also horn, booster

gamma radiation Ionizing radiation propagated by high-energy protons, e.g., emitted by a nucleus in transition between two energy levels.

general purpose polystyrene General purpose polystyrene is an amorphous thermoplastic prepared by homopolymerization of styrene. It has good tensile and flexural strengths, high light transmission and adequate resistance to water, detergents and inorganic chemicals. It is attacked by hydrocarbons and has a relatively low impact resistance. Processed by injection molding and foam extrusion. Used to manufacture containers, health care items such as pipettes, kitchen and bathroom housewares, stereo and camera parts and foam sheets for food packaging. Also called crystal polystyrene.

generator An electronic device that converts standard 120/240 volt, 50/60 Hz line voltage into high-frequency electrical energy.

glass fiber Glass fibers are a large family of short (staple, chopped, milled) or continuous fiber reinforcement, used widely in both thermosets and thermoplastics for increased strength, dimensional stability, thermal stability, corrosion resistance, and dielectric properties. The fibers are made by the melt drawing of various grades (electric, chemical, high tensile strength) of glass and are comprised of strands of filaments (roving) that can be further processed by size reduction, twisting, or weaving into fabrics or mats. Used in molding compounds, sprayup processes, die molding, layup, and other lamination processes. Glass fibers are often surface modified, e.g., with coupling agents, to improve bonding with polymer matrix or to impart special properties such as electrical conductivity (by coating with nickel). Also called glass roving.

glass filler Glass fillers are a widely used family of fillers in the form of beads, hollow spheres, flakes, or milled particles. They increase dimensional stability, chemical resistance, moisture resistance, and thermal stability of plastics.

glass roving See *glass fiber*.

glycol See *ethylene glycol*.

glycol chlorohydrin See *ethylene chlorohydrin*.

glycol modified polycyclohexylenedimethylene terephthalate Thermoplastic polyester comprising a glycol, cyclohexylenedimethanol, terephthalic acid terpolymer. It exhibits excellent physical properties, chemical resistance and clarity. It has notched Izod strength comparable to that of polycarbonate.

PCTG can be injection molded and film, sheet and tube extruded. It is often alloyed with polycarbonate or filled with glass fibers or mica. Also called PCTG.

graphite fiber See *carbon fiber*.

graphite filler A crystalline form of carbon in powder form. Graphite occurs naturally and also is produced by heating petroleum coke, carbon black, and organic materials. Used as a lubricating filler for nylons and fluoropolymers. Also called powdered graphite, plumbago, graphite powder, carbon graphite, black lead.

graphite powder See *graphite filler*.

grazing See *cracking*.

hard clays Sedimentary rocks composed mainly of fine clay mineral material without natural plasticity, or any compacted or indurated clay.

H

HAZ See *heat affected zone*.

haze The percentage of transmitted light which, in passing through a plastic specimen, deviates from the incident beam via forward scattering more than 2.5 degrees on average (ASTM D883).

HDPE See *high density polyethylene*.

HDT See *heat deflection temperature*.

heat affected zone In welding, the region of the part that is affected by heat used to melt the joining surface. Microstructure of the heat affected zone is an important determinant of the mechanical strength of the weld. Also called HAZ.

heat deflection temperature The temperature at which a material specimen (standard bar) is deflected by a certain degree under specified load. Also called tensile heat distortion temperature, heat distortion temperature, HDT, deflection temperature under load.

heat distortion temperature See *heat deflection temperature*.

heat seal temperature Temperature of a thermoplastic film or sheet required to join two or more films or sheets in contact by fusion.

heat sealing A method of joining plastic films by the simultaneous application of heat and pressure to the areas in contact. Heat can be applied using hot plate welding, dielectric heating, or radio-frequency welding.

heat stability See *thermal stability*.

heated tool welding A method for joining thermoplastic parts in which a hot plate or hot tool is used to provide heat to melt the joining surfaces. The tool is then removed, and the parts are pressed together. While in the molten state, molecular diffusion across the joint interface occurs, and a homogeneous, permanent bond is formed after the parts are allowed to cool. A hot plate is used for flat surfaces and a hot tool in the shape of the joint for irregularly shaped surfaces. Also called fusion bonding, heat sealing, hot shoe welding, butt fusion., hot plate welding.

hermetic seal A seal or weld that is impervious to liquids and air and other gases; airtight.

hexamethylenediamine sebacic acid polymer See *nylon 610*.

high density polyethylene HDPE is a linear polyethylene with density 0.94-0.97 g/cm³, molecular weight 50,000-250,000, and high crystallinity. Produced by co- or homopolymerization in a slurry or gas phase at relatively low pressure and temperature. High-density polyethylene has excellent low temperature toughness, chemical resistance, good dielectric properties, and relatively high softening temperatures, but poor weatherability. The properties improve with decreasing polydispersity. Processed by extrusion, blow molding, injection molding, rotational molding, and powder coating. Used as films and coatings and in housewares, containers, food packaging, liners, cable insulation, profiles, pipes, bottles, and toys. Also called HDPE.

high impact polystyrene See *impact polystyrene*.

high molecular weight low density polyethylene Thermoplastic polyolefin with improved environmental stress crack resistance, impact strength and abrasion resistance but reduced flow processibility and tensile strength. Also called HMWLDPE.

HMWLDPE See *high molecular weight low density polyethylene*.

hold time In welding, the length of time allotted for the melted plastic to solidify. In process engineering, the residence time of an individual ingredient in reaction vessel or other processing apparatus. Also called holding time.

holding load In mechanical fastening, the load required in tensile tests to pull an insert or screw out of the surrounding plastic.

holding time See *hold time*.

hoop stress The tensile or circumferential stress in the wall of a material of cylindrical form subjected to internal or external pressure.

horn An acoustical tool designed to transfer mechanical vibrations from the transducer-booster assembly directly to the parts to be assembled. See also *coupler*.

hot air welding See *hot gas welding*.

hot gas welding A method for joining thermoplastic materials in which the parts are softened by hot gas, usually air, from a welding torch and joined together at the softened points. A filler rod composed of the same material as the part is generally used to fill and consolidate the gap between the parts. Hot gas welding is used for joining and repair of thermoplastic parts and for lap welding of thin sheets. Also called hot air welding.

hot knife sealing A joining process in which a heated tool in the form of a knife blade is passed between the parts being joined, so that heat is applied to the seal side of the part. The blade is then removed, and surfaces are pressed together for a few seconds until the bond solidifies.

hot melt adhesive An adhesive that is applied in a molten state which forms a bond after cooling to a solid state. Acquires adhesive strength through cooling, unlike adhesives that achieve strength through solvent evaporation or chemical cure.

hot plate welding See *heated tool welding*.

hot tack strength The force required to separate a molten seal in heat-sealable thermoplastic films. It determines the rate at which the film can be sealed.

hydrophilic surface Surface of a hydrophilic substance that has a strong ability to bind, adsorb or absorb water; a surface that is readily wettable with water. Hydrophilic substances include carbohydrates such as starch.

hydroxy group See *hydroxyl group*.

hydroxyl group A combination of one atom of hydrogen and one atom of oxygen, -OH, attached by a single covalent bond to another atom, such as carbon, in a molecule of an organic or inorganic substance. It is a characteristic group of alcohols and hydroxides. Hydroxyl groups on the surface of a material usually make it hydrophilic. Hydroxyl groups are quite reactive, e.g., they readily undergo etherification or esterification. Also called hydroxy group.

impact energy The energy required to break a specimen, equal to the difference between the energy in the striking member of the impact apparatus at the instant of impact and the energy remaining after complete fracture of the specimen. Also called impact strength.

impact polystyrene Impact PS are thermoplastics produced by modifying PS with rubber such as butadiene rubber or with butadiene copolymers. Impact PS has good dimensional stability, high rigidity, and good low temperature impact strength, but poor barrier properties, grease resistance, and heat resistance. Processed by extrusion, injection molding, thermoforming, and structural foam molding. Used widely in food packaging, kitchen housewares, toys, small appliances, personal care items, and audio cassettes. Also called styrene rubber plastic, high impact polystyrene.

impact strength The energy required to break a specimen, equal to the difference between the energy in the striking member of the impact apparatus at the instant of impact with the specimen and the energy remaining after complete fracture of the specimen.

impact strength See *impact energy*.

induction welding A technique used for joining plastics and other materials. High frequency, electromagnetic energy is used to excite molecules of a ferromagnetic material placed at the joint interface. The heat generated melts the surrounding thermoplastic matrix, fusing the two parts together. Also called electromagnetic welding. Also called magnetic induction welding, electromagnetic welding.

infrared welding A welding technique in which infrared radiation is used to heat the surfaces of thermoplastic parts to the melting temperature. Flow of molten material across the joint interface allows molecular diffusion and weld formation after cooling. Infrared radiation pertains to the region of the electromagnetic spectrum between visible light and radar. Wavelengths of from 1 to 15 mm (0.000039 to 0.00059 in.) are used in infrared welding.

initial tear resistance The force required to initiate tearing of a flexible plastic film or thin sheeting at very low rates of loading, measured as maximum stress usually found at the onset of tearing.

insert In mechanical fastening, an integral part of a plastic molding consisting of a metal, plastic, or other material that can be molded into the plastic or pressed into position after molding.

interference fit A mechanical fastening method used to join two parts, such as a hub and a shaft, in which the external diameter of the shaft is larger than the internal diameter of the hub. This interference produces high stress in the material and must be determined carefully to avoid exceeding the allowable stress for the material. Stress relaxation can occur in interference fits, causing the joint to loosen over time. Also called press fit.

internal friction Conversion of mechanical strain energy to heat in a material exposed to a fluctuating stress. See also *Coulombic friction*.

iodine treatment In adhesive bonding, a surface preparation technique in which the surface crystallinity of the polymer is changed from the alpha form, in which N-H groups are parallel to the surface, to the beta form, in which the N-H functional groups are perpendicular to the surface. Commonly used for nylon, iodine treatment increases the reactivity of the surface but is not believed to provide sites for mechanical interlocking.

ionizing radiation dose See *radiation dose*.

ionomer Ionomers are thermoplastics containing pendant ionized acid groups which create ionic crosslinks between chains. Usually, only <10% repeating units of ionomers contain ionized groups, whereas polyelectrolytes contain substantially more. A typical commercial representative of this group is ethylene methacrylic acid copolymer sodium salt. The ionomers offer high flex and impact toughness in the temperature range from -160 to +180°F. They have excellent resistance to puncture and to organic solvents, mild acids and bases, and edible oils; high adhesion to paper and other substrates; and good dielectric properties. Many ionomers are FDA approved for food packaging. Some disadvantages of ionomers are poor weatherability, flammability, and high thermal expansion. Processed by injection, blow, and rotational molding; blown and cast film extrusion; and extrusion coating. Used in packaging, shoe soles, auto bumper guards, laminated bags, sporting goods, and foam sheets.

isocyanate resin See *nonelastomeric thermosetting polyurethane*.

isophthalate polyester A thermoset unsaturated polyester based on isophthalic anhydride. Also called isophthalic polyester.

isophthalic polyester See *isophthalate polyester*.

IVN See *Izod impact energy*.

Izod See *Izod impact energy*.

Izod impact energy The energy required to break a v-notched specimen equal to the difference between the energy in the striking member of the impact apparatus at the instant of impact with the specimen and the energy remaining after complete fracture of the specimen. For metals, it is measured according to ASTM E23. Also called notched Izod strength, notched Izod impact strength, Izod v notch impact strength, Izod strength, Izod impact strength, Izod, IVN.

Izod impact strength See *Izod impact energy*.

Izod strength See *Izod impact energy*.

Izod v notch impact strength See *Izod impact energy*.

J

J See *joule*.

jig A device used to hold parts in place and guide the tool during assembly or machining operations.

joint design Molding the shape of mating thermoplastic parts to achieve the intended assembly results.

joint efficiency A numerical value expressed as the ratio of the strength of the joint to the strength of the bulk material.

joule A unit of energy in SI system that is equal to the work done when the point of application of a force of one newton (N) is displaced through distance of one meter (m) in the direction of the force. The dimension of joule is N m. Also called J.

K

ketone resin See *polyketone*.

kinetic coefficient of friction The ratio of tangential force, which is required to sustain motion without acceleration of one surface with respect to another, to the normal force, which presses the two surfaces together.

L

lamella In plastics, the basic morphological unit of a crystalline polymer. Shaped like a thin plate or ribbon. Dimensions are usually approximately 10 nm (0.4 min.) thick, 1mm (40 min.) long, 0.1 mm (4 min.) wide (for ribbon-like shapes).

lap joint A joint in which one adherend is placed partly over the other adherend; overlapped areas are bonded together.

lap shear test See *ASTM D1002*.

laser A device used to produce an intense light beam with a narrow band width. Laser is an acronym for light amplification by stimulated emission of radiation.

laser welding A joining method for thermoplastics in which a high intensity laser beam is used to generate heat at the part surfaces, causing the materials to melt and coalesce.

LCP See *liquid crystal polyester*.

LDPE See *low density polyethylene*.

LIM See *reaction injection molding system*.

LIM system See *reaction injection molding system*.

linear low density polyethylene LLDPE are linear carbon-chain copolymers of ethylene with higher alpha-olefins such as 1 butene and 1 hexene, having density 0.91-0.94 g/cm³. They are prepared

by solution or gas-phase copolymerization. LLDPE have better tensile, tear, and impact strength and crack resistance properties, but poorer haze and gloss than those of low-density polyethylene. LLDPE are processed by extrusion, which requires increased pressure and higher melt temperatures than low-density polyethylene, and molding. Used as films and sheets and in pipes, electrical insulation, liners, bags, and food wraps. Also called LLDPE.

linear polyethylenes Linear polyethylenes are polyolefins with linear carbon chains. They are prepared by copolymerization of ethylene with small amounts of higher alpha-olefins such as 1-butene. Linear polyethylenes are stiff, tough and have good resistance to environmental cracking and low temperatures. Processed by extrusion and molding. Used to manufacture film, bags, containers, liners, profiles and pipe.

liquid crystal polyester Thermoplastics comprised of highly aromatic copolyesters with a highly ordered structure in both melt and solid states. Have very high tensile and flexural strengths at elevated temperatures and are resistant to all chemicals, weathering, radiation, and burning. Processed at high temperatures by sintering and injection molding. Used as ceramic and metal substitutions for electrical components, electronic devices, chemical process equipment, and parts for aerospace, transportation, and safety industry. Also called liquid crystalline polyester, LCP.

liquid crystal polymer Polymers exhibiting a crystalline phase in liquid, e.g., melt, state due to the presence of highly ordered molecular fragments. Also called liquid crystalline thermoplastic, liquid crystalline polymer.

liquid crystalline polyester See *liquid crystal polyester*.

liquid crystalline polymer See *liquid crystal polymer*.

liquid crystalline thermoplastic See *liquid crystal polymer*.

liquid injection molding system See *reaction injection molding system*.

