



Plastics Topics – Introduction to thermoplastics

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Plastics Topics – Introduction to thermoplastics

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1. A framework for plastics



SEMI-CRYSTALLINE PLASTICS GENERAL PROPERTIES		SEMI-CRYSTALLINE PERFORMANCE PLASTICS	
<p>Distinct & Sharp melting point</p> <p>Higher Specific Gravity</p> <p>Higher Tensile Strength and Tensile Modulus</p> <p>Lower Ductility</p> <p>Higher Creep Resistance</p> <p>Tend to be Translucent or opaque</p> <p>Lower Dimensional Stability</p> <p>Higher fatigue resistance</p> <p>Higher Surface Appearance</p> <p>Difficult to bond using adhesives and solvents</p> <p>Higher Chemical Resistance and Resistance to Stress Cracking</p> <p>Good for bearing and wear, as well as for structural applications</p>	 <p>Random molecular orientation in molten phase but densely packed crystallites in solid phase.</p>	<p>High cost</p> <p>High temperature resistance</p> <p>High strength</p> <p>Outstanding electrical properties</p> <p>Outstanding chemical resistance</p> <p>Low co-efficient of friction</p> <p>Good toughness</p>	<p>Examples</p> <p>PVDF</p> <p>PTFE</p> <p>ECTFE</p> <p>FEP</p> <p>PFA</p> <p>PPS</p> <p>PEEK</p>
AMORPHOUS PLASTICS GENERAL PROPERTIES		AMORPHOUS PERFORMANCE PLASTICS	
<p>Soften over a wide range of temperatures</p> <p>Lower Specific Gravity</p> <p>Lower Tensile Strength and Tensile Modulus</p> <p>Higher Ductility</p> <p>Lower Creep Resistance</p> <p>Tend to be Transparent</p> <p>Higher Dimensional Stability</p> <p>Lower fatigue resistance</p> <p>Higher Surface Appearance</p> <p>Bond well using adhesives and solvents</p> <p>Lower Chemical Resistance and Resistance to Stress Cracking</p> <p>Structural applications only (not for bearing and wear)</p>	 <p>Random molecular orientation in both molten and solid phases.</p>	<p>High cost</p> <p>High temperature resistance</p> <p>High strength and good stiffness</p> <p>High impact resistance</p> <p>Good chemical resistance</p> <p>Hot water and steam resistance</p>	<p>Examples</p> <p>Poly sulphone (PSU)</p> <p>Polyetherimide (PEI)</p> <p>Polyethersulphone (PES)</p> <p>Polyarylsulphone (PAS)</p>
AMORPHOUS PLASTICS GENERAL PROPERTIES		AMORPHOUS PERFORMANCE PLASTICS	
<p>Moderate cost</p> <p>Moderate temperature resistance</p> <p>Moderate strength and stiffness</p> <p>Good impact resistance</p> <p>Good dimensional stability</p> <p>Typically translucent</p> <p>Good optical qualities</p>	<p>Examples</p> <p>PC</p> <p>Modified PPO</p> <p>Modified PPE</p> <p>Thermoplastic Urethane</p>	<p>Low cost</p> <p>Low temperature resistance</p> <p>Low strength and stiffness</p> <p>Good dimensional stability</p> <p>Bond well</p> <p>Typically translucent</p>	<p>Examples</p> <p>PMMA (acrylic)</p> <p>PS</p> <p>ABS</p> <p>PVC</p> <p>PETG</p> <p>CAB</p>
SEMI-CRYSTALLINE ENGINEERING PLASTICS		SEMI-CRYSTALLINE COMMODITY PLASTICS	
<p>Moderate cost</p> <p>Moderate temperature resistance</p> <p>Moderate strength</p> <p>Good impact resistance</p> <p>Good chemical resistance</p> <p>Good bearing and wear properties</p> <p>Low co-efficient of friction</p> <p>Difficult to bond</p>	<p>Examples</p> <p>PA (nylon)</p> <p>POM (Acetal)</p> <p>PET</p> <p>PBT</p> <p>PE-UHMW</p>	<p>Low cost</p> <p>Low temperature resistance</p> <p>Low strength</p> <p>Good toughness</p> <p>Excellent chemical resistance</p> <p>Near zero moisture absorption</p> <p>Good electrical properties</p>	<p>Examples</p> <p>PE-LD</p> <p>PE-HD</p> <p>PP</p> <p>Polyethylpentene (TPX)</p>
IMIDE MATERIALS			
<p>Very high cost</p> <p>Excellent high temperature properties</p> <p>Excellent dimensional stability</p> <p>Low co-efficient of friction</p>		<p>Key Properties</p>	
		<p>EXAMPLES</p> <p>PI</p> <p>PAI</p> <p>PBI</p>	

