

POLYMERS IN STRUCTURAL DESIGN APPLICATIONS

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ABSTRACT

FEP resin applications include wire and cable insulation for computer and electronic systems, telephone and alarm systems, and business-machine interconnects, FEP resin is also supplied as extruded sheet and film for release surfaces, roll covers, linings for chemical-processing tanks, and piping. A concentrate is available for Freon-blown-foam wire coating. PFA resins are used for high-temperature wire and cable insulation, heat-shrinkable tubing and roll covers, chemical-resistant linings for process-equipment components, and in semiconductor processing equipment. Materials do not adhere readily to the slippery surface of FEP, PFA, and PTFE parts. Surfaces can be chemically etched, however, to permit bonding with adhesives. Thus, low-friction surfaces of fluorocarbon tape or film can be bonded to steel, aluminum, rubber, or other materials. FEP and PFA parts can be heat sealed to themselves, to PTFE parts, or to metals at low pressure and temperatures above 310 °C. CTFE: Sensitivity to processing conditions is greater in CTFE resins than in most polymers. Molding and extruding operations require accurate temperature control, flow channel streamlining, and high pressure because of the high melt viscosity of these materials. With too little heat, the plastic is unworkable; too much heat degrades the polymer. Degradation begins at about 274 °C. Because of the lower temperatures involved in compression molding, this process produces CTFE parts with the best properties. Thin parts such as films and coil forms must be made from partially degraded resin. Degree of degradation is directly related to the reduction in viscosity necessary to process a part. Although normal, partial degradation does not greatly affect properties, seriously degraded CTFE becomes highly crystalline, and physical properties are reduced. Extended usage above 121 °C also increases crystallinity. CTFE plastic is often compounded with various fillers. When plasticized with low-molecular-weight CTFE oils, it becomes a soft, extensible, easily shaped material. Filled with glass fiber, CTFE is harder, more brittle, and has better high-temperature properties.

Key words: properties, polymers, applications

1. INTRODUCTION

Nothing adheres readily to these materials, and they absorb practically no moisture. CTFE components do not carbonize or support combustion. Up to thicknesses of about 3,3mm., CTFE plastics can be made optically clear. Ultraviolet absorption is very low, which contributes to its good weatherability. Compared with PTFE, FEP, and PFA fluorocarbon resins, CTFE materials are harder, more resistant to creep, and less permeable; they have lower melting points, higher coefficients of friction, and are less resistant to swelling by solvents than the other fluorocarbons. Tensile strength of CTFE moldings is moderate, compressive strength is high, and the material has good resistance to abrasion and cold flow. CTFE plastic has the lowest permeability to moisture vapor of any plastic. It is also impermeable to many liquids and gases, particularly in thin sections.

Applications: Molded and extruded CTFE resin applications include components for handling and containing corrosive liquids (diaphragms, valves, sight glasses); seals, gaskets, O-rings, valve seats, and packings for liquid-oxygen and hydrogen equipment; and flexible-circuit laminations, wire insulation, jacketed cable, coil bobbins, and other electrical components.

CTFE materials are FDA-approved for use in food-handling equipment. Thin, optically clear CTFE moldings are used for infrared windows in missiles, radome covers, oil-reservoir covers, and gage faces. PVDF: Polyvinylidene fluoride, the toughest of the fluoroplastic resins, is available as pellets for extrusion and molding and as powders and dispersions for corrosion-resistant coatings. This high-molecular-weight homopolymer has excellent resistance to stress fatigue, abrasion, and to cold flow. Although insulating properties and chemical inertness of PVDF are not as good as those of the fully fluorinated polymers. PTFE and FEP, the balance of properties available in PVDF qualifies this resin for many engineering applications. It can be used over the temperature range from -38 to 150 °C and has excellent resistance to abrasion. PVDF can be used with halogens, acids, bases, and strong oxidizing agents, but it is not recommended for use in contact with ketones, esters, amines, and some organic acids. Oxygen index is 44. Although electrical properties of PVDF are not as good as those of other fluoroplastics, it is widely used to insulate wire and cable in computer and other electrical and electronic equipment. Heat-shrinkable tubing of PVDF is used as a protective cover on resistors and diodes, as an encapsulant over soldered joints. Valves, piping, and other solid and lined components are typical applications of PVDF in chemical-processing equipment. It is the only fluoroplastic available in rigid pipe form. Woven cloth made from PVDF monofilament is used for chemical filtration applications. A significant application area for PVDF materials is as a protective coating for metal panels used in outdoor service. Blended with pigments, the resin is applied, usually by coil-coating equipment, to aluminum or galvanized steel. The coil is subsequently formed into panels for industrial and commercial buildings. A recently developed capability of PVDF film is based on the unique piezoelectric characteristics of the film in its so-called beta phase. Beta-phase PVDF is produced from ultrapure film by stretching it as it emerges from the extruder. Both surfaces are then metallized, and the material is subjected to a high voltage to polarize the atomic structure. When compressed or stretched, polarized PVDF generates a voltage from one metallized surface to the other, proportional to the induced strain. Infrared light on one of the surfaces has the same effect. Conversely, a voltage applied between metallized surfaces expands or contracts the material, depending on the polarity of the voltage. Representative commercial fluoroplastics: PTFE, Du Pont (Teflon TFE), Allied-Signal (Halon, TFE), ICI Americas (Fluon) FEP, Du Pont (Teflon FEP) PFA, Du Pont (Teflon PFA) CTFE, 3M (Kel-F), Allied-Signal (Plaskon CTFE) PVDF, Pennwalt (Kynar), Atochem (Foraflon) PVF, Du Pont (Tedlar) ETFE, Du Pont (Tefzel) ECTFE, Allied-Signal (Halar).