LLDPE See *linear low density polyethylene*.

long glass fiber See *continuous glass fiber*.

low density polyethylene LDPE is a branched carbon-chain polyethylene thermoplastic prepared by homopolymerization of ethylene under high pressure. Its density is 0.91-0.94 g/cm³. It has high toughness, impact strength, flexibility, film transparency, chemical resistance, good dielectric properties, and low water permeability and brittleness temperature. It is susceptible to environmental stress cracking, weathering, burns, and has poor thermal stability. Processed by extrusion coating, injection and blow molding, and film techniques; crosslinkable. Used in packaging and shrink films, bags, laminates, toys, bottle caps, cable insulation, and coatings. Also called LDPE.

M

magnetic induction welding See *induction welding*.

marking In part assembly, the scuffing or marring of a plastic part, which detracts from its cosmetic appearance.

mass density See *density*.

mass spectrometry A method of substance structure analysis based on sending an ionized beam of substance molecules or molecular fragments through a magnetic field to achieve a separation depending on the mass-electric charge ratio of the particles.

maximum diametral interference In interference fit design, the maximum allowable interference for a particular hub and shaft, per unit measurement of shaft diameter. The maximum diametral interference depends on the types of materials used in the hub and shaft and on the ratio of shaft diameter to hub outside diameter. It is determined to ensure that hoop stress in the interference fit does not exceed the allowable stress of materials used in the design.

mechanical fastening A method of joining plastics and / or metals using fasteners such as machine screws, self-tapping screws, inserts, rivets, nuts and bolts, or by molding in interlocking configurations directly into the parts, such as in snap-fits.

mechanical properties Properties describing the reaction of physical systems to stress and strain.

mechanical strain See *strain*.

medium glass fiber See *chopped glass fiber*.

megarad One rad is equivalent to an energy absorption per unit mass of 0.01 joule per kilogram of irradiated material; one megarad is 1E+06 rads. Also called Mrad.

MEK See *butanone 2-*.

MEK peroxide See *methyl ethyl ketone peroxide*.

melt flow index See *melt index*.

melt flow rate See *melt index*.

melt index The amount, in grams, of a thermoplastic polymer which can be forced through an orifice of 0.0825 in. diameter when subjected to a force of 2160 gf in 10 min at 190°C. The test is performed by an extrusion rheometer described in ASTM D1238. Also called MI, MFR, MFI, melt flow rate, melt flow index, base resin melt index.

metal embrittlement See *embrittlement*.

methanol See *methyl alcohol*.

methyl acrylate ethylene polymer See *ethylene methyl acrylate copolymer*.

methyl alcohol An aliphatic alcohol, CH₃OH. A colorless, volatile, flammable liquid. Autoignition point is 464°C. Toxic by ingestion. Derived by catalytic hydrogenation of carbon monoxide, oxidation of natural gas, or gasification of wood. Used as fuel, as solvent for cellulosic and other resins, and in organic synthesis for manufacture of formaldehyde and proteins. Also called methanol.

methyl ethyl ketone See *2-butanone*.

methyl ethyl ketone peroxide (C₈H₁₆O₄) A colorless liquid. A strong oxidizing agent and irritant to skin and tissue. Its TLV is 0.2 ppm in air (ceiling level). Fire hazard in contact with organic materials. Used as a hardening agent for fiber glass reinforced plastics and in the manufacture of acrylic resins. Also called ethyl methyl ketone peroxide. Also called MEK peroxide.

methyl methacrylate (CH₂:C(CH₃)COOCH₃) A colorless, volatile liquid; melts at -48.2°C (-54.8°F) and boils at 101°C (214°F).

Soluble in most organic solvents; slightly soluble in water. Easily polymerized by light, heat, ionizing radiation and chemical catalysts; can be copolymerized by other methacrylate esters or other monomers. Its TLV is 100 ppm in air. It is flammable; explosive limit in air is 2.1 - 12.5%. Derived from oxidation of tert-butyl alcohol first to methacrolein then to methacrylic acid, followed by reaction with methanol, or from reaction of methanol, acetone cyanohydrin and dilute sulfuric acid. Used as a monomer for polymethacrylate and acrylic resins.

methyl methacrylate butadiene styrene terpolymer A thermoplastic comprising a polymer of methyl methacrylate, butadiene and styrene. Also called styrene methyl methacrylate butadiene polymer, styrene butadiene methyl methacrylate polymer, butadiene styrene methyl methacrylate polymer.

methyl methacrylate terpolymer A thermoplastic comprising a polymer of methyl methacrylate with two other unsaturated monomers. Also called MMA terpolymer.

methylene chloride See *dichloromethane*.

methylene oxide See *ethylene oxide*.

methylfluoropolysiloxane See *methylfluorosilicone*.

methylfluorosilicone Thermosetting elastomers designed for demanding service applications. They possess good resistance to corrosive fluids and other chemicals, as well as to high temperatures. Uses include automotive fuel line hoses, gaskets, tubing, and seals. Also called methylfluoropolysiloxane, FMQ.

methylphenylpolysiloxane See *methylphenylsilicone*.

methylphenylsilicone Methylphenylsilicone is a thermosetting elastomer comprised of a siloxane backbone with pendant phenyl and methyl groups. The presence of phenyl groups improves high temperature resistance, oxidation properties, radiation resistance, and compatibility with organic materials. It may be used as a plastics additive or as a flow control agent in polyester coatings. Also called methylphenylpolysiloxane.

methylpolysiloxane See *methylsilicone*.

methylsilicone Methylsilicone is a thermosetting elastomer comprised of a siloxane backbone with pendant methyl groups. It is characterized by excellent thermal stability and good resistance to oxidation. Uses include electrical insulation, heat-resistant paints and varnishes, and protective and decorative finishes. Also called MQ, methylpolysiloxane.

methylvinylfluoropolysiloxane See *methylvinylfluorosilicone*.

methylvinylfluorosilicone Methylvinylfluorosilicone is a thermosetting elastomer comprised of a siloxane backbone with pendant vinyl, methyl, and fluorine groups. Because of the presence of the vinyl group it may be vulcanized to high degrees of crosslinking. It is commonly used in applications where high or low temperatures are encountered and where resistance to fuels or oils is required. Also called methylvinylfluoropolysiloxane.

methylvinylpolysiloxane See *methylvinylsilicone*.

methylvinylsilicone Methylvinylsilicone is a thermosetting elastomer comprised of a siloxane backbone with pendant methyl and vinyl groups. Because of the presence of the vinyl group it can be vulcanized to high degrees of crosslinking. It is generally used in sealants, encapsulants, coatings in construction, automotive cables, gaskets, vending machine tubing, pressure-sensitive adhesives, electrical insulating tapes, and masking tapes. Also called methylvinylpolysiloxane.

methylvinylsilicone methylvinylfluorosilicone alloy A thermosetting elastomer comprising an alloy of methylvinylsilicone and methylvinylfluorosilicone.

MFI See *melt index*.

MFR See *melt index*.

MI See *melt index*.

micron A unit of length equal to 1E-6 meter. Its symbol is Greek small letter mu or mum.

microwave welding A welding technique in which high frequency electromagnetic radiation, usually 2 - 10 GHz, is used to heat a susceptor material placed at the joint interface. Heat conduction from the susceptor to the joint interface melts the thermoplastic parts, and the molten polymers diffuse together, forming a weld after cooling.

migration A mass-transfer process in which the matter moves from one place to another usually in a slow and spontaneous fashion. In plastics and coatings, migration of pigments, fillers, plasticizers and other ingredients via diffusion or floating to the surface or through interface to other materials results in various defects called blooming, chalking, bronzing, flooding, bleeding, etc.

milled glass fiber See *milled glass filler*.

milled glass filler Milled glass fillers are made by hammer milling continuous glass strands. Used as anticrazing reinforcing fillers for adhesives and in plastics. Also called milled glass fiber.

mineral filler Mineral fillers are a large subclass of inorganic fillers comprised of ground rocks or natural or refined minerals. Some fillers, so-called commodity minerals, are relatively inexpensive and are used mostly as extenders. A good example of these is ground limestone. Other fillers, so-called specialty minerals, are usually reinforcing fillers. These are inherently small particle size fillers, such as talc, and surface chemically modified fillers.

MMA terpolymer See *methyl methacrylate terpolymer*.

modified polyphenylene ether Modified PPE are thermoplastic polyphenylene ether alloys with polystyrene, usually high impact. The alloys have high impact strength and improved resistance to heat, fire, and chemicals, compared to polystyrene, but are attacked by organic solvents. Processed by injection molding, extrusion, and structural foam molding. Used in automotive parts, telecommunication devices, and appliances. Also called MPO, modified PPO, modified PPE, modified polyphenylene oxide.

modified polyphenylene ether nylon 6 alloy An thermoplastic alloy of modified polyphenylene ether and nylon 6.

modified polyphenylene oxide See *modified polyphenylene ether*.

modified PPE See *modified polyphenylene ether*.

modified PPO See *modified polyphenylene ether*.

modified PTFE See *polytetrafluoroethylene*.

modulus of elasticity The ratio of unit stress to the unit if deformation of an elastic material below the proportional limit. It gives an indication of a material's stiffness. Also called elasticity constant.

modulus of rupture See *flexural strength*.

molded threaded fastener A fastener or insert, usually metal, that is molded into the part during the molding process. The outside surface can be smooth, knurled, or grooved. The inside surface is threaded to allow insertion of a machine screw.

molded-in insert A method of mechanical fastening in which an insert, usually metal, is molded into one of the parts to be joined. The insert is internally threaded to accept a machine screw, and knurls and grooves on the outer surface of the insert provide pull-out and rotation resistance. Molded-in inserts create high stress in the material around the insert.

molded-in thread A mechanical assembly method in which internal or external threads are molded into plastic parts.

molecular weight The molecular weight (formula weight) is the sum of the atomic weights of all the atoms in a molecule (molecular formula). Also called MW, formula weight, average molecular weight.

MPO See *modified polyphenylene ether*.

MQ See *methylsilicone*.

Mrad See *megarad*.

multilayer film A thermoplastic film consisting of two or more different or similar films jointed together, e.g., by coextrusion or lamination, to attain special properties uncharacteristic for a conventional film.

MW See *molecular weight*.

N

N,N-dimethylformamide (HCON(CH₃)₂) A water-white liquid that boils at 152.8°C (307.0°F). A dipolar, aprotic solvent miscible with water and organic solvents except for halogenated hydrocarbons. Its autoignition temperature is 445°C (833°F). Its TLV is 10 ppm in air; it is toxic by skin absorption. Derived from reaction of methyl formate with dimethylamine. Used as a solvent for vinyl resins, acetylene, butadiene, and acid gases, in polyacrylic fibers, as a carrier for gases, and in organic synthesis. Also called DMF.

N-methyl-2-pyrrolidone (C₅H₉NO) A colorless, combustible liquid with an amine-like odor that boils at 202°C (396°F). Soluble in water, castor oil, various organic solvents. Derived by reaction of acetylene and formaldehyde under high pressure. Used as a solvent for petroleum, acetylene, and resins, a spinning agent for polyvinyl chloride, a pigment dispersant, and a chemical intermediate. Also called NMP.

nanometer A unit of length equal to 1E-9 meter. Often used to denote the wavelength of radiation, especially in UV and visible spectral region. Also called nm.

NBR See *nitrile rubber*.

near field Refers to the distance that ultrasonic energy is transmitted from the horn to the joint interface in ultrasonic welding. Near field welding occurs when the joint is 0.25 in. (6.4 mm) or less from the point at which the horn contacts the part. See also *far field*.

neoprene See *neoprene rubber*.

neoprene rubber Generic name for synthetic rubbers made from polymers of chloroprene. They are noted for their good resistance to oil, solvents, heat, sunlight, ozone, and weathering. Most types may be vulcanized to tough products without the use of sulfur. Also called polychloroprene, neoprene, chloroprene rubber.

nest See *fixture*.

nitrile rubber A synthetic rubber made by random polymerization of acrylonitrile with butadiene by free radical catalysis. The copolymers vary basically in butadiene-acrylonitrile ratios, Mooney viscosities, and staining properties. Typical properties include tensile strength 1000-3000 psi, elongation 100% and maximum service temperature 121-148°C. In addition, they are resistant to oils, solvents, and greases, and to heat and abrasion. Common uses: oil-resistant applications, shoe soles, gaskets, fuel hose, packing oil seals, hydraulic equipment, and adhesives. Also called NBR, acrylonitrile rubber, acrylonitrile butadiene rubber.

nm See *nanometer*.

NMP See *N-methyl-2-pyrrolidone*.

nodal point In ultrasonic welding, the point or points in a booster or horn where little or no linear motion occurs.

noncontact hot tool welding A form of heated tool welding in which parts are placed very near the hot tool but are not in direct contact with it. Heat is transferred to the part surfaces by radiation and convection. The hot tool is removed when melting occurs, and parts are then pressed together for cooling and solidification. Used for high temperature polymers when high melting temperatures prohibit the use of non-stick coatings on the hot tool surface. See also heated tool welding, direct contact hot tool welding

nonelastomeric thermoplastic polyurethane Nonelastomeric thermoplastic PURs are polyisocyanate polyol polymers that are not chemically crosslinked. They have high abrasion resistance, good retention of properties at low temperatures, but poor heat resistance, weatherability, and resistance to solvents. Nonelastomeric PUR are flammable and are made with toxic substances (isocyanates). Processed by injection molding and extrusion. Also called TPUR, rigid thermoplastic urethane, rigid thermoplastic polyurethane, polyurethane, RTPU.

nonelastomeric thermosetting polyurethane Urethane resins are thermosets comprised of polyisocyanate polyol prepolymers or monomer mixtures that can be cured at moderate or ambient temperatures in the presence of catalysts. The resins can be foamed. Cured resins have a wide range of properties including high abrasion resistance, good retention of properties at low temperatures, but poor heat resistance, weatherability, and resistance to solvents. The resins are flammable and are made with toxic substances (isocyanates). Processed by reaction injection molding, various foam techniques, casting, and coating. Used widely in heat insulation, machine parts, potting, encapsulation, electronic housings, and auto body panels and trim. Also called urethane resin, urethane, PUR, PU, polyurethane, isocyanate resin.

nonpolar In molecular structure, a molecule in which positive and negative electrical charges coincide. Most hydrocarbons, such as polyolefins, are nonpolar.

notch effect The effect of the presence of specimen notch or its geometry on the outcome of a test such as an impact strength test of plastics. Notching results in local stresses and accelerates failure in both static and cycling testing (mechanical, ozone cracking, etc.).

notched Izod impact strength See *Izod impact energy*.

notched Izod strength See *Izod impact energy*.

nylon Nylons are thermoplastic, mostly aliphatic polyamides prepared usually either by polymerization of dicarboxylic acid with diamine, or polymerization of amino acid, or ring opening polymerization of lactam. Nylons have good resistance to solvents, bases, and oils; to impact; abrasion; and creep. They have also high tensile strength and barrier properties, and a low coefficient of friction. The disadvantages include high moisture pickup, light degradation, and high mold shrinkage. Processing is achieved by injection, blow, and rotational molding; extrusion; and powder coating. Uses are automotive parts, electrical and electronic devices such as plugs, machine parts such as gears and pumps, housings for appliances and power tools, wire and cable jacketing, pipes, films, and fibers.

