

# **High Performance Thermoplastics**

## ***Materials, properties and applications.***

*Prepared by the IAPD Education Committee (Module 5)*

*Presented courtesy of Modern Plastics. Inc.*



IAPD THERMOPLASTICS RECTANGLE

IMIDE MATERIALS				
<p><b>Key Characteristics:</b>                      Very High Cost Per Pound                      Excellent Properties Above 400°F                      Excellent Electrical Properties                      Excellent Dimensional Stability                      Low Coefficient of Friction</p>		<p><b>Materials:</b>                      PI                      PAI                      PBI</p>		
AMORPHOUS PLASTICS	AMORPHOUS HIGH PERFORMANCE PLASTICS		SEMI-CRYSTALLINE HIGH PERFORMANCE PLASTICS	
	<p><b>Key Characteristics:</b>                      High Cost                      High Temperature                      High Strength &amp; Good Stiffness                      Good Chemical Resistance                      Transparency                      Hot Water &amp; Steam Resistance</p>	<p><b>Materials:</b>                      Polysulfone                      Polyetherimide                      Polyethersulfone                      Polyarylsulfone</p>	<p><b>Key Characteristics:</b>                      High Cost                      High Temperature                      High Strength                      Good Electrical Properties                      Outstanding Chemical Resistance                      Low Coefficient of Friction                      Good Toughness</p>	<p><b>Materials:</b>                      PVDF                      PTFE                      ECTFE                      FEP                      PFA                      PPS                      PEEK</p>
	AMORPHOUS ENGINEERING PLASTICS		SEMI-CRYSTALLINE ENGINEERING PLASTICS	
	<p><b>Key Characteristics:</b>                      Moderate Cost                      Moderate Temperature Resistance                      Moderate Strength                      Good Impact Resistance                      Translucency                      Good Dimensional Stability                      Good Optical Qualities</p>	<p><b>Materials:</b>                      Polycarbonate                      Modified PPO                      Modified PPE                      Thermoplastic Urethane</p>	<p><b>Key Characteristics:</b>                      Moderate Cost                      Moderate Temperature Resistance                      Moderate Strength                      Good Chemical Resistance                      Good Bearing and Wear Properties                      Low Coefficient of Friction                      Difficult to Bond</p>	<p><b>Materials:</b>                      Nylon                      Acetal                      PET                      PBT                      UHMW-PE</p>
	AMORPHOUS COMMODITY PLASTICS		SEMI-CRYSTALLINE COMMODITY PLASTICS	
	<p><b>Key Characteristics:</b>                      Low Cost                      Low Temperature Resistance                      Low Strength                      Good Dimensional Stability                      Bond Well                      Typically Transparent</p>	<p><b>Materials:</b>                      Acrylic                      Polystyrene                      ABS                      PVC                      PETG                      CAB</p>	<p><b>Key Characteristics:</b>                      Low Cost                      Low Temperature Resistance                      Low Strength                      Excellent Chemical Resistance                      Low Coefficient of Friction                      Near Zero Moisture Absorption                      Very Good Electrical Properties                      Good Toughness</p>	<p><b>Materials:</b>                      Polyethylene                      Polypropylene                      Polymethylpentene(TPX)</p>
AMORPHOUS PLASTICS KEY CHARACTERISTICS:		SEMI-CRYSTALLINE PLASTICS KEY CHARACTERISTICS:		
<p>Soften Over a Broad Range Of Temperatures                      Easy to Thermoform                      Tend to Be Transparent                      Bond Well Using Adhesives and Solvents                      Prone To Stress Cracking                      Poor Fatigue Resistance                      Structural Applications Only (Not for Bearing &amp; Wear)</p>		<p>Sharp Melting Point                      Difficult to Thermoform                      Tend to Be Opaque                      Difficult To Bond Using Adhesives and Solvents                      Good Resistance To Stress Cracking                      Good Fatigue Resistance                      Good For Bearing and Wear, As Well As Structural Applications</p>		



