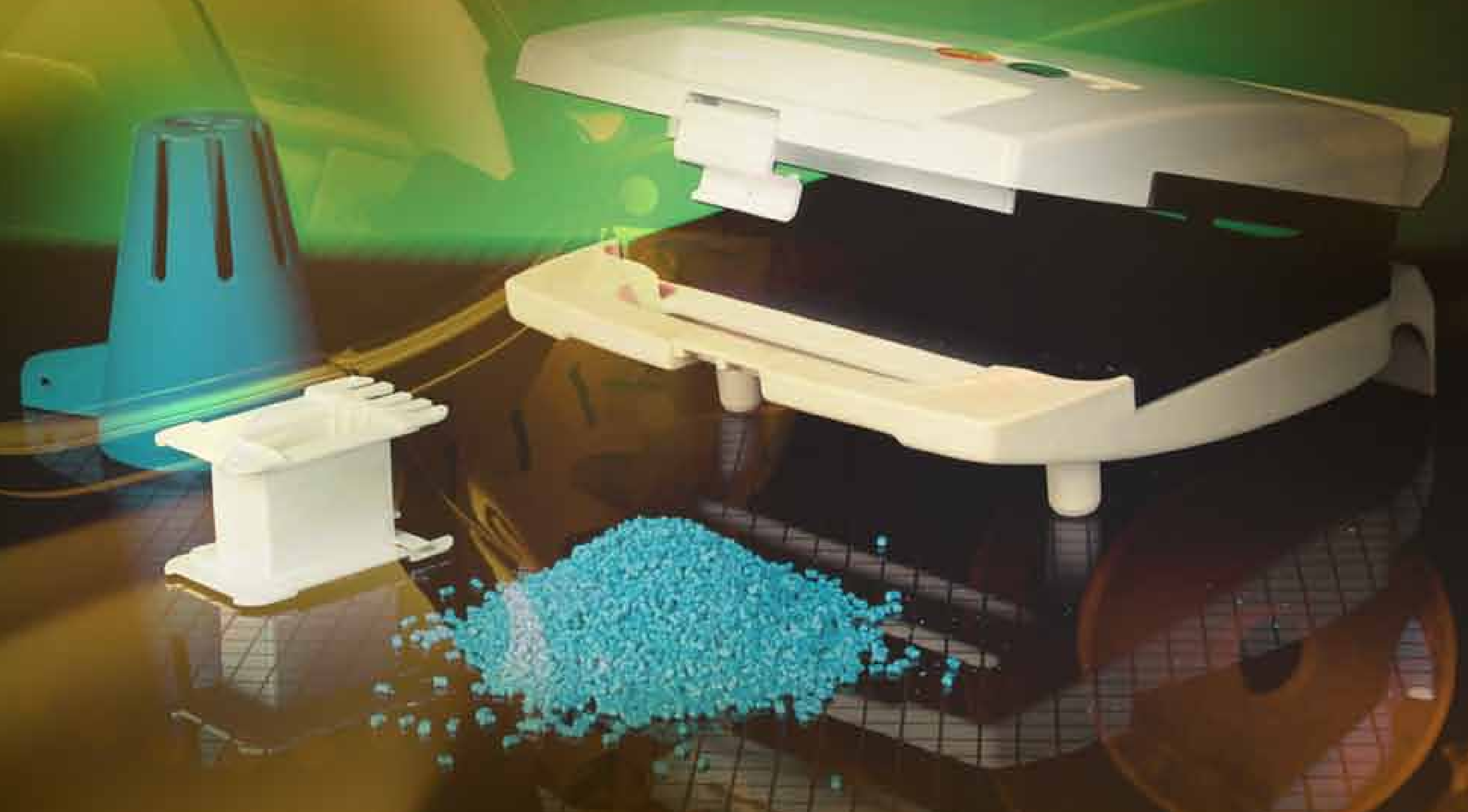


NAN YA PET Engineering Plastics

High Rigidity · Heat Resistant · High Tensile Strength ·
Impact Resistant · Stability · High Moldability

Introduction

PET melting temperature is at 260℃ . Besides being obtained through Purified Terephthalic Acid(PTA) reactions, PET can also be obtained through Dimethyl terephthalate(DMT) reactions. Also, through molecular extensions, PET can possess excellent strengths, hence besides being used extensively in synthetic fibers, PET is in great demand for film extensions and blow bottles. As PET is already in mass production, PET costs are reduced.