nylon 11 Nylon 11 is an aliphatic polyamide thermoplastic prepared by polycondensation of 11-aminoundecanoic acid. It possesses good impact strength, hardness, and abrasion resistance. Very low water absorption of nylon 11 results in high dimensional stability. Other mechanical properties of nylon 11 are lower than those of most other nylons. Relatively low melting point of nylon 11 allows processing by powder coating and rotational molding in addition to extrusion and conventional molding. Uses include electric wire and cable insulation, tubing, mechanical parts, profiles, bearings, and coatings. Also called polyaminoundecanoic acid, polyamide 11, PA 11.

nylon 12 Nylon 12 is an aliphatic polyamide thermoplastic prepared by ring opening polycondensation of lauric lactam (azacyclotridecan-2-one). It has good impact strength, hardness, abrasion resistance, and dimensional stability. Its water absorption and specific gravity are the lowest among nylons. Other mechanical properties of nylon 12 are somewhat inferior. Nylon 12 can be processed by powder coating and rotational molding in addition to extrusion and conventional molding. Uses include sporting goods, automotive parts, and mechanical parts. Also called polyazacyclotridecanone, polyamide 12, PA 12.

nylon 46 Thermoplastic polyamide prepared by copolymerization of 2 and epsilon-caprolactam. Also called polyiminobutanediyliminodioxohexanediyl, polyamide 46, PA 46, caprolactam pyrrolidone polymer.

nylon 6 Nylon 6 is an aliphatic polyamide thermoplastic made by ring opening polycondensation of epsilon-caprolactam. The mechanical properties of nylon 6 are similar to those of nylon 66 but it picks up moisture more rapidly and loses strength more rapidly as moisture content and temperature increase. Nylon 6 has a lower melting point and is somewhat softer and less stiff than nylon 66. Nylon 6 has good weldability. It can be processed by injection, blow, and rotational molding and extrusion. Used for textile fibers, tire cord and molded articles such as machine parts. Also called polycaprolactam, polyamide 6, PA 6.

nylon 610 Nylon 610 is an aliphatic polyamide thermoplastic made by polycondensation of hexamethylenediamine with sebacic acid. It has lower melting point and lower water absorption than nylon 66 or nylon 6. It retains stiffness and mechanical properties better when wet than does nylon 66. Processed by injection molding and extrusion. Used as monofilament in paint brushes. Also called polyhexamethylene sebacamide, polyamide 610, PA 610, hexamethylenediamine sebacic acid polymer.

nylon 612 Nylon 612 is an aliphatic polyamide thermoplastic made by polycondensation of 1,12-dodecanedioic acid with hexamethylenediamine. Nylon 612 has good dimensional stability and low moisture absorption. Its physical and mechanical properties remain stable through a wide humidity range. It is processed by injection molding and extrusion. Uses include wire jacketing, cable sheathing, packaging film, bristles, bushings, and

housings. Also called polyamide 612, PA 612, dodecanedioic acid hexamethylenediamine polymer.

nylon 66 Nylon 66 is an aliphatic polyamide thermoplastic prepared by polycondensation of adipic acid with hexamethylenediamine. It exhibits high tensile strength, elasticity, toughness, and abrasion resistance. Nylon 66 has good solvent resistance but low weatherability and undergoes discoloration in air at elevated temperatures. Good mechanical properties are maintained up to 300°F. Moisture resistance of nylon 66 is fair; moisture acts as plasticizer, increasing flexibility and toughness of the polymer. It is processed by injection molding and extrusion. The major applications are textile fibers, self lubricating bearing parts and gears, rollers and door latches in appliances. Electrical applications are restricted to wire jacketing, due to the ease of polarization. Also called polyhexamethyleneadipamide, polyamide 66, PA 66, adipic acid hexanediamine polymer.

nylon 666 Nylon 6/66 is an adipic acid-caprolactam-hexamethylenediamine polymer thermoplastic. Characterized by high strength, toughness, low friction coefficient, good abrasion and fatigue resistance, adequate dielectric properties, and relatively high moisture absorption and decreased dimensional stability. Processed by injection molding and extrusion. Used in transportation, electrical, and industrial applications. Also called polyamide 666, PA 666.

nylon MXD6 Nylon MXD6 is a poly-m-xylyleneadipamide thermoplastic with lower elongation at break than nylon 6 or 66, low melt viscosity, and good flexural strength and modulus. It resists alkalis and hydrolytic degradation. Also called polyxylyleneadipamide, poly meta xylyleneadipamide.

O

olefinic plastic See *polyolefin*.

olefinic resin See *polyolefin*.

olefinic thermoplastic elastomer Olefinic thermoplastic elastomers are usually continuous blends of EPDM or EPR rubbers with polypropylene or polyethylene, which are sometimes crosslinked. They have low specific gravity, good resistance to weak acids and bases and to polar solvents, excellent dielectric properties, wide range of mechanical properties, and good (re)processability. The negatives include poor oil resistance and flammability. Blended materials have low compression set at elevated temperatures, where as crosslinked materials have good compression set but cost more. Processed by extrusion, injection and blow molding, thermoforming, and calendaring. Applications include automotive parts, building materials (e.g., weather stripping), wire and cable jacketing, and sporting goods. Also called TPO, thermoplastic polyolefin rubber, thermoplastic olefinic rubber, TEO, polyolefin thermoplastic rubber, olefinic TPE, olefinic thermoplastic rubber.

olefinic thermoplastic rubber See *olefinic thermoplastic elastomer*.

olefinic TPE See *olefinic thermoplastic elastomer*.

one-part adhesive An adhesive that does not require a separate hardener or catalyst for bonding to occur. Types of one-part adhesives include UV curing, curing, emulsion, solvent, and water-activated. UV curing adhesives cure only by application of ultraviolet light; other curing one-part adhesives contain an integral catalyst or hardener with a degree of latency, so that cure

at either room temperature or elevated temperature is possible. These curing adhesives must be refrigerated during storage and can have unpredictable curing behavior; examples are a liquid epoxy and dicyandiamide hardener, aerobic adhesives that require oxygen or moisture for activation, or silicone adhesives that require moisture. Emulsion adhesives are thermoplastics or elastomers dispersed in an aqueous phase, such as a copolymer of vinyl acetate and ethylene; one substrate must be permeable to allow escape of water from the system. Solvent adhesives are solutions or pastes of thermoplastics or elastomers in organic or water solvents. Water-activated adhesives, based on starch, cellulose, or protein, are dry powders that must be mixed with water for activation; adhesive strength develops when water is lost, so that usually one substrate must be permeable. See also *two-part adhesive*.

optical properties The effects of a material or medium on light or other electromagnetic radiation passing through it, such as absorption, reflection, etc.

orientation A process of drawing or stretching of as-spun synthetic fibers or hot thermoplastic films to orient polymer molecules in the direction of stretching. The fibers are drawn uniaxially and the films are stretched either uniaxially or biaxially (usually longitudinally or longitudinally and transversely, respectively.) Oriented fibers and films have enhanced mechanical properties. The films will shrink in the direction of stretching, when reheated to the temperature of stretching.

orthophthalate polyester A thermoset unsaturated polyester based on o-phthalic anhydride. Also called orthophthalic polyester.

orthophthalic polyester See *orthophthalate polyester*.

oven stability See *thermal stability*.

oxirane See *ethylene oxide*.

P

PA See *polyamide*.

Pa See *pascal*.

PA 11 See *nylon 11*.

PA 12 See *nylon 12*.

PA 46 See *nylon 46*.

PA 6 See *nylon 6*.

PA 610 See *nylon 610*.

PA 612 See *nylon 612*.

PA 66 See *nylon 66*.

PA 666 See *nylon 666*.

PABM See *polyaminobismaleimide*.

PAI See *polyimide*.

PARA See *polyarylamide*.

particulate filler A material in the form of small particles added to a plastic to alter its physical, mechanical, thermal, electrical, or other properties or to decrease cost. Sometimes used to refer to mineral but not glass particles.

parts per hundred A relative unit of concentration, parts of one substance per 100 parts of another. Parts can be measured by weight, volume, count or any other suitable unit of measure. Used often to denote composition of a blend or mixture, such as plastic, in terms of the parts of a minor ingredient, such as plasticizer, per 100 parts of a major, such as resin. Also called phr.

parts per hundred million A relative unit of concentration, parts of one substance per 100 million parts of another. Parts can be measured by weight, volume, count or any other suitable unit of measure. Used often to denote very small concentration of a substance, such as impurity or toxin, in a medium, such as air. Also called ppm.

parylene Thermoplastics made by vapor-phase polymerization of p-xylene. Hot p-xylene vapors are cooled to condense the monomer and deposit it as a polymer in the form of a thin, uniform coating on a substrate such as paper or fabric.

pascal An SI unit of measurement of pressure equal to the pressure resulting from a force of one newton acting uniformly over an area of one square meter. Used to denote the pressure of gases, vapors or liquids and the strength of solids. Also called Pa.

PBI See *polybenzimidazole*.

PBT See *polybutylene terephthalate*.

PBTR See *polybutylene terephthalate*.

PC See *polycarbonate*.

PCT See *polycyclohexylenedimethylene terephthalate*.

PCTFE See *polychlorotrifluoroethylene*.

PCTG See *glycol modified polycyclohexylenedimethylene terephthalate*.

PDAP See *diallyl phthalate resin*.

PE See *polyethylene*.

PEEK See *polyetheretherketone*.

PEI See *polyetherimide*.

PEK See *polyetherketone*.

perfluoroalkoxy resin Thermoplastic formed by polymerization of perfluoroalkoxyethylene. The material has higher temperature limit (500°F) than fluorinated ethylene-propylene polymer and is similar to polytetrafluoroethylene in chemical resistance. It has low compressive and tensile strengths, but its creep resistance is superior to other fluoropolymers. Processed readily by molding, extrusion, rotational molding, and powder coating. Used as films, coatings, pipes, containers, and linings for chemical apparatus. Also called polyperfluoroalkoxyethylene, PFA, perfluoroalkoxyalkane resin.

perfluoroalkoxyalkane resin See *perfluoroalkoxy resin*.

permittivity loss factor See *dielectric dissipation factor*.

PESV See *polyethersulfone*.

PET See *polyethylene terephthalate*.

PETG See *polycyclohexylenedimethylene ethylene terephthalate*.

PETR See *polyethylene terephthalate*.

PF See *phenolic resin*.

PFA See *perfluoroalkoxy resin*.

phenol formaldehyde resin See *phenolic resin*.

phenolic See *phenolic resin*.

phenolic resin Thermoset phenolics are prepared by reacting phenols with excess or less than the stoichiometric amount of aldehydes such as formaldehyde in the presence of base or acid catalysts to give resole or novolak resins, respectively. The resins are soluble and heat curable. Novolak resins require a bifunctional crosslinking agent, usually diamine, to cure. Uncured or partially cured resins are used as coatings, adhesives, potting compounds, and binders. Cured resins are characterized by good dielectric properties, hardness, thermal stability, rigidity, and compressive strength but poor resistance to bases and oxidizers and dark color. Filled or reinforced phenolic powders can be processed by compression, transfer, or injection molding and extrusion. Molding uses include handles, electrical devices, and automotive parts. Also called phenolic, phenol formaldehyde resin, PF.

phr See *parts per hundred*.

physical adsorption See *adsorption*.

PI See *polyimide*.

piezoelectric material A material, such as ceramic, that changes dimensions when voltage is applied, or produces voltage (electrical potential) when deformed. Used to convert mechanical energy into electrical energy and vice versa.

pitch diameter The average between the major (outside) and minor (root) diameter of a thread. For practical purposes, this diameter is assumed to be equal to the diameter of the smooth shaft prior to threading.

plasma arc treatment In adhesive and solvent bonding, a method for treating the surfaces of parts prior to solvent and adhesive bonding, in which an electrical current between two electrodes in a gas at low pressure excites the gas particles, producing free radicals. Contaminants are stripped from the surface of the part, and wettability is increased by reduction of the contact angle. Also called plasma discharge, plasma treatment. See also *corona discharge treatment*.

plastic See *polymer*.

plasticizer A substance incorporated into a material such as plastic or rubber to increase its softness, processability and flexibility via solvent or lubricating action or by lowering its molecular weight. Plasticizers can lower melt viscosity, improve flow and increase low-temperature resilience of material. Most plasticizers are nonvolatile organic liquids or low-melting-point solids, such as dioctyl phthalate or stearic acid. They have to be non-bleeding, nontoxic and compatible with the material. Sometimes plasticizers play a dual role as stabilizers or crosslinkers.

plumbago See *graphite filler*.

PMMA See *polymethyl methacrylate*.

PMP See *polymethylpentene*.

pneumatic Air-powered, operated, or controlled.

polar In molecular structure, a molecule in which the positive and negative electrical charges are permanently separated. Polar molecules ionize in solution and impart electrical conductivity to the solution. Water, alcohol, and sulfuric acid are polar molecules; carboxyl and hydroxyl are polar functional groups.

poly meta xylylene adipamide See *nylon MXD6*.

polyacrylate See *acrylic resin*.

polyallomer Crystalline thermoplastic block copolymers of ethylene, propylene, and sometimes other unsaturated monomers. Produced by anionic coordination polymerization. Have high impact strength, low density, and flex life.

polyamide Thermoplastic polymers prepared usually by either polymerization of dicarboxylic acid with diamine, or polymerization of amino acid, or ring opening polymerization of lactam. Polyamides are characterized by the presence of backbone amide groups and can be aromatic (aramids) or aliphatic (nylons). Characterized by outstanding mechanical properties, chemical resistance, and antifriction properties. Processed by extrusion and molding. Used as reinforcement and textile fibers, machine parts, and coatings. Also called polyamide resin, polyamide plastic, PA.

polyamide 11 See *nylon 11*.

polyamide 12 See *nylon 12*.

polyamide 46 See *nylon 46*.

polyamide 6 See *nylon 6*.

polyamide 610 See *nylon 610*.

polyamide 612 See *nylon 612*.

polyamide 66 See *nylon 66*.

polyamide 666 See *nylon 666*.

polyamide plastic See *polyamide*.

polyamide polyimide See *polyimide*.

polyamide resin See *polyamide*.

polyamide thermoplastic elastomer These thermoplastic elastomers are mostly copolymers containing soft polyether and hard polyamide blocks. Have improved chemical, abrasion, and thermal resistance and good impact strength and elongation. Processed by extrusion and injection and blow molding. Used in sporting goods, automotive and electrical applications, brushes, and bellows. Also called thermoplastic polyamide rubber, polyamide TPE, polyamide thermoplastic rubber.

polyamide thermoplastic rubber See *polyamide thermoplastic elastomer*.

polyamide TPE See *polyamide thermoplastic elastomer*.

polyamideimide See *polyimide*.

