Phenolics

Description

Image

Caption

1. 1950's telephone made using phenolics. © F_l_a_n_k_e_r at en.wikipedia - (CC BY 3.0) 2. Lamp made using phenolics. © Chris Lefteri

The material

Bakelite, commercialized in 1909, triggered a revolution in product design. It was stiff, fairly strong, could (to a muted degree) be colored, and - above all - was easy to mold. Products that, earlier, were handcrafted from woods, metals or exotics such as ivory, could now be molded quickly and cheaply. At one time the production of phenolics exceeded that of PE, PS and PVC combined. Now, although the ration has changed, phenolics still have a unique value. They are stiff, chemically stable, have good electrical properties, are fire-resistant and easy to mold - and they are cheap.

General properties

Density	77.4	-	82.4	lb/ft^3
Price	0.798			USD/lb
Date first used	1909			

Mechanical properties

Young's modulus	0.4	-	0.701	10^6 psi
Shear modulus	* 0.144	-	0.253	10^6 psi
Bulk modulus	0.754	-	0.783	10^6 psi
Poisson's ratio	* 0.378	-	0.394	
Yield strength (elastic limit)	* 4	-	7.21	ksi
Tensile strength	5	-	9.01	ksi
Compressive strength	* 4.4	-	7.93	ksi
Elongation	1.5	-	2	% strain
Hardness - Vickers	8.3	-	14.9	HV
Fatigue strength at 10^7 cycles	* 2	-	3.6	ksi
Fracture toughness	* 0.716	-	1.1	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 0.00828	-	0.0145	

Thermal properties

Glass temperature		332	-	512	°F
Maximum service temperature	*	392	-	446	°F
Minimum service temperature	*	-190	-	-99.7	°F
Thermal conductor or insulator?		Good insulator			
Thermal conductivity		0.0815	-	0.0878	BTU.ft/h.ft^2.F
Specific heat capacity	*	0.35	-	0.364	BTU/lb.°F
Thermal expansion coefficient		66.7	-	69.4	µstrain/°F

Electrical properties

Electrical conductor or insulator?		Good insulator			
Electrical resistivity		3.3e18	-	3e19	µohm.cm
Dielectric constant (relative permittivity)	*	4	-	6	
Dissipation factor (dielectric loss tangent)	*	0.005	-	0.01	
Dielectric strength (dielectric breakdown)		250	-	399	V/mil

Optical properties

Transparency		Opaque			
Refractive index		1.59	-	1.6	

Processability

Castability		3	-	4	
Moldability		3	-	5	
Machinability		4			
Weldability		1			

Eco properties

Embodied energy, primary production	*	8.16e3	-	9.02e3	kcal/lb
CO2 footprint, primary production	*	3.44	-	3.81	lb/lb
Recycle		✖			

Supporting information

Design guidelines

Phenolic resins hard, tolerate heat and resist most chemicals except the strong alkalis. Phenolic laminates with paper have excellent electrical and mechanical properties and are cheap; filled with cotton the mechanical strength is increases and a machined surface is finer; filled with glass the mechanical strength increases again and there is improved chemical resistance. Fillers play three roles: extenders (such as wood flour and mica) are inexpensive and reduce cost; functional fillers add stiffness, impact resistance and limit shrinkage; reinforcements (such as glass, graphite and polymer fibers) increase strength, but cost increases too. Phenolic resins have creep resistance, and they self-extinguish in a fire. They can be cast (household light and switch fittings) and are available as rod and sheet. Impregnated into paper (Nomex) and cloth (Tufnol), they have exceptional durability, chemical resistance and bearing properties. Phenolics accept paint, electroplating, and melamine overlays.

Technical notes

Phenolic resins are formed by a condensation, generating water in the process, involving a reaction between phenol and formaldehyde to form the A-stage resin. Fillers, colorants, lubricants and chemicals to cause cross-linking are added to form the B-stage resin. This resin is then fused under heat and pressure converting to the final product - a C-stage resin - or completely cross-linked polymer.

Typical uses

Electrical parts - sockets, switches, connectors, general industrial, water-lubricated bearings, relays, pump impellers, brake pistons, brake pads, microwave cookware, handles, bottles tops, coatings, adhesives, bearings, foams and sandwich structures.

Tradenames

Bakelite, Durez, Ferropreg, Fiberite, Norsophen, Plaslok, Plenco, Polychem, Reliapreg, Resinoid, Texolite, Trolitan, Vyncolite, Tufnol

Links

Reference

ProcessUniverse

Producers