Figure 1: A framework for thermoplastics

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3. The basic thermoplastics – properties and applications

COMMON POLYMERS - PROPERTIES AND APPLICATIONS		
<p>ABS - Acrylonitrile-Butadiene-Styrene</p> <p>Properties Tough, hard and rigid and can be produced in high gloss colours. Good chemical resistance and low shrinkage. Good electrical properties. Can be electroplated, painted, dyed, and extruded into thin sheets. Moderate strength. Inexpensive. Tendency to stress crack.</p> <p>Applications Telephone handsets, electronic housings, luggage, auto parts, consumer goods, machine parts, computer cases, etc. (electroplated on the inside) and automotive trim.</p>	<p>LCP - Liquid Crystal Polymer</p> <p>Properties Excellent strength but expensive. Good high temperature properties. Can be used in thin walls (as thin as 0.2 mm). Parts are stable up to 335 °C. High chemical resistance and flame retardancy. Very low expansion. High modulus. Tensile from 10 to 24 GPa.</p> <p>Applications High performance engineering applications such as electrical insulators, machine parts, surgical devices.</p>	<p>PET - Polyester</p> <p>Properties Rigid, clear and extremely strong with excellent dimensional stability and high dielectric strength. Moderate chemical resistance. Strong resistance to acids and bases, not notch sensitive, not for outdoor use or in hot water.</p> <p>Applications Carbonated drink bottles, video and audio tapes, clothing and handles.</p>
<p>EP - Epoxy</p> <p>Properties Rigid, clear and tough with good chemical resistance. Air curable, highly fillable, with low shrinkage and low susceptibility to moisture. High tensile strength. High heat resistance. High modulus. Good electrical properties. Odourless, tasteless, low flammability. Systems can be formulated to meet specific requirements.</p> <p>Applications Adhesives, coatings, encapsulation compounds, aerospace applications.</p>	<p>MF - Melamine formaldehyde</p> <p>Properties Hard, opaque (but wide colour range), tough with high surface hardness and scratch resistance. High resistance to water, high temperature, and shrinkage. Easy to crack.</p> <p>Applications Decorative laminates, lighting fixtures, picnic ware, toilet seats, general purpose components, electrical insulators, food containers (e.g. dishes).</p>	<p>PF - Phenol formaldehyde (Phenolic)</p> <p>Properties Hard brittle opaque strength and can be filled with wood fillers such as wood pulp and cellulose. Good electrical insulation. High chemical and heat resistance.</p> <p>Applications Ashtrays, lamp holders, saucers, handles and early consumer electronic components such as radio and radios.</p>
<p>PE - Polyethylene (Low Density: PE-LD, Linear Low Density: PE-LLD, High Density: PE-HD)</p> <p>Properties PE is really a family of polymers and all have varying properties. Flexible, translucent with a waxy feel and at low temperatures and low cost. PE-HD: Semi-rigid, tough, good chemical resistance with low absorption and low cost.</p> <p>Applications PE applications vary with the type of material. PE-LD/PE-LLD: Squeeze bottles, toys, carrier bags, packaging, and pipes. PE-HD: Kitchen ware, chemical drums, and wrapping materials. Car petrol tanks.</p>	<p>PA - Polyamide (Nylon)</p> <p>Properties Rigid translucent and tough with moderate strength. Inexpensive but poor dimensional stability due to water absorption (nature). Available in many different forms and properties can be significantly improved by the use of glass fillers. Generally resistant to fuels and oils (dependent on type of PA used). Steam sterilisable.</p> <p>Applications Gear wheels, zips, bearings, pressure tubing, kitchen utensils and blow mouldings, and clothing fabrics.</p>	<p>PI - Polyimide (Aramids)</p> <p>Properties Rigid, opaque with high impact and dielectric strength. High heat resistance (to 400°C intermittent), and a thermal expansion at low temperature.</p> <p>Applications Bearing materials, thrust washers, and semiconductor water dams.</p>
<p>EVAL - Ethylene vinyl alcohol</p> <p>Properties Flexible and tubular. EVAL films are hydrophilic, crystal clear, glossy and do not need special anastatic treatments. Good barrier properties for gases and aromatic materials. Its permeability depends on temperature and humidity. It has a glass transition from 70 to 70°C. High coefficient of friction.</p> <p>Applications Flexible tubing for various applications from beer tubing to vacuum cleaner hoses. Packaging of textiles. EVAL powder coatings are used in chemical plants, buildings, steel structures, and firestone engineering.</p>	<p>PEEK - Polyether ether ketone</p> <p>Properties High tensile and flexural strength, high impact strength, and high fatigue limit. High heat distortion temperature. High electrical properties. Good electrical properties, good slip and wear characteristics, and low flammability. Easy to machine. Thermal stability. Treatment of injection moulding.</p> <p>Applications Microscope girds, nuclear reactor components, surgical tools.</p>	<p>PMMA - Polymethyl methacrylate</p> <p>Properties Hard, rigid, glass clear with good weather resistance and can be used in casting, thermoforming and fabricating.</p> <p>Applications Signs and leaflet dispensers, automotive lens clusters, lighting diffusers.</p>