polyaminobismaleimide Polyaminobismaleimide (PABM) resins are thermosets derived from aromatic diamines and bismaleimides, and may be cast and compression or transfer molded. High percentages of fillers may be incorporated. PABMs possess flow properties comparable to common thermosetting resins and thermochemical properties exceeding those of some

light alloys. They are also flame- and radiation-resistant. They may be used for aircraft, electrical/electronic friction, and ablation applications. Also called PABM.

polyaminoundecanoic acid See *nylon 11*.

polyaniline A family of polymers that exists in three different oxidation states at the molecular level: leucoemeraldine (fully reduced), emeraldine (half-oxidized), and pernigraniline (fully oxidized). The polyaniline emeraldine base becomes electrically conductive when doped with aqueous protonic acids, such as HCl. Conductivity is dependent on the morphology of the polyaniline. For high conductivity, polyaniline is spun into fibers with high crystallinity and orientation.

polyaryl ether See *polyphenylene ether*.

polyaryl oxide See *polyphenylene ether*.

polyarylamide Thermoplastic aromatic polyamide prepared by polymerization of aromatic diamine and aromatic diacid or its derivatives (e.g., anhydride). These plastics are characterized by high heat resistance, good retention of mechanical and dielectric properties at elevated temperatures, good dielectric properties, chemical resistance, high stiffness, and low flammability. High crystallinity results in good mechanical properties such as impact strength. Resistance to light is somewhat low. Processing is difficult because of high melting point. Processed by solution casting, molding, and extrusion. Uses include film, fibers, and molded parts requiring good surface finish. Also called PARA, aromatic polyamide, aramid.

polyarylate See *aromatic polyester*.

polyarylene ether See *polyphenylene ether*.

polyarylene oxide See *polyphenylene ether*.

polyarylsulfone Polyarylsulfone is a thermoplastic containing repeating sulfone and ether groups in its wholly aromatic backbone. It has excellent resistance to high and low temperatures, good impact strength, improved resistance to environmental stress cracking, good dielectric properties, rigidity, and resistance to acids and alkalies. Polyarylsulfone is nonflammable, but is attacked by some organic solvents. Processed by injection molding, compression molding, and extrusion. Used in high temperature electrical and electronic applications such as circuit boards and lamp housings, piping, and auto parts.

polyazacyclotridecanone See *nylon 12*.

polybenzimidazole Polybenzimidazole, or PBI, is produced from the condensation of 3,3',4,4'-tetraaminobiphenyl (diaminobenzidine) and diphenyl isophthalate. It is characterized by the high degree of thermal and chemical stability. PBIs are dark brown in color and are used in applications requiring fibers with resistance to high temperatures and flame. Typical uses have been in the aerospace field, as protective coatings and reinforced laminates. Also called PBI.

polybutylene terephthalate PBT is a saturated polyester thermoplastic prepared by transesterification of dimethyl terephthalate with butanediol during melt polycondensation. PBT has good tensile strength, dielectric properties, and chemical resistance, except for resistance to strong bases and halogenated solvents. Water absorption of PBT is very low. The material has a relatively low Izod impact strength and thermal stability, but these can be easily overcome by proper modification. Processed by injection and blow molding, extrusion, and thermoforming. Used in automotive body parts, electrical switches and relays, household appliances, and housings for power tools and various consumer

products. Also called polytetramethylene terephthalate, PBTR, PBT.

polycaprolactam See *nylon 6*.

polycarbodiimide Polymers containing -N=C=N- linkages in the main chain, typically formed by catalyzed polycondensation of polyisocyanates. They are used to prepare open-celled foams with superior thermal stability. Sterically hindered polycarbodiimides are used as hydrolytic stabilizers for polyester-based urethane elastomers.

polycarbonate Polycarbonates are thermoplastics prepared by either phosgenation of dihydric phenols such as bisphenol A or by ester exchange between diaryl carbonate, usually diphenyl carbonate, and dihydric phenol. They are characterized by the presence of repeating carbonyldioxy groups in the backbone, but classified by some as polyesters. They have very good mechanical properties, especially impact strength, low moisture absorption, and good thermal and oxidative stability. They are self-extinguishing and some grades are transparent; but are attacked by strong acids and bases, soluble in organic solvents, and subject to stress cracking. Processed by injection and blow molding, extrusion, thermoforming, but require high processing temperatures. Used in telephone parts, dentures, business machine housings, safety equipment, nonstaining dinnerware, and food packaging. Also called PC.

polycarbonate polyester alloy Thermoplastic alloy of polycarbonate and polyester with improved performance. The impact modified and filled grades available are suitable for injection and blow molding. Uses include automotive parts.

polychloroprene See *neoprene rubber*.

polychlorotrifluoroethylene Thermoplastic prepared by radical polymerization of chlorotrifluoroethylene. It has good transparency and great barrier properties. Dielectric properties and resistance to solvents, especially chlorinated, of CTFE are somewhat lower than those of perfluoropolymers, but tensile strength and creep resistance are higher. Processing is difficult, because of high melt viscosity, but possible by extrusion, injection molding, compression molding, and coating. Uses include chemical apparatus, cryogenic seals, films, and coatings. Also, CTFE spheres are used as fillers and CTFE oil is used as a lubricant in various plastics. Also called PTFCE, PCTFE, CTFE.

polycyclohexylenedimethylene ethylene terephthalate PETG is a thermoplastic polyester prepared by polycondensation of cyclohexylenedimethylenediol, ethylene glycol, and terephthalic acid. Processed by injection and blow molding and shape, tubing, film and sheet extrusion. It is an amorphous, clear polymer having high stiffness and hardness and good toughness even at low temperatures. PETG is FDA approved. Applications include containers for cosmetics and foods, packaging film, medical devices, instrument covers, machine guards and toys. Also called PETG.

polycyclohexylenedimethylene terephthalate PCT is a thermoplastic polyester which can be prepared by polycondensation of cyclohexylenedimethylenediol and terephthalic acid. It is usually filled with glass fiber for high-heat applications. Processed by molding and extrusion. Also called PCT.

polyester A large class of polymers usually made by polycondensation of polyol with polycarboxylic acid or anhydride, or polycondensation of hydroxycarboxylic acid. Polyesters are characterized by the presence of a repeating carbonyloxy group in the backbone and can be aliphatic or aromatic. There are thermosetting polyesters consisting of alkyd resins and unsaturated polymers, and thermoplastic polyesters including

elastomers. The properties, processing techniques, and applications of polyesters vary widely. Also called copolyester.

polyester terephthalate See *terephthalate polyester*.

polyester thermoplastic elastomer These thermoplastic elastomers are mostly copolymers containing soft polyether and hard polyester blocks. They have a broad flexibility/stiffness spectrum, good dielectric strength, chemical resistance, exceptional dynamic performance, superior appearance, good creep resistance, and excellent retention of properties at temperatures ranging from -40 to +300°F, but require protection from ultraviolet radiation. Processed by injection, blow, and rotational molding, extrusion casting, and film blowing. Uses include electrical insulation, medical products, exterior automotive parts, business equipment, and consumer goods. Also called TEEE, polyester TPE, polyester thermoplastic rubber, copolyester TPE, copolyester thermoplastic rubber.

polyester thermoplastic rubber See *polyester thermoplastic elastomer*.

polyester TPE See *polyester thermoplastic elastomer*.

polyestercarbonate See *aromatic polyester estercarbonate*.

polyether polyimide See *polyetherimide*.

polyether polysulfone See *polyethersulfone*.

polyetheretherketone Polyetheretherketone is a partially crystalline thermoplastic containing repeating ether and keto groups in the backbone. Its systematic name is poly(oxy-1,4-phenyleneoxy-1,4-phenylenecarbonyl-1,4-phenylene). PEEK has superb chemical resistance, toughness, rigidity, loadbearing properties, thermal stability, radiation resistance, and very low flammability. Processed readily by injection molding, spinning, cold forming, and extrusion. Used in fibers, films, automotive engine parts, aerospace composites, and wire and cable insulation. Also called PEEK.

polyetherimide Polyetherimides are thermoplastics containing repeating cyclic imide and ether groups in the backbone. They are prepared by cyclopolycondensation of diether dianhydrides such as that of benzoic acid and bisphenol A, and aromatic diamine. Polyetherimides have good chemical resistance, thermal and hydrolytic stability, and good dielectric properties and resistance to creep at elevated temperatures. Processed by extrusion, thermoforming, compression molding, injection molding, blow molding, and film techniques. Used in automotive parts, jet engine components, surgical instruments, industrial fluid and air handling components, food packaging, cookware, and computer disks. Also called polyether polyimide, PEI.

polyetherketone Thermoplastic with excellent high-temperature properties and thermal stability. Used in advanced composites, wire coating, chemical-resistant filters, integrated circuit wafer carriers, and bearings. Synthesized by polyarylation or polyetherization. Also called PEK.

polyethersulfone Polyethersulfone is a thermoplastic containing repeating sulfone and ether groups in its wholly aromatic backbone. It has excellent thermal stability in air and water, good transparency, very low flammability and smoke emission, good dimensional stability, rigidity, and toughness. It has low mold shrinkage and is a good, heat resistant dielectric. Polyethersulfone has good resistance to acids and bases but is attacked by many organic solvents, has poor weatherability, and is subject to stress cracking. Processed by injection molding, extrusion, blow molding, and compression molding; but requires high processing temperatures. Used in high temperature electrical applications such as multipin connectors, bakery oven windows, medical

devices, radomes, structural aircraft components, appliance housings, and auto parts. Also called polyether polysulfone, PESV.

polyethylene A family of polyolefins consisting of linear and branched polyethylenes. Polyethylenes are thermoplastics but can be crosslinked by irradiation or chemically and then show improved strength and dielectric properties. All linear polyethylenes, except the high density grade, are prepared by copolymerization of ethylene with higher olefins. Branched polyethylenes are prepared from ethylene alone or together with polar comonomers such as vinyl acetate. The density, melt index, crystallinity, degree of branching, molecular weight, polydispersity, and related properties of polyethylenes vary widely depending on the catalysts and methods of polymerization and on modifying comonomers and treatments. Polyethylenes have good impact resistance at low temperatures, good chemical resistance, and good moisture resistance, but high thermal expansion, poor weatherability, poor thermal stability and resistance to stress cracking. They are readily processable by all thermoplastic methods but are flammable and difficult to bond. Food grades are available. Processed by extrusion, blow and injection molding, thermoforming. Used very broadly as films, coatings, in containers and consumer goods, electrical insulation, and piping. Also called PE, expandable polyethylene bead, EPE bead.

polyethylene copolymer PE copolymers are thermoplastics prepared by copolymerization of ethylene with other olefins such as propylene. Processed by molding and extrusion.

polyethylene glycol terephthalate See *polyethylene terephthalate*.

polyethylene terephthalate PET is a saturated polyester thermoplastic prepared by polycondensation of ethylene glycol with terephthalic acid or its dimethyl ester. PET is extremely hard, wear resistant, dimensionally stable, resistant to chemicals, and has good dielectric properties. Its tensile strength and thermal stability improve dramatically with increasing crystallinity and orientation. PET is processed by high temperature extrusion, injection and blow molding, melt spinning, and film extrusion. Uses include fiber, FDA approved film for food packaging, beverage bottles, magnetic tapes, photographic films, and food trays. Also called polyethylene glycol terephthalate, PETR, PET.

polyfluorocarbon See *fluoropolymer*.

polyfluorohydrocarbon See *fluoropolymer*.

polyformaldehyde See *acetal resin*.

polyhexamethylene sebacamide See *nylon 610*.

polyhexamethylenedipamide See *nylon 66*.

polyimide Thermoplastic aromatic polyimides (polyamide-imides) are normally made in a two step process by polymerizing trimellitic anhydride with an aromatic diamine to form a polyamic acid containing amide groups in the backbone and pendant carboxyl groups, followed by cyclocondensation of carboxyl and amide groups to form imide groups. They are characterized by superior tensile and compressive strengths at temperatures up to 500°F with good dimensional stability and creep, impact, and chemical resistance. High thermal stability of polyamide imides is complimented by low flammability and good adhesive, dielectric, and barrier properties. On the other hand, polyamide-imides have poor processability, due to their highly viscoelastic behavior in the melt, and poor resistance to alkali. Processing is achieved by compression and injection molding, and various powder sintering, film casting and solution coating techniques. Thermoset polyimides are usually supplied as polyamic acids and require curing at elevated temperatures. The properties of thermoset

polyimides are similar to those of thermoplastic polyimides. Thermoset polyimides have good processability due to their low melt viscosity. They are processed by transfer and injection molding, lamination, and coating. Uses of both thermoset and thermoplastic polyimides include jet engine components, compressor parts, electronic coatings, automotive parts such as seal rings in transmissions, and business machine parts. Also called polyamideimide, polyamide polyimide, PI, PAI, amideimide resin.

polyiminobutanediyliminodioxohexanediyl See *nylon 46*.

polyketone Polyketones are a class of thermoplastics, the most important representatives of which are polyetherketone and polyetheretherketone. Characterized by the presence of repeating keto groups in the backbone. Also called ketone resin.

polymer Polymers are high molecular weight substances with molecules resembling linear, branched, crosslinked, or otherwise shaped chains consisting of repeating molecular groups. Synthetic polymers are prepared by polymerization of one or more monomers. The monomers comprise low-molecular-weight reactive substances, often containing >1 reactive molecular bond or chemical bond. Natural polymers have molecular structures similar to synthetic polymers but are not man made, occur in nature, and have various degrees of purity. Also called synthetic resin, synthetic polymer, resin, plastic.

polymer coated material joining technique This technology involves precoating non-thermoplastic components with a layer of thermoplastic. The components are then joined by welding the plastic coatings together using a plastics welding technique. The mechanical integrity of these joints relies on the bonding between the thermoplastic coating and the non-thermoplastic substrate, and on the strength of the weld between the coatings.

polymethyl methacrylate An acrylic resin that is made by polymerizing the monomer methyl methacrylate. Good optical clarity (92% light transmission), excellent resistance to weathering, good impact strength and electrical properties, non-toxic, tasteless. Powders can be injection molded, extruded, and compression molded. Liquid can be cast into rods, sheets, lenses. Used in airplane canopies, signs, lighting fixtures. Also called PMMA.

polymethylpentene Polymethylpentene is a thermoplastic polyolefin prepared by Ziegler copolymerization of 4-methyl-1-pentene. It has very low density (0.83 g/cm³); high light transmission; high melting point; good rigidity, dielectric, and tensile properties and chemical resistance. Processed by injection molding, extrusion, and blow molding. Used in laboratory ware, extrusion-coated paper, high-intensity light fixtures, automotive parts such as radiator plugs, sight glasses, wire insulation, and small appliances. Also called PMP.

polyolefin Polyolefins are a large class of carbon-chain elastomeric and thermoplastic polymers usually prepared by addition (co)polymerization of olefins or alkenes such as ethylene. The most important representatives of this class are polyethylene and polypropylene. There are branched and linear polyolefins and some contain polar pendant groups or are halogenated. Unmodified polyolefins are characterized by relatively low thermal stability and a nonporous, nonpolar surface with poor adhesive properties. Processed by extrusion, injection molding, blow molding, and rotational molding. Other thermoplastic processes are used less frequently. This class of plastics is used more and has more applications than any other. Also called olefinic resin, olefinic plastic.