2. ALL MOLDING PROCESSES

Designers used to take little interest in the molding of parts they designed. They sent the drawings to the molder in another department or another company and expected perfect parts to emerge. But design and processing have become so interrelated that this separation can no longer exist if products are to be consistently successful. Molders can usually be relied upon to detect and correct visible problems or readily measured factors such as color, surface condition, and dimensions. However, less apparent property changes are another matter. These may not show up until the moldings are in service, unless extensive testing and quality control are used. Such properties as impact strength, toughness, and chemical resistance can be diminished by improper control of processing parameters. Close cooperation between designers and molders can eliminate disappointment and help ensure successful products. After candidate materials are selected, the design should be tested under real-life conditions involving the temperatures, loading, and environment of the anticipated service. Ideally, the test part should be molded in the shape and from the material to be used in production. In the beginning, this is costly and time consuming, but as experience is acquired, accelerated tests can be developed on simpler shapes; testing will then be more economical but just as reliable. Understanding the molding process that will produce the part is also necessary. The process directly affects material choice, shape, tolerances, and properties of the part. For example, a container or housing can be made by injection molding, blow molding, thermoforming, or rotational molding. But each process requires a markedly different design, would use a different grade of plastic or a different plastic entirely, and would produce a component with significantly different properties. All molding processes alter the published data-sheet properties, reducing most strengths and often creating areas of stress concentrations. But each process may create stresses in different areas.

These characteristics are improved by compounding the resins with inorganic fibers or particulate materials. For example, the poor wear resistance of PTFE as a bearing material is overcome by adding glass fiber, carbon, bronze, or metallic oxide. Wear resistance is improved by as much as 1,000 times, and the friction coefficient increases only slightly. As a result, the wear resistance of filled PTFE is superior, in its operating range, to that of any other plastic bearing material and is equalled only by some forms of carbon. The static coefficient of friction for PTFE resins decreases with increasing load. Thus, PTFE bearing surfaces do not seize, even under extremely high loads. Sliding speed has a marked effect on friction characteristics of unreinforced PTFE resins; temperature has very little effect. PTFE resins have an unusual thermal expansion characteristic. A transition at 18 °C produces a volume increase of over 1%. Thus, a machined part, produced within tolerances at a temperature on either side of this transition zone, will change dimensionally if heated or cooled through the zone. Electrical properties of PTFE, FEP, and PFA are excellent, and they remain stable over a wide range of frequency and environmental conditions. Dielectric constant, for example, is 2.1 from 60 to 10 (to the 9th power) Hz. Heat-aging tests at 300 °C for six months show no change in this value. Dissipation factor of PTFE remains below 0.0003 up to 10 (to the 8th power) Hz. The factor for FEP and PFA resins is below 0.001 over the same range. Dielectric strength and surface arc resistance of fluorocarbon resins are high and do not vary with temperature.

3. EXTRUDED SHEET CAN BE THERMOFORMED

Impact properties of ABS are exceptionally good at room temperature and, with special grades, at temperatures as low as -40°C. Because of its plastic yield at high strain rates, impact failure of ABS is ductile rather than brittle. Also, the skin effect which, in other thermoplastics, accounts for a lower impact resistance in thick sections than in thin ones, is not pronounced in ABS materials.