<p>PB - Polystyrene</p> <p>Properties Semi-rigid, tough with low temperature, high abrasion resistance, high chemical resistance to water and to stress cracking. Good barrier properties but has poor handling in the form of semi-finished products. Can be processed after processing because of the softening of the start of rearrangement.</p> <p>Applications Boiling-bag films, industrial pipes, tubes and sheets. Used for central heating system because of good resistance to hot water.</p>	<p>PP - Polypropylene</p> <p>Properties High lubricity and high resistance to living hinges), excellent chemical resistance, and high solvent resistance. Can be sterilised by steam and has good heat resistance. It is inexpensive and difficult to paint. It is attacked by sulfuric acid and degraded by UV and ionising radiation.</p> <p>Applications Sterilisable hospital ware, syringes, beakers, and parts for auto vacuum flasks.</p>	<p>POM - Polyacetal (Acetal)</p> <p>Properties Rigid, translucent and tough with good spring like qualities. It has good dimensional stability and resistant to creep and fatigue. High abrasion and chemical resistance.</p> <p>Applications Business machine, toys, valves, clock and watch parts and bearings.</p>
<p>PPS - Polyphenylene sulfide</p> <p>Properties High temperature resistance with non-burning continuous use at 240°C, low temperature endurance, good flame retardance, and flame retardance.</p> <p>Applications Chemical pumps, high performance electrical medical components and automotive parts.</p>	<p>PP - Polypropylene</p> <p>Properties High lubricity and high resistance to living hinges), excellent chemical resistance, and high solvent resistance. Can be sterilised by steam and has good heat resistance. It is inexpensive and difficult to paint. It is attacked by sulfuric acid and degraded by UV and ionising radiation.</p> <p>Applications Sterilisable hospital ware, syringes, beakers, and parts for auto vacuum flasks.</p>	<p>PTFE - Polytetrafluoroethylene and other fluoroplastics (FEP, PFA, CTFE, ECTFE, ETFE)</p> <p>Properties Semi-rigid, translucent with excellent low coefficient of friction and excellent chemical resistance. High temperature and low temperature toughness (to -160°C). Good weathering resistance and electrical properties. Low thermal strength. Expensive.</p> <p>Applications Non-stick coatings, gaskets, bearings, high and low temperature electrical and medical products, other uses needing excellent dielectric chemical, and temperature resistance.</p>
<p>PVC - Polyvinyl chloride</p> <p>Properties PVC is one of the most versatile of all polymers. The polymer cannot be state but it can create an enormous range of properties from rigid products (window frames) through to flexible sheets and hoses. PVC is easy to process. Rigid grades have a high dielectric strength, outdoor stability, chemical resistance, stability and low cost. Material has low heat resistance.</p> <p>Applications Pipes and fittings, cable insulation, window profiles, extruded film and sheet, and medical applications.</p>	<p>PET - Polyester</p> <p>Properties Rigid, clear and extremely strong with excellent dimensional stability and high dielectric strength. Moderate chemical resistance. Strong resistance to acids and bases, not notch sensitive, not for outdoor use or in hot water.</p> <p>Applications Carbonated drink bottles, video and audio tapes, clothing and handles.</p>	<p>PU - Polyurethane</p> <p>Properties Flexible, clear, highly elastic with high impact resistance, dielectric strength, and abrasion resistance. Can be made into films, solid mouldings, or flexible foams. Outdoor exposure turns brittle, to crum.</p> <p>Applications Soles and heels for sports shoes, automotive structural members, computer furniture, seals and gaskets, skateboard packaging and foams.</p>
<p>SI - Silicone</p> <p>Properties Possesses dimensional stability and good electrical and dielectric properties over wide frequency and temperature ranges. It has flame resistance, low water absorption, moderate thermal shock resistance, and average polymeric mechanical strength. It has a high cost limited shelf-life, and a long curing time.</p> <p>Applications Computer chips, IC cooking ware, and food containers, high performance window seals.</p>	<p>PP - Polypropylene</p> <p>Properties High lubricity and high resistance to living hinges), excellent chemical resistance, and high solvent resistance. Can be sterilised by steam and has good heat resistance. It is inexpensive and difficult to paint. It is attacked by sulfuric acid and degraded by UV and ionising radiation.</p> <p>Applications Sterilisable hospital ware, syringes, beakers, and parts for auto vacuum flasks.</p>	<p>SI - Silicone</p> <p>Properties Possesses dimensional stability and good electrical and dielectric properties over wide frequency and temperature ranges. It has flame resistance, low water absorption, moderate thermal shock resistance, and average polymeric mechanical strength. It has a high cost limited shelf-life, and a long curing time.</p> <p>Applications Computer chips, IC cooking ware, and food containers, high performance window seals.</p>
<p>SAN - Styrene acrylonitrile</p> <p>Properties Rigid, transparent and tough, resistant to stress cracking and crazing.</p> <p>Applications Sterilisable hospital ware, medical syringes, beakers, and parts for auto vacuum flasks.</p>	<p>PVC - Polyvinyl chloride</p> <p>Properties PVC is one of the most versatile of all polymers. The polymer cannot be state but it can create an enormous range of properties from rigid products (window frames) through to flexible sheets and hoses. PVC is easy to process. Rigid grades have a high dielectric strength, outdoor stability, chemical resistance, stability and low cost. Material has low heat resistance.</p> <p>Applications Pipes and fittings, cable insulation, window profiles, extruded film and sheet, and medical applications.</p>	<p>SI - Silicone</p> <p>Properties Possesses dimensional stability and good electrical and dielectric properties over wide frequency and temperature ranges. It has flame resistance, low water absorption, moderate thermal shock resistance, and average polymeric mechanical strength. It has a high cost limited shelf-life, and a long curing time.</p> <p>Applications Computer chips, IC cooking ware, and food containers, high performance window seals.</p>