polyolefin thermoplastic rubber See *olefinic thermoplastic elastomer*.

polyoxymethylene See *acetal resin*.

polyperfluoroalkoxyethylene See *perfluoroalkoxy resin*.

polyphenylene ether PPE are amorphous thermoplastics containing repeating ether groups in the backbone. They are prepared by oxidative polycondensation of substituted phenols such as 2 and are characterized by a wide range of service temperatures and excellent dielectric properties and resistance to acids and bases. They have outstanding impact and fatigue strength and resistance to radiation and oxidation. They are miscible with polystyrene and other polymers in a wide range of ratios and are used usually in modified or alloyed form. Processed by extrusion and injection molding. Used in automotive parts, battery cases for aerospace use, and appliances. Also called PPO, PPE, polyphenylene oxide, polyarylene oxide, polyarylene ether, polyaryl oxide, polyaryl ether.

polyphenylene ether nylon alloy PPE-nylon alloys are thermoplastics with excellent heat resistance, toughness, and chemical resistance and improved resistance to organic solvents, compared with modified PPE. Processed by molding and extrusion. Used in automotive body panels.

polyphenylene oxide See *polyphenylene ether*.

polyphenylene sulfide PPS is a high-performance engineering thermoplastic. Its linear chains consist of benzene rings para-substituted with sulfur atom links. PPS has excellent thermal stability; good resistance to solvents and chemicals, except for chlorinated hydrocarbons; good radiation resistance; excellent dimensional stability; low water absorption; and good dielectric properties, but somewhat low impact strength. PPS is nonburning. Processing of PPS is hampered by its high melting point and is achieved at elevated temperatures by injection molding, compression molding, transfer molding, and extrusion. Used in hydraulic components, bearings, valves, electronic parts, small appliances such as hair dryers, and under-the-hood automotive parts. Also, PPS spheres are used as fillers in various plastics. Also called polythiophenylene.

polyphenylene sulfide sulfone Thermoplastic with good thermal stability, chemical resistance, and dielectric properties and low flammability and creep. Processed by injection molding. Used in electrical components. Also called polyphenylenesulfidesulfone.

polyphenylenesulfidesulfone See *polyphenylene sulfide sulfone*.

polyphthalamide Thermoplastic aromatic polyamide prepared by polymerization of aromatic diamine and phthalic acid or its derivatives (e.g., anhydride). These plastics are characterized by high heat resistance, good retention of mechanical and dielectric properties at elevated temperatures, good dielectric properties, chemical resistance, high stiffness, and low flammability. High crystallinity results in good mechanical properties such as impact strength. Resistance to light is somewhat low. Processing is difficult because of high melting point. Processed by solution casting, molding, and extrusion. Uses include film, fibers, and molded parts requiring good surface finish. Also called PPA.

polypropylene PP is a carbon chain thermoplastic comprised of propylene homopolymer prepared by stereospecific polymerization in the presence of Ziegler Natta catalysts. The majority of PP is isotactic. PP has low density and good flexibility and resistance to chemicals, abrasion, moisture, and stress cracking, but decreased dimensional stability, mechanical strength, and resistance to UV light and heat. PP is flammable. Processed by injection molding, spinning, extrusion, and film techniques. Used as films for pressure sensitive tapes, packaging, liners, and shrink films, and as fibers in textiles. Also called PP homopolymer, PP, polypropylene homopolymer, expandable polypropylene bead, EPP bead.

polypropylene homopolymer See *polypropylene*.

polypyrrole A polymer of pyrrole, a five-membered heterocyclic substance with one nitrogen and four carbon atoms and with two double bonds. The polymer can be prepared via electrochemical polymerization. Polymers thus prepared are doped by electrolyte anion and are electrically conductive. Polypyrrole is used in lightweight secondary batteries, as electromagnetic interference shielding, anodic coatings, photoconductors, solar cells, and transistors.

polysiloxane See *silicone*.

polystyrene Polystyrene is a thermoplastic produced by homopolymerization of styrene. It has good rigidity, high dimensional stability, low moisture absorption, optical clarity, high gloss, and good dielectric properties. On the other hand, it is flammable, has poor impact strength and resistance to solvents, heat, UV radiation, and chemicals. Processed by injection molding, extrusion, compression molding, and foam molding. Used widely in medical devices, household items such as cutlery handles and housewares, food packaging, electronics, and foam insulation. Also called polystyrol, expandable polystyrene bead, EPS bead, crystal polystyrene.

polystyrol See *polystyrene*.

polysulfide Polysulfides is a large class of polymers containing repeating thio linkages in the aromatic, alicyclic, or aliphatic backbone. The most important families of polysulfides are polythiophenylenes and sulfide rubber. The former resemble polyethers with sulfur substituting oxygen, whereas the latter has usually a series of connected sulfur atoms in the repeating unit.

polysulfide adhesive Flexible, one- or two-part adhesives that cure by a crosslinking reaction. Also called sulfide adhesive.

polysulfone Polysulfones are a class of thermoplastics characterized by the presence of sulfone linkages in their repeating units. Most polysulfones are aromatic and also contain ether linkages to enhance oxidation resistance. The most important of those are polyarylsulfone and polyethersulfone. As a class, polysulfones show excellent thermal stability, low creep, good dielectric properties, transparency, self extinguishing properties, and resistance to chemicals, but are attacked by many solvents, have poor weatherability, are subject to stress cracking, and require high processing temperatures. Processed by injection molding, compression molding, blow molding, and extrusion. Used in appliances, electronics, automotive parts, and electric insulators. A high-performance engineering thermoplastic, called polysulfone in the trade, consists of diaryl sulfone groups linked by oxygen atoms and shares many properties typical for its class. It has good rigidity at elevated temperatures, good impact strength, and resists alkalies and acids but is attacked by polar solvents. Used for medical devices, in food processing equipment, electronics, chemical apparatus, and battery cells. Also called PSU, PSO.

polytetrafluoroethylene Thermoplastic prepared by radical polymerization of tetrafluoroethylene. It has low dielectric constant, superior chemical resistance, very high thermal stability, low friction coefficient, excellent antiadhesive properties, low flammability, and high weatherability. Impact resistance of PTFE is high, but permeability is also high whereas strength and creep resistance are relatively low. The very high melt viscosity of PTFE restricts its processing to sinter molding and powder coating. Uses include coatings for cooking utensils, chemical apparatus, electrical and nonstick items, bearings, containers. Also, PTFE spheres are used as fillers and PTFE oil is used as a lubricant in various plastics. Also called TFE, PTFE, modified PTFE.

polytetramethylene terephthalate See *polybutylene terephthalate*.

polythiophenylene See *polyphenylene sulfide*.

polyurethane Polyurethanes (PU) are a large class of polymers, the backbone of which consists of repeating units containing urethane group. PU are usually prepared by interfacial polycondensation of polyisocyanates with polyols. The latter may be based on polyesters or polyethers or both. The most important members of this class are urethane rubbers, nonelastomeric thermoplastic PU, urethane thermoplastic elastomers, and thermoset urethane resins. PU may be rigid or soft and flexible, cellular or solid and offer a wide range of properties depending on composition and molecular structure. In general they have high abrasion resistance, good retention of properties at low temperatures, and good foamability, but poor heat resistance, weatherability, and resistance to solvents. PU are flammable and are made with toxic substances (isocyanates). Nonelastomeric thermoplastic PU are not chemically crosslinked and are processed by injection molding and extrusion. Thermoset PU can be cured at moderate and ambient temperatures and give foams with good heat insulating properties. They are processed mainly by reaction injection molding, various foam techniques, casting, and coating. PU are used in load bearing rollers and wheels, acoustic clamping materials, sporting goods, seals and gaskets, rigid and flexible foams for heat insulation and other uses, potting, and encapsulation. Also called urethane polymer. See also *nonelastomeric thermosetting polyurethane*.

polyurethane adhesive One- or two-part adhesives that cure by a polymerization reaction to form temperature resistant bonds that are both rigid and flexible.

polyurethane thermoplastic rubber See *urethane thermoplastic elastomer*.

polyurethane TPE See *urethane thermoplastic elastomer*.

polyvinyl chloride PVC is a thermoplastic prepared by free-radical polymerization of vinyl chloride in dispersion (emulsion), bulk, or suspension processes. A small amount of comonomer is sometimes added to enhance adhesion or other properties. Unmodified PVC is rigid and requires plasticizers to make it more flexible. The main end forms of PVC are rigid and flexible. The flexible form is often made from plastisols, suspensions of PVC in liquid plasticizers. PVC can be chlorinated to increase its heat deflection temperature and tensile strength and to reduce flammability and smoke generation. PVC is dimensionally stable, largely nonflammable, and resistant to weathering, but has limited thermal stability, high density, and is attacked by many solvents. Processed by injection molding, calendaring, extrusion, powder coating, blow molding, extrusion coating, and film techniques. Used very widely as films, fabric coatings, wire coatings, toys, bottles, and pipes. Also called PVC.

polyvinyl dichloride See *polyvinylidene chloride*.

polyvinyl fluoride Polyvinyl fluoride, commercially available only as a film, is a highly crystalline material with high toughness, high flexibility, outstanding weathering resistance, and good abrasion resistance. Useful properties are maintained over a temperature range of -94 to 230°F. PVF is used for packaging, glazing, and electrical applications. Also called PVF.

polyvinylidene chloride A stereoregular, thermoplastic polymer derived by the polymerization of vinylidene chloride or copolymerization of vinylidene chloride with lesser amounts of other unsaturated compounds. This polymer is resistant to abrasion and chemical attack, impermeable to flavor, and possesses low vapor transmission properties. Uses include packaging for food, insecticide-impregnated multiwall paper bags, pipes for chemical processing equipment, seat covers, upholstery, fibers, bristles, and latex coatings. Also called PVDC, polyvinyl dichloride.

polyvinylidene fluoride Thermoplastic prepared from vinylidene fluoride. It has substantially higher strength, wear resistance, and creep resistance than other fluoropolymers but relatively high dielectric constant and loss factor. PVDF is nonflammable, resists most solvents, and has excellent weatherability. Its service temperature limit and chemical resistance are lower than those of perfluoropolymers. PVDF is processed readily by extrusion, injection molding, transfer molding, and powder or dispersion coating. Uses include electrical insulation, pipes, chemical apparatus, coatings, films, containers, and fibers. Also called VF2, PVF2, PVDF.

polyxylylene adipamide See *nylon MXD6*.

POM See *acetal resin*.

powdered carbon See *carbon filler*.

powdered graphite See *graphite filler*.

PP See *polypropylene*.

PP homopolymer See *polypropylene*.

PPA See *polyphthalamide*.

PPE See *polyphenylene ether*.

pphm See *parts per hundred million*.

ppm A unit for measuring small concentrations of material or substance as the number of its parts (arbitrary quantity) per million parts of medium consisting of another material or substance.

PPO See *polyphenylene ether*.

press fit See *interference fit*.

pressure sensitive adhesive An adhesive that requires applied pressure on the parts for bonding to occur. Usually composed of a rubbery elastomer and modifying tackifier, pressure sensitive adhesives are applied to the parts as solvent-based adhesives or hot melts; curing does not usually occur. They adhere tenaciously under slight pressure and are highly thixotropic. Disadvantages include limited temperature capability and susceptibility to oxidative degradation. See also *contact sensitive adhesive*.

primer In adhesive bonding, a reactive chemical species dispersed in a solvent that is applied to the part surface by spraying or brushing. After the solvent is flashed off, the part surface may be bonded immediately, as in polyolefin primers for cyanoacrylates, or may require time to react with atmospheric moisture, as in silane and isocyanate-based primers used for silicone and polyurethane-based adhesives, respectively. Primers generally contain a multifunctional chemically reactive species capable of acting as a chemical bridge between the substrate and the adhesive. Primers are commonly used with acetals, fluoropolymers, polybutylene terephthalate, silicone, polyurethane, and polyolefins. In coatings, coatings applied on a substrate prior to subsequent coatings or topcoat in order to seal the pores, improve adhesion of the topcoat, improve corrosion protection, hide surface imperfections or color, etc. Usually based on polymers with functional additives. Applied by the same techniques as coatings. Also called primer coating.

primer coating See *primer*.

process time See *processing time*.

processing agents Agents or media used in the manufacture, preparation and treatment of a material or article to improve its processing or properties. The agents often become a part of the material.

processing defects Structural and other defects in material or article induced inadvertently during manufacturing, preparation and treatment processes by using wrong tooling, process parameters, ingredients, part design, etc. Usually preventable. Also called processing flaw.

processing flaw See *processing defects*.

processing methods Method names and designations for material or article manufacturing, preparation and treatment processes.
Note: Both common and standardized names are used.

processing parameters Measurable parameters such as temperature prescribed or maintained during material or article manufacture, preparation and treatment processes.

processing time Time required for the completion of a process in the manufacture, preparation and treatment of a material or article. Also called recommended processing time, process time.

promoter See *accelerator*.

propene See *propylene*.

propylene An alkene (unsaturated aliphatic hydrocarbon) with three carbon atoms, $\text{CH}_2=\text{CHCH}_3$. A colorless, highly flammable gas. Autoignition temperature 497°C. Derived by thermal cracking of ethylene or from naphtha. Used as monomer in polymer and organic synthesis. Also called propene.

PSO See *polysulfone*.

PSU See *polysulfone*.

PTFCE See *polychlorotrifluoroethylene*.

PTFE See *polytetrafluoroethylene*.

PU See *nonelastomeric thermosetting polyurethane*.

PU TPE See *urethane thermoplastic elastomer*.

pullout strength The resistance of a screw or insert to forces that tend to pull it out of the part or boss.

pulp See *cellulose*.

PUR See *nonelastomeric thermosetting polyurethane*.

PUR TPE See *urethane thermoplastic elastomer*.

PVC See *polyvinyl chloride*.

PVD See *chlorinated polyvinyl chloride*.

PVDC See *polyvinylidene chloride*.

PVDF See *polyvinylidene fluoride*.

PVF See *polyvinyl fluoride*.

PVF2 See *polyvinylidene fluoride*.