ABS resins are stable in warm environments and can be decorated with durable coatings that require baking at temperatures to 71°C for 30 to 60 min. Heat-resistant grades can be used for short periods at temperatures to 110°C in light load applications. Acrylic-styrene-acrylonitrile (ASA) polymers are amorphous plastics which have mechanical properties similar to those of ABS resins. However, the ASA properties are far less affected by outdoor weathering. ASA is a terpolymer that can be produced by either a patented, proprietary reaction process or by a graft process. In the reaction method, ASA is made by introducing a grafted acrylic ester elastomer during a copolymerization of styrene and acrylonitrile (SAN). The finely divided powder is uniformly distributed in and grafted to the SAN molecular chains. The outstanding weatherability of ASA is due to the acrylic ester elastomer. ASA resins are available in natural, off white, and a broad range of standard and custom-matched colors. Base ASA resins are sold under the trade names Luran S (BASF Plastic Materials), Geloy (General Electric Plastics) and Centrex (Monsanto Chemical Co.). ASA resins can be compounded with other polymers to make alloys and compounds that benefit from ASA's weather resistance. Also, ASA sheet is used as a capstock over other plastics. Properties: ASA parts have high gloss, good chemical and heat resistance, and high impact strength, even at low temperatures. ASA is resistant to saturated hydrocarbons, low-aromatic gasoline and lubricating oil, vegetable and animal oils, water, aqueous solutions of salts, and dilute acids and alkalis. However, it is attacked by concentrated inorganic acids, aromatic and chlorinated hydrocarbons, esters, ethers, ketones, and some alcohols. ASA offers better resistance to environmental stress cracking than ABS. With respect to flame resistance, ASA is available with UL 94-HB classification. Processing: ASA resins can be processed by most conventional methods. These include profile and sheet extrusion and coextrusion, injection molding, structural foam molding, and extrusion-blow molding. Extruded sheet can be thermoformed. ASA should be blow molded using extruders with grooved, cooled, and thermally insulated feed sections. Screws should have somewhat deeper flights in order to reduce frictional heat. Optimum results are obtained with machines having accumulators. ASA parts can be welded using thermal and spin techniques. In some cases, ultrasonic welding is possible. ASA parts also can be solvent welded using 2-butanone, dichloroethylene, or cyclohexane. ASA parts readily accept and retain print and coatings without prior surface treatment. Vacuum metallizing by conventional methods is also possible. Applications: Building/construction -- Gutters and fittings, drain pipe and fittings, signs, mail boxes, mobile home skirting, flower boxes, and shutters. Recreation/leisure -- Outdoor furniture, windsurfer boards, swimming pool pumps, boat hulls, pickup truck caps, and filter housings and spas.

4. CONCLUSIONS

Even here, there is the danger that these sources may not be aware of the many compromises a company must make internally among production, engineering, purchasing, and marketing considerations to produce a product that will sell at a profit. Also, a molder might be inclined to recommend the material that works best in his equipment, rather than the best for the application. Thus, the successful design of plastic parts that have the optimum cost/performance characteristics require learning as much as possible about many different plastics and the peculiarities of their processing. These models are somewhat flawed as they emphasise engineering aspects, and do not stress sufficiently the 'people' aspect and the necessity for a designer to find out about all potential reactions to the solution. In spite of their tendency towards regimentation, the models clearly reflect the iterative nature of design. As each monomer joins with others, the chain length grows until it meets a stray hydrogen, which combines with the reactive end, stopping chain growth at that point. During the polymerization reaction, millions of separate polymer chains grow in length simultaneously, until all of the monomer is exhausted. By adding predetermined amounts of hydrogen (or other chain-stoppers), chemists can produce polymers having a fairly consistent average chain length. Chain length (molecular weight) is important because it determines many properties of a plastic, and it also affects its processing characteristics. The major effects of increasing chain length are increased toughness, creep resistance, stress-crack resistance, melt temperature, melt viscosity, and processing difficulty. However, not all polymer molecules can be manufactured to an exact, specified length, so each batch will have an average molecular-weight distribution. There can be either a broad or a narrow spread between molecular weights of the largest and smallest molecules, and the polymer still could have the same average. A narrow distribution provides more uniform properties; a broad distribution makes a plastic easier to process. Acetal resins are highly crystalline plastics based on formaldehyde polymerization technology. These engineering resins are strong, rigid, and have good moisture, heat, and solvent resistance. Acetals produced in the U.S. include homopolymers by Du Pont Co. (Delrin) and copolymers by Celanese Engineering Plastics Div., Hoechst Celanese Corp. (Celcon) and copolymers by BASF Corporation Plastic Materials (Ultraform). Melting points of the homopolymers are higher, and they are harder, have higher resistance to fatigue, are more rigid, and have higher tensile and flexural strength with generally lower elongation. Some high-molecular-weight homopolymer grades are extremely tough and have higher elongation than the copolymers. Homopolymer grades are available that are modified for improved hydrolysis resistance to 82 °C, similar to copolymer materials. The copolymers remain stable in long-term, high-temperature service and offer exceptional resistance to the effects of immersion in water at high temperatures. Neither type resists strong acids, and the copolymer is virtually unaffected by strong bases. Both types are available in a wide range of melt-flow grades. The copolymers process easier and faster than the conventional homopolymer grades. However, with the introduction in 1987 of Delrin II homopolymer resins, Du Pont claims to have eliminated that difference. The improve moldability is attributed to the use of a new thermal stabilizer, which gives Delrin II the thermal stability of copolymers while retaining the higher properties of the homopolymer. Both the homopolymers and copolymers are available in several unmodified and glass-fiber-reinforced injection-molding grades. Both are available in PTFE or silicone-filled grades, and the homopolymer is available in chemically lubricated low-friction formulations.

5. REFERENCES

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