# Imidized Plastics

## *Key Characteristics*

- Very high cost per pound
- Excellent properties above 204°C/400°F
- Excellent electrical properties
- Excellent dimensional stability
- Low coefficient of friction (COF)

# Imidized Plastics

## *Materials*

- Polyimide (PI)
- Polyamide Imide (PAI)
- Polybenzimidazole (PBI)

# **Polyimide (PI)**

## *Strengths*

- Excellent high temperature mechanical performance
- Very high tensile and compressive strength
- Outstanding bearing and wear properties
- Very high purity
- Good chemical resistance

# **Polyimide (PI)**

## *Limitations*

- Low physical properties
- Poor in high temp applications
- Cost

# **Polyimide (PI)**

## *Applications*

- Aerospace
- Semiconductor
- Electrical/electronic
- Transportation
- Off highway equipment
- Pump and valve
- Hydraulics
- Automotive
- Textile
- Clean rooms

# **Polyamide-imide (PAI)**

## *Strengths*

- Good stiffness and strength
- Good creep resistance
- Inherently flame retardant
- Good chemical resistance
- Good wear resistance
- Good friction properties
- Versatile

# **Polyamide-imide (PAI)**

## *Limitations*

- Molding limitations
- High temperature limitations
- Post curing may be required
- Very high cost

# Polyamide-imide (PAI)

## *Applications*

- Computer wafer handling units
- Bearings
- Compressor vanes
- Lantern rings
- Pump housings
- Hydraulic components
- Glass handling parts
- Seals
- High temperature electrical connectors
- Gears
- Semiconductor test sockets
- Insulators
- Transmission seal rings

# **Polybenzimidazole (PBI)**

## *Strengths*

- Outstanding heat resistance and mechanical property retention at temperatures above 204°C /400°F
- Excellent wear resistance
- Excellent load bearing capabilities
- Low COF
- “Clean”

# **Polybenzimidazole (PBI)**

## *Limitations*

- Not available as a resin
- Not processed by conventional techniques
- Not good in hot, aqueous solutions

# **Polybenzimidazole (PBI)**

## *Applications*

- Protective clothing
- Aircraft furnishings
- Thermal insulators
- Electrical connectors
- Seals

# **Amorphous High Performance Thermoplastics**

## *Key Characteristics*

- Thermal stability
- Cost effective high-performance materials
- Toughness
- High heat deflection temperatures
- Good chemical resistance
- Transparency
- Hot water and steam resistance
- Good radiation stability
- FDA compliant grades available

# **Amorphous High Performance Thermoplastics**

## *Materials*

- Polysulfone (PSU)
- Polyetherimide (PEI)
- Polyether Sulfone (PES)
- Polyaryl Sulfone (PAS)

# **Polysulfone (PSU)**

## *Key Characteristics*

- Self-extinguishing
- Good electrical properties
- Good chemical resistance
- High heat distortion temperature
- High melt viscosity
- Tendency toward jetting

# **Polysulfone (PSU)**

## *Applications*

- High temperature
- Electrical
- Reverse osmosis

# **Polyetherimide (PEI)**

## *Key Characteristics*

- High heat resistance
- High strength and rigidity
- Low smoke generation
- Outstanding electrical properties
- Good chemical resistance
- Excellent hydrolysis resistance
- Good processability

# **Polyetherimide (PEI)**

## *Applications*

- Electrical
- Automotive
- Aircrafts
- Large, flat parts

# **Polyether Sulfone (PES)**

## *Key Characteristics*

- Self-extinguishing
- Stable over a wide range of temperatures
- High temperature resistance
- Little smoke when burned

# **Polyether Sulfone (PES)**

## *Applications*

- Aircraft interior parts
- Electrical
- Automotive
- Medical
- Consumer

# **Polyaryl Sulfone (PAS)**

## *Key Characteristics*

- Excellent oxidative stability
- Very good chemical resistance
- Sensitive to some materials