R

radiation dosage See *radiation dose*.

radiation dose Amount of ionizing radiation energy received or absorbed by the material during exposure. Also called radiation dosage, ionizing radiation dose. See also *conduction, convection*.

radiation resistant materials Materials that resist degradation on long- and medium-term or repeated exposure to ionizing radiation, e.g., steel grades designed for nuclear reactors. Radiation damage to materials includes swelling, radiolysis, blistering, changes in electrical and mechanical properties, etc. There are different mechanisms of radiation damage but most can be linked to free-radical reactions. The resistance of materials to radiation can be improved by stabilizing them with agents that can neutralize free radicals, such as dimethyl sulfoxide, carbohydrates and various reducing agents. Also called radiation stabilized material.

radiation stabilized material See *radiation resistant materials*.

radio frequency welding A method of welding thermoplastics that uses a radio-frequency electromagnetic field. (usually 27.1 MHz) to apply the necessary heat. The radio-frequency field is usually applied with a metal die in the shape of the joint, causing an increase in molecular motion in the region of the joint and an increase in temperature that generates heat in the parts being joined. The parts melt in the joint region, allowing molecular diffusion across the joint interface and weld formation after cooling. Commonly used for sealing polar plastic sheets and films. Also called high frequency welding or heat sealing. Also called RF welding.

reaction injection molding system Reaction-injection molding systems are liquid compositions based on thermoset resins, prepolymers, monomers, or mixtures thereof. The components of the systems are mixed together at a given ratio and then poured into a mold under pressure wherein they polymerize and cure at elevated temperatures to form a molded part. The majority of RIM systems are based on polyurethanes or polyurethane-polyurea hybrids. They are used to produce solid or integral skin flexible foam moldings. The solid moldings are elastomeric with a high or low modulus. The low-modulus moldings are used as automobile fascia, bumper covers, and trim. The high-modulus moldings are used in large industrial and consumer parts. Either can be reinforced with fillers to improve the flexural modulus, thermal properties, and dimensional stability. The foam moldings are used as steering wheels, armrests, and protective automotive covers. Other RIM systems are based on polyureas, polyisocyanurates, nylons, acrylamate resins, or polydicyclopentadiene. Also called RIM system, RIM, liquid injection molding system, LIM system, LIM.

recommended processing time See *processing time*.

relative humidity The ratio of the actual vapor pressure of the air to the saturation vapor pressure. Also called RH.

relative viscosity The ratio of solution viscosity to the viscosity of the solvent. Also called viscosity ratio, RV.

replaceable tip In ultrasonic welding, a machined titanium forming tool threaded to attach to a horn. Commonly used in ultrasonic staking and spot welding.

resin See *polymer*.

resistance to cracking See *cracking*.

resistance to tear propagation See *tear propagation resistance*.

resistance welding A method for joining plastics, composites, and metals in which heat is generated by application of an electric current to a conductive heating element placed at the joint interface. Thermoplastic material at the joint interface melts and fuses, forming a weld. Thermosets, composites, and metals require a thermoplastic interlayer for bonding. The conductive heating element is usually stainless steel or carbon fiber prepreg and remains in the joint after welding.

resorcinol modified phenolic resin A phenolic resin which has been modified by the addition of resorcinol. This thermosetting resin is commonly used in applications that require good heat resistance, dimensional stability, and creep resistance. Also called resorcinol phenolic resin.

resorcinol phenolic resin See *resorcinol modified phenolic resin*.

RF welding See *radio frequency welding*.

RH See *relative humidity*.

rigid thermoplastic polyurethane See *nonelastomeric thermoplastic polyurethane*.

rigid thermoplastic polyurethanes Rigid thermoplastic polyurethanes are not chemically crosslinked. They have high abrasion resistance, good retention of properties at low temperatures, but poor heat resistance, weatherability and resistance to solvents. Rigid thermoplastic polyurethanes are flammable and can release toxic substances. Processed by injection molding and extrusion.

rigid thermoplastic urethane See *nonelastomeric thermoplastic polyurethane*.

RIM See *reaction injection molding system*.

RIM system See *reaction injection molding system*.

riveting An assembly process in which a short rod with a head on one side is inserted into a preformed hole in two or more parts. The straight end is then pressed or hammered in order to form another head.

Rockwell A See *Rockwell hardness*.

Rockwell E See *Rockwell hardness*.

Rockwell hardness A number derived from the net increase in the depth of impression as the load on an indenter is increased from a fixed minor load (10 kgf) to a major load and then returned to the minor load. This number consists of the number of scale divisions (each corresponding to 0.002 mm vertical movement of the indenter) and scale symbol. Rockwell scales, designated by a single capital letter of English alphabet, vary depending on the diameter of the indenter and the major load. For example, scale A indicates the use of a diamond indenter and major load 60 kgf, E - 1/8" ball indenter and 100 kgf, K - same ball and 150 kgf, M - 1/4" ball and 100 kgf, R - 1/2" ball and 60 kgf. The hardness increases in the order of R, M, K, E, and A scales. Also called Rockwell R, Rockwell M, Rockwell K, Rockwell E, Rockwell A.

Rockwell K See *Rockwell hardness*.

Rockwell M See *Rockwell hardness*.

Rockwell R See *Rockwell hardness*.

room temperature vulcanizing silicone Silicone that is vulcanized or cured at room temperature by a chemical reaction.

Room temperature vulcanizing is commonly used for silicones and other thermoset elastomers. Also called RTV silicone.

rotational welding See *spin welding*.

RTV silicone See *room temperature vulcanizing silicone*.

rubber See *thermosetting elastomer*.

RV See *relative viscosity*.

S

SAN See *styrene acrylonitrile copolymer*.

satining In adhesive and solvent bonding, a chemical etching process in which a mildly acidic solution is used to produce uniform anchor points on a part surface. Finishes, cements, or adhesives then bond to the anchor points, resulting in strong adhesion. Developed by DuPont for Delrin Acetal.

scan welding See *ultrasonic scan welding*.

seal initiation temperature The lower limit of a heat-seal temperature range at which a thermoplastic material such as film is beginning to fuse and adhere to itself or other thermoplastic materials.

seating torque A level of torque below the stripping torque at which clamp force is optimized. Seating torque is generally 50-75% of the stripping torque. High seating torques are preferred. See also *seating torque*.

secant modulus The slope of a line drawn from the origin to a point on the stress-strain curve for a material that corresponds to a particular strain. Used in designing parts subjected to short-term, infrequent, intermittent stress for plastics in which the stress-strain curve is nonlinear.

self-reinforcing plastics Plastics with densely packed, fibrous polymer chains. Liquid crystal polymers are called self-reinforcing plastics.

self-tapping screw A method of mechanically fastening two plastic parts together in which screws inserted into a pilot hole form mating threads in the plastic part. Self-tapping screws can be either thread-forming or thread-cutting. See also *thread forming screw*, *thread cutting screw*.

shear joint A joint design used in welding in which the thermoplastic parts melt in a telescoping action due to a small interference in one of the mating parts.

shelf life Time during which a physical system such as material retains its storage stability under specified conditions. Also called storage life.

Shore A See *Shore hardness*.

Shore D See *Shore hardness*.

Shore hardness Indentation hardness of a material as determined by the depth of an indentation made with an indenter of the Shore-type durometer. The scale reading on this durometer is from 0, corresponding to 0.100" depth, to 100 for zero depth. The Shore A indenter has a sharp point, is spring-loaded to 822 gf, and is used for softer plastics. The Shore B indenter has a blunt point, is

spring-loaded to 10 lbf, and is used for harder plastics. Also called Shore D, Shore A.

short glass fiber See *chopped glass fiber*.

SI See *silicone*.

silicone Silicones are polymers, the backbone of which consists of alternating silicon and oxygen atoms. Pendant organic groups are attached to silicon atoms. They are usually made by hydrolyzing chlorosilanes, followed by polycondensation and crosslinking. Depending on the degree of crosslinking and the nature of pendant groups, silicones can be liquid, elastomeric, or rigid. Liquid silicones or silicone fluids such as dimethylsiloxane have very good antiadhesive properties, lubricity, resistance to heat and chemicals and are used as release agents, surfactants, and lubricants in plastics. As lubricants they improve wear resistance of plastics. Silicone elastomers, or rubbers, have high adhesion, resistance to compression set, flexibility, good dielectric properties, weatherability, low flammability, good moisture barrier properties, and thermal stability, but somewhat low strength. Optically clear grades are available. Processed by coating and injection molding. Used as optical fiber coatings, electronic connector encapsulants, printed circuit board coatings, seals, diaphragms, fabric coatings, medical products, adhesives, sealants, and glazing compounds. Rigid silicone resins offer good flexibility, weatherability, dirt release properties, dimensional stability, and are stronger and harder than silicone rubbers. The resins are attacked by halogenated solvents. Processed by coating, casting, injection molding, compression molding, and transfer molding. Used as coatings, adhesives, sealants, bonding agents, and molded parts. Also called siloxane, silicone rubber, silicone plastic, silicone fluid, SI, polysiloxane.

silicone fluid See *silicone*.

silicone plastic See *silicone*.

silicone rubber See *silicone*.

siloxane See *silicone*.

sink mark A shallow depression on the surface of an injection molded part. Usually caused by collapse of the part surface following local internal shrinkage after the gate seals. Frequently occurs on the part face opposite to a face in which the section thickness increases, as in a rib. Also called shrink mark, heat mark.

sliding velocity The relative speed of movement of one body against the surface of another body (counterbody) without the loss of contact as in a sliding motion during wear and friction testing of materials. In the sliding motion, the velocity vectors of the body and the counterbody remain parallel and should be unequal if they have the same direction.

SMA See *styrene maleic anhydride copolymer*.

snap fit A method of mechanical fastening in which two plastic parts are joined by an interlocking configuration that is molded directly into the parts. A protrusion molded into one part, such as a hook or bead, is briefly deflected during assembly and engages a depression or undercut molded into the other part. The joint is usually stress-free after joining. Snap-fit design is important in proper functioning of the snap-fit. Cantilever snap-fits are the most common; other types of snap-fits include annular and torsional.

snap-on connection A type of snap-fit connection in which one part is snapped onto another part, such as a lid on a container. Usually used with rounded parts.

sodium treatment In adhesive bonding, a surface preparation technique in which the substrate is immersed in an aggressive etching solution containing either a sodium-naphthalene complex dissolved in tetrahydrofuran or a sodium-ammonia complex dissolved in ammonia. This process increases surface roughness and the potential for mechanical interlocking by dissolving the amorphous regions of the part surface and increases surface reactivity and wettability by introducing carbonyl and carboxyl functional groups and unsaturated bonds. Sodium treatment darkens the part surface to a depth of 1 nm and can substantially degrade the surface after extended exposure. Commonly used for fluorocarbons.

solubility The solubility of a substance is the maximum concentration of a compound in a binary mixture at a given temperature forming a homogeneous solution. Also called dissolving capacity.

solubility coefficient The volume of a gas that can be dissolved by a unit volume of solvent at a fixed pressure and temperature.

solubility parameter Solubility parameter characterizes the capacity of a substance to be dissolved in another substance, e.g., of a polymer in a solvent. It represents the cohesive energy of molecules in a substance and determines the magnitude and the sign of the heat of mixing two substances in given concentrations. The magnitude and the sign of the heat of mixing determine the sign of the free energy of mixing. The solution occurs when the sign of the free energy of mixing is negative.

solvent bonding A method of joining two thermoplastics by application of a solvent to soften the part surfaces. Softening the polymer increases the movement of polymer chains, allowing them to intermingle at the joint interface. Adhesion occurs after solvent evaporation. Solvent application must be carefully controlled for optimal joint strength and to avoid damage to the part. Also called solvent fusion.

solvent fusion See *solvent bonding*.

spherulite In plastics, a rounded aggregate of radiating lamellar crystals with amorphous material between the crystals. Has the appearance of a pom-pom. Spherulites exist in most crystalline plastics and usually impinge on one another to form polyhedrons. Range in size from a few tenths of a micron in diameter to several millimeters.

spin welding A method used for joining cylindrical thermoplastic parts. Frictional heat develops as one part spins against the other, stationary part, resulting in melting at the joint interface. Spinning is then stopped, and the parts are held together under pressure until cool. Also called friction welding. Also called rotational welding. See also *vibration welding*.

stability Resistance to degradation or deterioration from any of a number of conditions (heat, moisture, exposure to chemicals, prolonged storage, etc.) Also called durability. See also *stability*.

staking In part assembly, a process in which a thermoplastic stud protruding out of the parts being joined is made to soften and flow, forming a head that locks the parts together. Flow can occur as a result of heat or pressure. An alternate form of staking occurs when a thermoplastic is forced to cold flow around a metal insert placed into a plastic boss, locking the insert in place.

static coefficient of friction The ratio of the force that is required to start the friction motion of one surface against another to the force, usually gravitational, acting perpendicular to the two surfaces in contact.

steric hindrance A spatial arrangement of the atoms of a molecule that blocks a reaction of the molecule with another molecule.

storage life See *shelf life*.

strain The per unit change, due to force, in the size or shape of a body referred to its original size or shape. **Note:** Strain is nondimensional but is often expressed in unit of length per unit of length or percent. Also called mechanical strain.

stress cracking Appearance of external and/or internal cracks in the material as a result of stress that is lower than its short-term strength.

stress decrease See *stress relaxation*.

stress relaxation Time-dependent decrease in stress in a solid material as a result of changes in internal or external conditions. Also called stress decrease.

strip-to-drive ratio The ratio of stripping torque to driving torque of a self-tapping screw. A high strip-to-drive ratio provides easier assembly and a higher safety factor.

stripping torque The torque at which threads are stripped out of the molded part. High stripping torques are optimal. See also *seating torque*.

styrene ($C_6H_5CH:CH_2$) A colorless, oily liquid with a strong odor. Boils at 145.2°C (293.4°F); freezes at -30.63°C (-23.13°F). Soluble in alcohol and ether; insoluble in water. Polymerizes rapidly when exposed to heat, light, or a peroxide catalyst; polymerization may become explosive. Toxic by ingestion and inhalation; its TLV is 50 ppm in air. Moderate fire risk; autoignition temperature is 490°C (914°F); explosive limit in air is 1.1 - 6.1%. Derived from reaction of ethylene and benzene in the presence of aluminum chloride to form ethylbenzene, followed by catalytic dehydrogenation at 630°C (1166°F). Used in the production of polystyrene, styrene-butadiene rubber (SBR), acrylonitrile-butadiene-styrene (ABS), and styrene-acrylonitrile (SAN) resins; copolymers, rubber-modified polystyrene, styrenated polyesters, and protective coatings. Also called vinylbenzene, phenylethylene.

styrene acrylonitrile copolymer Thermoplastic copolymers of about 70% styrene and 30% acrylonitrile with higher strength, rigidity, and chemical resistance than polystyrene. Characterized by transparency, high heat deflection properties, excellent gloss, hardness, and dimensional stability. Have low continuous service temperature (185°F) and impact strength. Processing is accomplished by injection molding, extrusion, injection-blow molding, and compression molding. Used in appliances (refrigerator shelves), housewares, instrument lenses for automobiles, medical devices, and electronics (cassette parts). Also called SAN.

styrene butadiene block copolymer This thermoplastic block polymer is amorphous and is composed of alternating block structures of butadiene and styrene. The butadiene blocks impart toughness and impact resistance to the plastic. The styrene blocks provide thermoplasticity, rigidity, high gloss, and compatibility with other styrenic resins. These polymers exhibit low gel content, water absorption, and mold shrinkage, as well as ease of processing. They may be used in food and drink containers, display containers, toy parts, blister packs, and shrink wrap. Also called styrene butadiene block polymer, butadiene styrene block polymer.

styrene butadiene block polymer See *styrene butadiene block copolymer*.