Figure 2: Properties and applications of thermoplastics and thermosets

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4. Process selection for thermoplastics

Every processing method has limitations and advantages. Use Table 1 to select the right process for your product.

Process Feature	Injection Moulding	Extrusion	Blow Moulding	Rotational Moulding	Thermoforming
Equipment Cost	High	High	High	Moderate	Moderate
Tooling Cost	High	Moderate	Moderate	Low	Low
Cycle Time	<1 min	Continuous	<1 min	>3 min	1-3 min
Economic Quantity	>10K	>5Km	>10K	100 - 10K	100 - 10K
Precision	Good	Good	Moderate	Moderate	Low
Wall Thickness Control	Yes	Yes	No	No	No
Open-ended Hollows	Yes	No	Yes	Yes	Yes
Enclosed Hollows	No	No	Yes	Yes	No
Very Small Items	Yes	No	No	No	No
Complicated/ Intricate Shapes	Yes	Yes	Yes	No	No
Large Enclosed Volumes	No	No	Yes	Yes	No
Inserts	Yes	No	No	Yes	No
Moulded-in Holes	Yes	No	No	No	No
Threads	Yes	No	Yes	No	No

Table 1: Processing methods for thermoplastics

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5. Materials selection for the process

Not every material is suitable for every process. Use Table 2 to select the best material for the process.

Process Material	Injection Moulding	Extrusion	Blow Moulding	Rotational Moulding	Thermoforming
ABS	Yes	Yes	No	Yes	Yes
EVA	No	No	No	Yes	No
PA	Yes	Yes	No	Yes	No
PC	Yes	Yes	Yes	No	Yes
PE-LD	Yes	Yes	Yes	Yes	No
PE-HD	Yes	Yes	Yes	Yes	No
PMMA	Yes	Yes	No	No	Yes
POM	Yes	Yes	Yes	No	No
PP	Yes	Yes	Ye	No	Yes
PS / PS-HI	Yes	Yes	Yes	Yes	Yes
PVC-U	Yes	Yes	Yes	Yes	Yes
PVC-P	Yes	Yes	Yes	Yes	Yes
SAN	Yes	Yes	Yes	No	No

Table 2: Materials and processes