# **Polyaryl Sulfone (PAS)**

## *Applications*

- Electrical

# **Semi-Crystalline High Performance Thermoplastics**

## *Key Characteristics*

- High cost
- High temperature resistance
- High strength
- Good electrical properties and toughness
- Outstanding chemical resistance
- Low COF

# Semi-Crystalline High Performance Thermoplastics

## *Materials*

- Polyphenylene sulfide (PPS)
- Polyetheretherketone (PEEK)
- Fluoropolymers
  - Fluorinated ethylene propylene (FEP)
  - Ethylene chlorotrifluoroethylene (ECTFE)
  - Ethylene tetrafluoroethylene (ETFE)
  - Polychlorotrifluoroethylene (PCTFE)
  - Polytetrafluoroethylene (PTFE)
  - Polyvinylidene fluoride (PVDF)
  - Perfluoroalkoxy (PFA)

# **Polyphenylene Sulfide (PPS)**

## *Key Characteristics*

- High temperature resistance
- High strength resistance
- High chemical resistance
- Flame resistance
- 40 percent glass filled available
- Suffers from brittleness (overcome by above)

# **Polyphenylene Sulfide (PPS)**

## *Applications*

- Automotive (under hood)
- Electrical (lamp sockets, fuse holders)
- Semi-conductor manufacturing
- Oil and gas (valves, seals, pump housing)
- Nuclear

# **Polyetheretherketone (PEEK)**

## *Key Characteristics*

- Excellent environmental resistance
- Excellent wear resistance
- Excellent creep, fatigue and modulus
- Radiation resistance
- Low flammability
- Low smoke emission
- Low toxic gas emission
- Tribological grade available

# **Polyetheretherketone (PEEK)**

## *Applications*

- Transportation
- Industrial
- Medical
- Food contact
- Semiconductor products



# **Fluoropolymers**

## *Key Characteristics*

- Superior flammability properties
- Excellent heat resistance properties
- Chemical resistance
- Very low COF
- Good dielectric properties

# Fluoropolymers

## *Materials*

- Fluorinated ethylene propylene (FEP)
- Ethylene chlorotrifluoroethylene (ECTFE)
- Ethylene tetrafluoroethylene (ETFE)
- Polychlorotrifluoroethylene (PCTFE)
- Polytetrafluoroethylene (PTFE)
- Polyvinylidene fluoride (PVDF)
- Perfluoroalkoxy (PFA)

# **Fluorinated Ethylene Propylene (FEP)**

## *Key Characteristics*

- Low friction properties
- Low dielectric constant
- Low gas permeability
- Good chemical resistance
- Mechanical properties similar to PTFE
- High melt viscosity

# **Ethylene Chlorotrifluoroethylene (ECTFE)**

## *Key Characteristics*

- Good flame resistance
- Better wear properties than PTFE
- Relatively high tensile strength
- Very smooth surface
- Combines abrasion resistance with good impact strength

# **Ethylene Tetrafluoroethylene (ETFE)**

## *Key Characteristics*

- Relatively high melting point (270°C/518°F)
- High use temperature
- Good abrasion resistance
- Good impact strength

# **Polychlorotrifluoroethylene (PCTFE)**

## *Key Characteristics*

- Outstanding barrier properties
- High optical transparency
- High stress crack resistance

# **Polytetrafluoroethylene (PTFE)**

## *Key Characteristics*

- Lowest COF
- Excellent low loss characteristics
- Exceptional resistance to most chemicals
- High limiting oxygen index
- High impact strength



# **Polyvinylidene Fluoride (PVDF)**

## *Key Characteristics*

- Good chemical resistance
- Good weather resistance
- Not suitable for polar solvents or caustic solutions
- Relatively low cost
- Will not burn in air
- High purity grades available

# **Perfluoroalkoxy (PFA)**

## *Key Characteristics*

- Higher maximum use temperature (over FEP)
- Reduced creep (over FEP)
- Lower melt viscosity (over FEP)

# Fluoropolymers

## *Applications*

- Chemical processing
- Pulp and paper
- Oil and gas
- Cable and wire
- Outdoor signs
- Coatings
- Decorative film



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