styrene butadiene copolymer A family of thermoplastic copolymers that are comprised of over 50% styrene. They are

transparent, have high toughness, are easily processed, and have a low cost. They can be processed by sheet extrusion, injection molding, thermoforming, and blow molding, typically at temperatures between 380 and 450°F. When blended with general purpose polystyrene, applications include disposable packaging, blister packs, and other display packaging. Molded applications include medical devices, parts for toys, display boxes and racks, and office articles. Film applications include wraps.

styrene butadiene methyl methacrylate polymer See *methyl methacrylate butadiene styrene terpolymer*.

styrene maleic anhydride copolymer SMA copolymers are thermoplastics prepared by copolymerization of styrene with maleic anhydride. Using butadiene as a third monomer or alloying with ABS results in impact versions of SMA. SMA have high thermal stability and good adhesion, but limited chemical resistance and resistance to UV light. Impact SMA have good impact strength. Processed by injection molding, extrusion, and foam molding. Used in automotive parts such as consoles, small appliances, door panels, pump components, and business machines. Also called SMA.

styrene maleic anhydride copolymer PBT alloy Thermoplastic alloys of styrene-maleic anhydride copolymer with polybutylene terephthalate with improved dimensional stability and tensile strength. Processed by injection molding.

styrene maleic anhydride copolymer polycarbonate alloy Thermoplastic alloys of SMA with polycarbonate. Processed by injection molding and extrusion.

styrene methyl methacrylate butadiene copolymer A polymer of styrene, methyl methacrylate, and butadiene.

styrene methyl methacrylate butadiene polymer See *methyl methacrylate butadiene styrene terpolymer*.

styrene plastic See *styrenic resin*.

styrene resin See *styrenic resin*.

styrene rubber plastic See *impact polystyrene*.

styrenic methyl methacrylate copolymer A polymer of styrene and methyl methacrylate.

styrenic plastic See *styrenic resin*.

styrenic resin Styrenic resins are a class of thermoplastics prepared mainly by free-radical homopolymerization of styrene or copolymerization of styrene with other unsaturated monomers. The most important families of this class are ABS plastics, polystyrene, styrene maleic anhydride copolymer, and styrene acrylonitrile copolymers. The properties of styrenic resins vary widely with molecular structure, some attaining the high performance level of engineering plastics. Processed by blow and injection molding, extrusion, thermoforming, film techniques, and structural foam molding. Used very heavily in automotive parts, household goods, packaging, films, tools, containers, and pipes. Also called styrenic plastic, styrene resin, styrene plastic, ASR, advanced styrenic resin.

styrenic thermoplastic elastomer These thermoplastic elastomers are comprised of linear or branched copolymers containing polystyrene end blocks and elastomer (e.g., isoprene rubber) middle blocks. The elastomers have hardnesses ranging from 28 to 95 Shore A, tensile strengths from 300 to 5000 psi, and elongation from 250 to 1300%. They also retain their flexibility to temperatures as low as -112°F and have good dielectric properties and hydrolytic stability. They are processable by injection and

blow molding and extrusion. Uses include adhesives, coatings, sealants, impact and asphalt modifiers, soles, medical devices, tubing, cable insulation, and automotive parts. Also called thermoplastic styrenic rubber, styrenic TPE, styrenic thermoplastic rubber.

styrenic thermoplastic rubber See *styrenic thermoplastic elastomer*.

styrenic TPE See *styrenic thermoplastic elastomer*.

sulfide adhesive See *polysulfide adhesive*.

surface grafting In adhesive bonding, a surface preparation technique in which a chemical species, such as vinyl acetate monomer, is grafted onto the substrate surface. Commonly used to graft vinylic compounds onto polyolefins.

surface roughening In adhesive bonding, a commonly used surface preparation technique in which the substrate surface is mechanically abraded. The roughened surface increases bondability by dramatically increasing the number of sites available for mechanical interlocking.

surface roughness The closely spaced unevenness of a solid surface (pits and projections); can be quantified by various methods, e.g., by using a profilometer in coatings.

surface tack Stickiness of a surface of a material such as wet paint when touched.

surface tension The surface tension is the cohesive force at a liquid surface measured as a force per unit length along the surface or the work which must be done to extend the area of a surface by a unit area, e.g., by a square centimeter. Also called free surface energy.

syndiotactic A polymer molecule in which pendant groups and atoms attached to the main chain are arranged in a symmetrical and recurring fashion relative to it in a single plane.

synergistic effect The boosting effect of one substance on the property of another so that the total effect of both substances in a mixture is greater than the sum of the effects of each substance individually, such as synergistic effect of zinc bis(dibutylthiocarbamate) on the UV absorption by zinc oxide.

synthetic polymer See *polymer*.

synthetic resin See *polymer*.

synthetic rubber See *thermosetting elastomer*.

T

Taber abrasion resistance The weight loss of a plastic or other material specimen after it was subjected to abrasion in Taber abraser for a prescribed number of specimen disk rotations, usually 1000. Taber abraser consists of an idling abrasive wheel, designated depending on the type and grit of the abrasive used as CS-10F, H 22, etc., and a rotary disk with the specimen mounted on it. The load is applied to the wheel. The produced motion simulates that of rolling with slip.

tack See *tackiness*.

tackiness Pull-resistance exerted by a material adhering completely to two separating surfaces; slight stickiness of the surface of a

coating, apparent when it pressed with the finger, a characteristic of cure. Also called tack.

tan delta See *dielectric dissipation factor*.

tapping The process of forming threads in the walls of a circular pilot hole in a plastic, metal, or similar material. See also *self-tapping screws*.

tear propagation force See *tear propagation resistance*.

tear propagation resistance The force required to propagate a slit in a flexible plastic film or thin sheeting at a constant rate of loading, calculated as an average between the initial and the maximum tear-propagation forces. Also called tear propagation force, resistance to tear propagation.

tearing energy Tearing energy is a function of strain energy density and crack length, often expressed in kN/m. Plots of tearing energy vs. fatigue crack growth rate are used to characterize the kinetics of fatigue crack extension in rubbers, which do not obey the classical theory of elasticity. Also called tearing energy parameter.

tearing energy parameter See *tearing energy*.

TEEE See *polyester thermoplastic elastomer*.

tensile elongation See *elongation*.

tensile heat distortion temperature See *heat deflection temperature*.

tensile properties Properties describing the reaction of physical systems to tensile stress and strain.

tensile strength The maximum tensile stress that a specimen can sustain in a test carried to failure. **Note:** The maximum stress can be measured at or after the failure or reached before the fracture, depending on the viscoelastic behavior of the material. Also called ultimate tensile strength, tensile ultimate strength, tensile strength at break.

tensile strength at break See *tensile strength*.

tensile stress The force related to the smallest original cross-section of the specimen at any time of the test.

tensile ultimate strength See *tensile strength*.

TEO See *olefinic thermoplastic elastomer*.

terephthalate polyester A thermoset unsaturated polyester based on terephthalic anhydride. Also called terephthalic polyester, polyester terephthalate.

terephthalic polyester See *terephthalate polyester*.

tetrachloroethylene A colorless, chemically stable and nonflammable liquid with ether odor, $\text{CCl}_2=\text{CCl}_2$. Irritant to skin. Derived by chlorination of hydrocarbons. Used as dry-cleaning solvent and drying agent for electronics.

tetrafluoroethylene propylene copolymer Thermosetting elastomeric polymer of tetrafluoroethylene and propylene having good chemical and heat resistance and flexibility. Used in auto parts.

TFE See *polytetrafluoroethylene*.

thermal expansion coefficient The change in volume per unit volume resulting from a change in temperature of the material.

The mean coefficient of thermal expansion is commonly referenced to room temperature.

thermal properties Properties related to the effects of heat on physical systems such as materials and heat transport. The effects of heat include the effects on structure, geometry, performance, aging, stress-strain behavior, etc.

thermal stability The resistance of a physical system such as material to decomposition, deterioration of properties or any type of degradation in storage under specified conditions. Also called oven stability, heat stability.

thermal treatment In adhesive bonding, a surface preparation technique in which the substrate surface is oxidized by exposure to a blast of hot air (~500 °C). Oxidation proceeds by a free radical mechanism and introduces carbonyl, carboxyl, amide, and some hydroperoxide functional groups to the part surface, accompanied by chain scission and some crosslinking. Commonly used for polyolefins, thermal treatment increases wettability and interfacial diffusivity.

thermoforming The process of heating a thermoplastic sheet to a point at which it softens and flows, then applying differential pressure to make the sheet conform to the shape of a mold or die.

thermoplastic Thermoplastics are resin or plastic compounds which, after final processing, are capable of being repeatedly softened by heating and hardened by cooling by means of physical changes. There are a large number of thermoplastic polymers belonging to various classes such as polyolefins and polyamides. Also called thermoplastic resin.

thermoplastic elastomer Polymers and blends that resemble vulcanized rubbers in that they can be deformed significantly at room temperature and return to their original shape after the stress has been removed, but are true thermoplastics that undergo normal plastic flow when heated in uncured state. The thermoplastic elastomers usually consist of hard and soft domains and can be of many chemical types, e.g., olefinic, urethane, polyester, polyamide, and styrenic. The properties of thermoplastic elastomers vary widely but all exhibit good impact strength and toughness. They are processed mainly by (co)extrusion and (co)molding. Uses include automotive parts, wire and cable insulators, adhesives, footwear, and mechanical goods. Also called TPV, TPEL, TPE, thermoplastic rubber.

thermoplastic olefinic rubber See *olefinic thermoplastic elastomer*.

thermoplastic polyamide rubber See *polyamide thermoplastic elastomer*.

thermoplastic polyesters A class of polyesters that can be repeatedly made soft and pliable on heating and hard (flexible or rigid) on subsequent cooling.

thermoplastic polyolefin rubber See *olefinic thermoplastic elastomer*.

thermoplastic polyurethanes A class of polyurethanes including rigid and elastomeric polymers that can be repeatedly made soft and pliable on heating and hard (flexible or rigid) on subsequent cooling. Also called TPUR, TPU.

thermoplastic resin See *thermoplastic*.

thermoplastic rubber See *thermoplastic elastomer*.

thermoplastic styrenic rubber See *styrenic thermoplastic elastomer*.

thermoset Thermosets are resin and plastic compounds which, after final processing, are substantially infusible and insoluble. Thermosets are often liquids at some stage in their manufacture or processing and are cured by heat, oxidation, radiation, or other means often in the presence of curing agents and catalysts. Curing proceeds via polymerization and/or cross-linking. Cured thermosets cannot be resoftened by heat. There are a large number of thermosetting polymers belonging to various classes such as alkyd and phenolic resins. Also called thermosetting resin, thermoset resin.

thermoset resin See *thermoset*.

thermosetting elastomer A large class of polymers that can be stretched at room temperature to at least twice their original length and, after having been stretched and the stress removed, return with force to approximately their original length in a short time. To attain this elastic property the rubbers must be crosslinked or vulcanized, usually by heating in the presence of various crosslinking agents and catalysts. There are natural and synthetic rubbers. The most important synthetic rubber families are olefinic rubbers, dienic rubbers (nitrile, butadiene, neoprene), silicone rubbers, and urethane rubbers. Used often as impact modifiers/fillers in plastics. Also called synthetic rubber, rubber.

thermosetting resin See *thermoset*.

thermotropic A material in which the shape and packing of the macromolecules is affected by temperature.

thread-cutting screw A type of self-tapping screw that has a sharp cutting edge. Thread-cutting screws remove plastic chips as the screw is inserted, so that internal stresses produced are low. Only minimum reassemblies are possible. See also *self-tapping screw*.

thread-forming screw A type of self-tapping screw that forms threads by displacing and deforming plastic material, which then flows around the screw head. No material is removed, and large internal stresses are produced in the plastic. See also *self-tapping screw*.

threaded mechanical insert A metal, self-threading insert with an exterior locking feature for anchorage in the part to be joined. The threaded interior of the insert allows for repeated assembly and disassembly. Threaded mechanical inserts provide high strength joining of plastic parts with low stress.

through transmission infrared welding An infrared welding method in which infrared radiation is transmitted through a part composed of a polymer that does not absorb infrared energy to the other part, composed of a polymer that does absorb infrared energy, at the weld interface. Heat builds up in the absorbing polymer and is transferred to the nonabsorbing polymer through conduction, causing melting at the weld interface. Parts flow together to form a weld. Also called TTIR.

Ti See *titanium*.

tightening torque The torque to which self-tapping screws are tightened. Tightening torque is greater than driving torque but less than stripping torque.

titanium High strength, stiffness, good toughness, low density, good corrosion resistance, nonmagnetic, good heat-transfer and acoustic properties. Commercially pure titanium used primarily for corrosion-resistant service (tanks, heat exchangers, reactor vessels for desalination, chemical processing, or power-generation plants prosthetic devices), titanium alloys for structural, strength-efficient applications (aerospace industry most prominent) from cryogenic to high temperatures, Ti-6Al-4V being the most widely used. Used in manufacturing horns and boosters for ultrasonic welding of plastics. Strength efficiency, fatigue and creep

resistance, fracture toughness, weldability, and formability are determined by the alloy chemical composition and microstructure (alpha, beta, or alpha-beta), the latter controlled by composition and heat treatment (annealing or solution treatment and aging). Ti-Al-V and Ti-Al-Sn-base alloys are used in gas turbine, aerospace, marine, and other high-performance applications; titanium beta alloys are ideal spring materials; optic-system support structures (surveillance and guidance for aircraft and missiles) use titanium alloys because their thermal expansion coefficient closely matches that of the optics. Also called Ti.

toluene (C₆H₅CH₃) A colorless liquid with an aromatic odor. Boils at 110.7°C (231.3°F); freezes at -94.5°C (-138.1°F). Soluble in alcohol, benzene, and ether; insoluble in water. Flammable, fire risk; explosive limit in air is 1.27 - 7%; autoignition temperature is 536°C (997°F). Toxic by ingestion, inhalation, and skin absorption; TLV is 100 ppm in air. Derived from coal tar or the catalytic reforming of petroleum. Used in high-octane gasolines, explosives (TNT); as a solvent for paints, coatings, gums, resins, oils, rubber, and vinylorganosols; as a chemical intermediate in the production of polyurethanes and polyesters; in saccharin, medicines, dyes, perfumes, detergents, scintillation counters. Also called methylbenzene, phenylmethane, toluol.

toughness Property of a material indicating its ability to absorb energy by plastic deformation rather than crack or fracture.

TPE See *thermoplastic elastomer*.

TPEL See *thermoplastic elastomer*.

TPO See *olefinic thermoplastic elastomer*.

TPU See *thermoplastic polyurethanes*.

TPU See *urethane thermoplastic elastomer*.

TPUR See *nonelastomeric thermoplastic polyurethane*.

TPUR See *thermoplastic polyurethanes*.

