General information

Overview

One of the cheapest, most versatile and widely used of polymers. PVC faces increasing competition from PP and thermoplastic elastomers.

Strengths

Cheap. Good acid and alkali resistance, inherently flame-retardant. UPVC: stiff and strong, can be transparent, good vapor barrier properties, generally relatively good UV resistance (though shows degradation in strong UV conditions if not stabilized, particularly UPVC and particularly discoloration).PPVC: tough and flexible, transparent, easier to process than UPVC.

Limitations

Processing requires more care than other thermoplastics as overheating will cause rapid degradation. Limited solvent stress cracking resistance. Becomes brittle at 5 °C (40 °F) unless impact modified, low continuous use temperature of 50 °C (120 °F). Will discolor in strong UV conditions if not stabilized (particularly UPVC). PPVC: poorer chemical resistance relative to UPVC, more flammable, properties change with time due to plasticizer migration and leeching, poor heat resistance, some plasticizers can cause environmental stress cracking of other amorphous polymers. Some plasticized materials are susceptible to microbiological attack - requiring expensive fungicides or bactericides to prevent this. Self-extinguishing PVC releases HCl and dioxins when burned. Relatively high density for a thermoplastic.

Designation

Flexible - plasticized. Rigid - unplasticized

Typical uses

Flexible: Simulated leather, seals, gaskets, cable covers, tape, hose, tubing, bottles, sachets, wall covering, flexible floor covering. Rigid: Pipe and pipe fittings, building products, bottles, film; records, floor tiling, soles for industrial footwear, heat-shrinking tubing.

Composition overview

Compositional summary

(CH2CHCl)n

Material family	Plastic (thermoplastic, amorphous)
Base material	PVC (Polyvinyl chloride, rigid, unplasticized)
CAS number	9002-86-2

Effect of composition

Lead stabilizers have long been used in PVC (e.g. tribasic lead sulfate) even for drinking water pipes. However, their use has either been discontinued for certain applications or their amounts reduced in a certain grade due to regulations. They have largely been replaced by soaps or salts of metals such as zinc or cadmium-barium systems (though these presumably present similar toxicity and disposal concerns to lead). For UPVC windows and food packaging applications, aminocrotonate stabilizers have become common. Plasticizers are essentially non-volatile solvents for PVC. The greater the degree of interaction between the plasticizer and the polymer, the more difficult it is to extract the plasticizer with solvents and the higher the brittle point. Phthalate plasticizers (intermediate interaction) are thought to give the best all-round properties. Di-iso-octyl phthalate and dialphanyl phthalate are commonly used as well as the highly volatile and water extractable dibutyl phthalate and di-isobutyl phthalate. Terephthalate plasticizers are also used for their similar properties but lower volatility. In general, as plasticizer content increases, tensile strength, hardness, and cold flex temperature decrease. Lubricants may be added to prevent the compound sticking to processing equipment. Fillers are also often used to reduce tackiness, increase hardness, and reduce cost (e.g. china clay and calcium carbonates). UPVC has a high melt viscosity and the finished product is often too brittle for some applications. Therefore polymeric additives and impact modifiers can be added such as rubbers or ABS. ABS modified materials show severe stress-whitening. Antimony oxide can be used to improve fire retardance. Cross-linked PVC has a better maximum operating temperature and heat distortion temperature though reduced tensile strength, modulus, and oxygen index.

Processing properties

Feedstocks & production

Ethene and chlorine to form 1,2-dichloroethane. Cracked to give vinyl chloride. Approx. 78% of world PVC is polymerized by suspension processes, 14% by emulsion processes, and 8% by mass (bulk) processes.

First commercial production	1933

Available forms

UPVC is usually mixed during processing from powdered raw materials and necessary additives rather than available as ready-to-use compounds. PPVC can come as pellets or powder.

Forming

At the processing temperatures of 150-200 °C (300-390 °F), PVC degrades significantly and relatively quickly, turning from white to yellow, orange, brown, and then black. Degradation past the black stage causes significant adverse changes in mechanical and electrical properties. To prevent this, stabilizers should be used to slow the rate of decomposition. Decomposition is accelerated by the presence of oxygen during processing and by the HCl formed upon decomposition. In general overheating must be avoided during processing, requiring more care than other thermoplastics. The major industrial processing methods are extrusion (of pipes, profiles, and sheet), calendering, and sheet pressing. Only PVC-S or PVC-M resins with appropriate processing aids are suitable for injection or blow-molding. Corrosion resistant surface treatment of equipment is recommended. Very suitable for blow-molding, extrusion, rotational molding, structural foam-molding, and vacuum-forming. UPVC is less suitable for injection molding than PPVC. Dip and electrostatic powder-coating of PPVC for wire coverings.

Machining

Poor machinability (PPVC). Easy to machine (UPVC). Dust not considered an additional health hazard (compared with normal dust).

Joining

Suitable for welding by hot gas, hot plate, ultrasonic, and radio frequency. Particularly good for radio freq. and hot plate welding. Suitable for solvent bonding with tetrahydrofuran or adhesive bonding with PUR or two-component adhesives based on epoxies. Hot plate and friction welds can have strengths up to 97% that of the bulk material. RF welds tend to have 50% or below strength of bulk (though can be higher). Self-tapping screws can be used for rigid PVC.

Surface treatment

Suitable for painting. Urethane or nitrocellulose paints recommended.

Geo-economic data for principal component

Annual world production	4.67e7	-	5.17e7	ton/yr

Notes

Warning

Lead and cadmium based stabilizers present concerns over disposal and general usage due to their toxicity. Some flooring grades also used asbestos fillers though these presumably no longer see use due to disposal issues. PVC produces HCl upon thermal decomposition during processing. Fumes from burning PVC contain HCl and dioxins.

Other notes

PVC-E (emulsion polymerization) grades typically have inferior transparency, water absorption, and electrical properties than PVC-S (suspension polymerization) and PVC-M (mass polymerization). PVC-E has better processability, giving smooth, non-porous surfaces, higher toughness, and low electrostatic chargeability. PVC-S and PVC-M are very pure products (due to the manufacturing processes) and produce very clear, high-quality products with better mechanical and electrical properties, corrosion and weathering resistance than PVC-E. UPVC is physiologically indifferent (as long as non-toxic additives are used).