TPV See *thermoplastic elastomer*.

transcrystalline growth In adhesive bonding, a surface preparation technique in which adherends are molded against a high energy metallic substrate that induces transcrystalline growth in the surface regions of the plastic. The formation of crystallites at the surface results in rod-like or columnar spherulites that form inward from the plastic-metal interface; these are thought to strengthen the surface by driving low molecular weight material into the interior. Surface oxidation may also occur, increasing surface reactivity and wettability. The effectiveness of transcrystalline growth is dependent on molding conditions, such as the cooling rate and mold surface. Commonly used for polyolefins, polyamides, and polyurethanes.

transducer A piezoelectric device that converts high-frequency electrical energy into high-frequency mechanical vibrations. See also *piezoelectric*.

trichloroethane -1,1,2 (CHCl₂CH₂Cl) A clear, colorless liquid with a sweet odor. Soluble in ethers, alcohols, esters and ketones; insoluble in water. Nonflammable, boils at 113.7°C (236.7°F). Its TLV is 10 ppm in air; it is absorbed by skin. Used in organic synthesis and as a solvent for resins, waxes, oils, fats, and other products. Also called vinyl trichloride.

trichloroethylene (CHCl:CCl₂) A colorless, photoreactive liquid with a slight odor of chloroform. Soluble in common organic solvents; slightly soluble in water. Boils at 86.7°C (188.1°F); not flammable. Does not attack metals, even in the presence of

moisture. TLV is 50 ppm in air; toxic by inhalation. Use in cosmetics, drugs, foods is prohibited; use as a solvent is prohibited in some states. Derived from reaction of tetrachloroethane with lime or alkali in the presence of water or from tetrachloroethane thermal decomposition followed by steam distillation. Used in metal degreasing, dry cleaning, diluent in paints and adhesives, cleaning and drying electronic parts, textile processing. Many other uses.

trigger force In ultrasonic welding, the force applied to the parts being joined before ultrasonic vibrations are initiated. Produced by contact of the horn with the parts to be welded. Ultrasonic vibrations are begun after a particular trigger force or distance has been reached by the horn.

trigger point In ultrasonic welding, the point in time during the welding operation when the horn is correctly positioned for the welding process, and ultrasonic vibrations are initiated. Ultrasonic triggering under applied clamp force assures reproducible welds. Reproducible welding cannot be achieved when ultrasonic vibrations are "pre-triggered", and positive controlled clamping cannot be achieved when the horn touches the part while ultrasonically active.

TTIR See *through transmission infrared welding*.

two-part adhesive An adhesive in which the monomer and catalyst or hardener are separate from each other. The two reactive components separately have an indefinite storage life but must be mixed thoroughly before use. Room or elevated temperature cures are possible. Two-part adhesives include an epoxy monomer and amine hardener; urethanes; and peroxide-initiated adhesive systems such as vulcanized silicone, unsaturated polyesters, and acrylics. See also *one-part adhesive*.

U

UF See *urea resin*.

UHMWPE See *ultrahigh molecular weight polyethylene*.

ultimate elongation See *elongation*.

ultimate seal strength Maximum force that a heat-sealed thermoplastic film can sustain in a tensile test without seal failure per unit length of the seal.

ultimate tensile strength See *tensile strength*.

ultrahigh molecular weight polyethylene UHMWPE is a linear carbon-chain polyethylene with molecular weight (3-5)*10**6, prepared by Ziegler polymerization of ethylene under special conditions. It has very high wear resistance, toughness, chemical resistance, low friction coefficient, and is self lubricating, but does not melt. Processed by compression molding and ram extrusion from powdered form. Used in bearings, gears, and sliding surfaces in mining and transportation. Also called UHMWPE.

ultrasonic scan welding A continuous, high-speed ultrasonic assembly technique used when at least one of the parts to be joined is perfectly flat. Also called scan welding.

ultrasonic spot welding An ultrasonic welding method in which the two parts are joined at localized points.

ultrasonic swaging An assembly method in which ultrasonic energy is used to form a ring or ridge of plastic in one of the mating parts in order to capture the other part.

ultrasonic weld force In ultrasonic welding, the force applied to the joint during the welding process. Greater than the trigger force. Intensifies the effectiveness of the colliding molecules in the joint area and provides fast thermal buildup. Must be optimized to the amplitude, generator output power, and geometry of the joint. Generally, high weld force is used with low amplitudes and low weld force with high amplitudes.

ultrasonic welding A joining method for thermoplastics in which energy at ultrasonic frequencies (20 - 40 kHz) is used to produce low amplitude mechanical vibrations. The vibratory pressure at the joint interface produces frictional heat that melts the thermoplastic parts, allowing them to flow together and bond. Parts may require the use of an energy director in order to concentrate ultrasonic energy. High quality welds are easier to obtain with amorphous than with crystalline thermoplastics.

ultrasound Mechanical vibrations having the same physical nature as sound but with frequencies normally above the range of human hearing.

ultraviolet light See *ultraviolet radiation*.

ultraviolet radiation Electromagnetic radiation in the 40-400 nm wavelength region. Sun is the main natural source of UV radiation on the earth. Artificial sources are many, including fluorescent UV lamps. UV radiation causes polymer photodegradation and other chemical reactions. **Note:** UV light comprises a significant portion of the natural sun light. Also called UV radiation, UV light, ultraviolet light. See also *ultraviolet radiation*.

ultraviolet radiation exposure In adhesive bonding, a surface preparation technique in which the substrate is irradiated with high intensity UV light. Exposure to UV radiation results in chain scissions, crosslinking, and oxidation of the polymer surface. The effectiveness of this technique is dependent on the wavelength of radiation used. It is commonly used for polyolefins. Also called UV exposure.

urea formaldehyde resin See *urea resin*.

urea plastic See *urea resin*.

urea resin Thermoset resins comprised of polycondensation products of formaldehyde with urea. The urea resins have lower hardness, heat resistance, and moisture resistance than melamine resins. They are clear, colorless, and easily colored. They have higher tensile strength and hardness than phenolic resins but have lower impact strength and heat and moisture resistance. The urea resins are also scratch resistant, self-extinguishing, and solvent resistant, including hot water. They have good rigidity and electrical arc and track resistance. They must be filled for successful molding and have low resistance to long-term oxidation and to strong acids and bases. The processing is accomplished by compression and injection molding, impregnation, and coating. The applications include cosmetic container closures, appliance housings, tableware, electrical insulators, laminates for counter and table tops, adhesives, and coatings. Also called urea plastic, urea formaldehyde resin, UF.

urethane See *nonelastomeric thermosetting polyurethane*.

urethane polymer See *polyurethane*.

urethane resin See *nonelastomeric thermosetting polyurethane*.

urethane thermoplastic elastomer These thermoplastic elastomers are comprised of block polyether or polyester polyurethanes containing soft and hard domains or phases. They offer good tensile strength and elongation, service temperatures ranging from 60 to +250°F, excellent adhesion, and a broad hardness range. The ester based elastomers are tougher but will degrade in water in contrast to the ether based elastomers. Both types are somewhat hygroscopic and require drying prior to processing. The processing is carried out by extrusion, injection molding, film blowing, and coating. The molding requires mold release agents. The applications include tubing, water tanks, packaging film, hot-melt adhesives, soles, medical devices, conveyor belts, automotive parts, and cable jacketing. Also called urethane TPE, urethane thermoplastic rubber, TPU, PUR TPE, PU TPE, polyurethane TPE, polyurethane thermoplastic rubber.

urethane thermoplastic rubber See *urethane thermoplastic elastomer*.

urethane TPE See *urethane thermoplastic elastomer*.

UV absorber A low-molecular-weight organic compound such as hydroxybenzophenone derivatives that is capable of absorbing significant amount of radiant energy in the ultraviolet wavelength region, thus protecting the material such as plastic in which it is incorporated from the damaging (degrading) effect of the energy. The absorbed energy is dissipated by UV absorber without significant chemical change via tautomerism of hydrogen bonds. Also called UV stabilizer.

UV exposure See *ultraviolet radiation exposure*.

UV light See *ultraviolet radiation*.

UV radiation See *ultraviolet radiation*.

UV stabilizer See *UV absorber*.

V

vapor pressure curve A curve for a substance such as water, showing the variation of boiling temperature with boiling pressure. Indicates combinations of temperature and pressure at which the substance will be in a fluid or vapor phase.

VF2 See *polyvinylidene fluoride*.

vibration welding A technique used for joining thermoplastics in which frictional heat is generated by rubbing the two parts together in a linear or angular motion. When the generated heat melts the two materials at the joint interface, vibration is terminated, and the parts are pressed together and allowed to cool. The vibratory motion is a low frequency (120 Hz, 240 Hz), high amplitude (0.10 - 0.2 in. or 0.25 - 0.51 mm of linear displacement), reciprocal motion; a rotary motion is used for circular parts. Vibration welding produces high strength bonds and is particularly suited to large parts or parts with irregular joint surfaces. Also called friction welding. See also *spin welding*.

Vicat softening point The temperature at which a flat-ended needle of 1 mm² circular or square cross section will penetrate a thermoplastic specimen to a certain depth under a specified load using a uniform rate of temperature rise. This test (ASTM D1525) is used for thermoplastics such as polyethylene which have no definite melting point. **Note:** Vicat softening point is determined according to ASTM D1525 test for thermoplastics such as polyethylene which have no definite melting point. Also called Vicat softening temperature.

Vicat softening temperature See *Vicat softening point*.

vinyl ester resin Vinyl ester resins are unsaturated thermosets prepared usually by esterification of glycidyl groups of epoxy resins with unsaturated carboxylic acids. Typically, bisphenol A epoxy resins are treated with methacrylic acid and mixed with styrene reactive diluent. The resins are cured by both peroxide catalyzed addition polymerization of vinyl groups and anhydride crosslinking of hydroxy groups at room or elevated temperatures. Cured bisphenol A vinyl ester resins are characterized by chemical resistance, epoxy novolak vinyl ester resins by solvent and heat resistance, and all vinyl resins in general are tough and flexible in a wide range, but shrink during cure. Processed by filament winding, transfer molding, pultrusion, coating, and lamination. Used in structural composites, coatings, sheet molding compounds, and chemical apparatus. Also called acrylic epoxy resin.

vinyl resin Vinyl resins are a large class of thermoplastics prepared mainly by radical polymerization of vinyl monomers with or without other unsaturated monomers. The most important family of this class are vinyl chloride polymers. Other families are vinyl acetate, vinyl alcohol, vinylidene chloride, and vinyl acetal polymers. Their properties vary widely. In general, they show good weatherability, barrier properties, and flexibility, but are attacked by many solvents and have limited thermal stability. Processed by molding, extrusion, coating, and film techniques. Used very widely, especially as films and in packaging.

vinyl thermoplastic elastomer Vinyl-alloyed thermoplastic elastomer with excellent resistance to ignition, low smoke generation, flexibility at very low temperatures, excellent dielectric properties, good toughness and elongation retention after thermal aging. Processed by extrusion and extrusion coating. Used in cable jacketing and wire coating. Also called vinyl TPE.

vinyl TPE See *vinyl thermoplastic elastomer*.

vinylidene fluoride hexafluoropropylene copolymer Thermoplastic copolymer of vinylidene fluoride and hexafluoropropylene. Has better thermal stability; antistick, dielectric, and antifriction properties; and chemical resistance, but lower mechanical strength at room temperature and creep resistance, compared to incompletely fluorinated fluoropolymers. Processing by conventional thermoplastic techniques is difficult due to its high melt viscosity. Uses include chemical apparatus, containers, films, and coatings. Also called FKM

vinylidene fluoride hexafluoropropylene tetrafluoroethylene terpolymer Thermosetting elastomeric polymer of vinylidene fluoride, hexafluoropropylene, and tetrafluoroethylene having good chemical and heat resistance and flexibility. Used in auto parts. Also called FKM/TFE

viscosity The internal resistance to flow exhibited by a fluid, the ratio of shearing stress to rate of shear. A viscosity of one poise is equal to a force of one dyne/square centimeter that causes two parallel liquid surfaces one square centimeter in area and one centimeter apart to move past one another at a velocity of one cm/second.

viscosity ratio See *relative viscosity*.

vulcanizate Rubber that had been irreversibly transformed from predominantly plastic to predominantly elastic material by vulcanization (chemical curing or crosslinking) using heat, vulcanization agents, accelerants, etc.

vulcanizate crosslinks Chemical bonds formed between polymeric chains in rubber as a result of vulcanization.

vulcanization A process in which a rubber or elastomer undergoes a change in its chemical structure, becoming less plastic, more elastic, and more resistant to swelling. An irreversible process accomplished by application of heat or reaction with sulfur or other suitable agents.

W

warpage See *warping*.

warping Dimensional distortion or deviation from the intended shape of a plastic or rubber article as a result of nonuniform internal stress, e.g., caused by uneven heat shrinkage. Also called warpage.

water swell Expansion of material volume as a result of water absorption.

Weissenburg effect The tendency of a material to flow inward. The change in normal stresses on a non-Newtonian, elastic material that causes the material to rise on the inner cylinder of two concentric, rotating cylinders, despite the centrifugal force.

weld factor The ratio of weld strength to strength outside the welded zone, typically determined by tensile stress tests.

welding amplitude The amplitude used in a welding process. In a vibratory motion such as in vibration or ultrasonic welding, the distance from the equilibrium position to the point of maximum displacement. Varies with welding process used and with the geometry and composition of the parts being welded.

welding by distance A form of heated tool welding in which mechanical stops on the hot tool and holding fixtures are used to control the dimensions of the welded parts. See also *welding by pressure, heated tool welding*.

welding by pressure A form of heated tool welding in which flow of the molten plastic after heating is regulated by application of specific pressures to the hot tool and parts. Accurate pressure control is necessary, and final part dimensions may vary due to variations in melt thickness and melt viscosity. See also *welding by distance, heated tool welding*.

welding frequency The frequency used in a welding process. The number of cycles or vibrations per unit of time, usually seconds. Welding frequencies vary depending on the welding process used and on the geometry and composition of the parts being joined. Welding frequencies range from 120 Hz and 240 Hz, used in vibration welding, to 2 to 10 GHz, used in microwave welding. See also *frequency*.

welding pressure The pressure applied to the parts during welding to hold the parts in place and provide intimate contact for bonding. Welding pressure varies depending on the welding process used and the composition of the parts being joined.

welding time A processing parameter in welding. Definition varies depending on the welding process - can refer to the time vibrations are applied to the parts being joined (ultrasonic welding), the amount of time parts are held together under pressure for cooling and solidification (heated tool welding), or both the spin time and cooling time (spin welding). Welding time is dependent on other processing parameters, such as weld amplitude, weld frequency, weld pressure, power level, temperature, etc.

wetting The spreading out (and sometimes absorption) of a fluid onto (or into) a surface. In adhesive bonding, wetting occurs when the surface tension of the liquid adhesive is lower than the critical surface tension of the substrates being bonded. Good surface wetting is essential for high strength adhesive bonds; poor wetting is evident when the liquid beads up on the part surface. Wetting can be increased by preparation of the part surface prior to adhesive bonding.

Y

yellowing Developing of yellow color in near-white or near-transparent materials such as plastics or coatings as a result of degradation on exposure to light, heat aging, weathering, etc. Usually is measured in terms of yellow index.