As for the development of PET engineering plastics, development occurred later than synthetic fibers. Its primary features are excellent heat resistance, rigidity and low costs. As the addition of glass fibers to PET has a good reinforcing effect, to maximize the advantages of heat resistance, rigidity and low costs of PET plastics, current engineering plastic PET are glass fiber reinforced PET. Despite its advantages in heat resistance, rigidity and low costs, its crystal formation speed is slower than Nylon, POM, and PBT, thus affecting its efficiency in molding and PET demands. In recent years, NAN YA PLASTICS has devoted considerable efforts to improve the crystal forming speed of PET and have developed some PET engineering plastics with improved crystal forming speeds. In the future, PET engineering plastics demands will increase significantly with improvements in crystal forming speed.

NAN YA PET Engineering Plastics Characteristics

1. Excellent Strength and Rigidity.
2. Excellent Heat Deflection.
3. Excellent Balance of Impact Strengths.
4. Excellent Electrical Resistance.

NAN YA PET APPLICATION

From the above properties, it can be observed that NAN YA PET has a wide range of applications, as listed below:

Electrical and Electronics	Circuit relay base, electrical appliances, toaster upper covers and lower covers, electric iron bases and motor casings.
Automotive Industry	Car ceiling window frames, ignition components, gears, carburetor components, diesel filters, ignition components, and carburetors.
Other Industries	Vacuum cleaner components, lamp bases, wire reels, and electricity distribution casings.
Others	Lamp shades, glue gun casings, and lamp casings.

PHYSICAL PROPERTIES

♦ Excellent Glass Fiber Reinforcement Effects

The addition of glass fibers, ore fibers, mica powder and talcum powder can reinforce the molding and physical properties of PET as shown in Table 1.

Table 2 shows the effects of different compositions of reinforcing materials on PET physical properties. Differences between adding glass fiber and ore fiber together and separately can be observed. Although reinforcement effect of adding both glass fiber and ore fiber is smaller, the addition of both fibers results in less anisotropy and reduced warpage. The addition of glass fibers creates a significant reinforcing effect. Table 3 compares the physical properties of non-reinforced PET and 30% glass fiber reinforced PET. From the table, the addition of 30% glass fiber increases the tensile strength by 3 times, allowing Flexural Strength to increase by 3.8 times, Impact Resistance by 2.5 times and Heat Deflection Temperature by 139℃ . (Under load of18.6kg/cm^2)

Table 1: Influence of Reinforcement Materials on PET Physical Properties

Models	Pros	Cons
Molding	1. May reduce molding cycle. 2. Improved product release.	1. Increased Abrasion on molding machine and molds. 2. Decreased flowability of plastic melting flow.
Properties	1. Increased mechanical properties such as tensile strength, impact strength and rigidity. 2. Increased heat deflection temperature. 3. Reduced heat expansion index. 4. Improved dimensional stability and reduced shrinkage	1. Increase in specific gravity. 2. Product appearance turns coarse. 3. Thermal properties and mechanical properties show anisotropy.

Table 2: Influence of addition of different reinforcing materials on PET

Models	Unit	Flow Direction	Horizontal Direction
Glass fiber 30%	Tensile Strength (kg/ cm^2)	1,500	1,000
	Elongation %	2.9	3.2
Ore fiber / glass fiber composite 30%	Tensile Strength (kg/ cm^2)	890	720
	Elongation %	2.4	2.2

Table 3: Influence of addition of reinforcing materials on PET Physical Properties

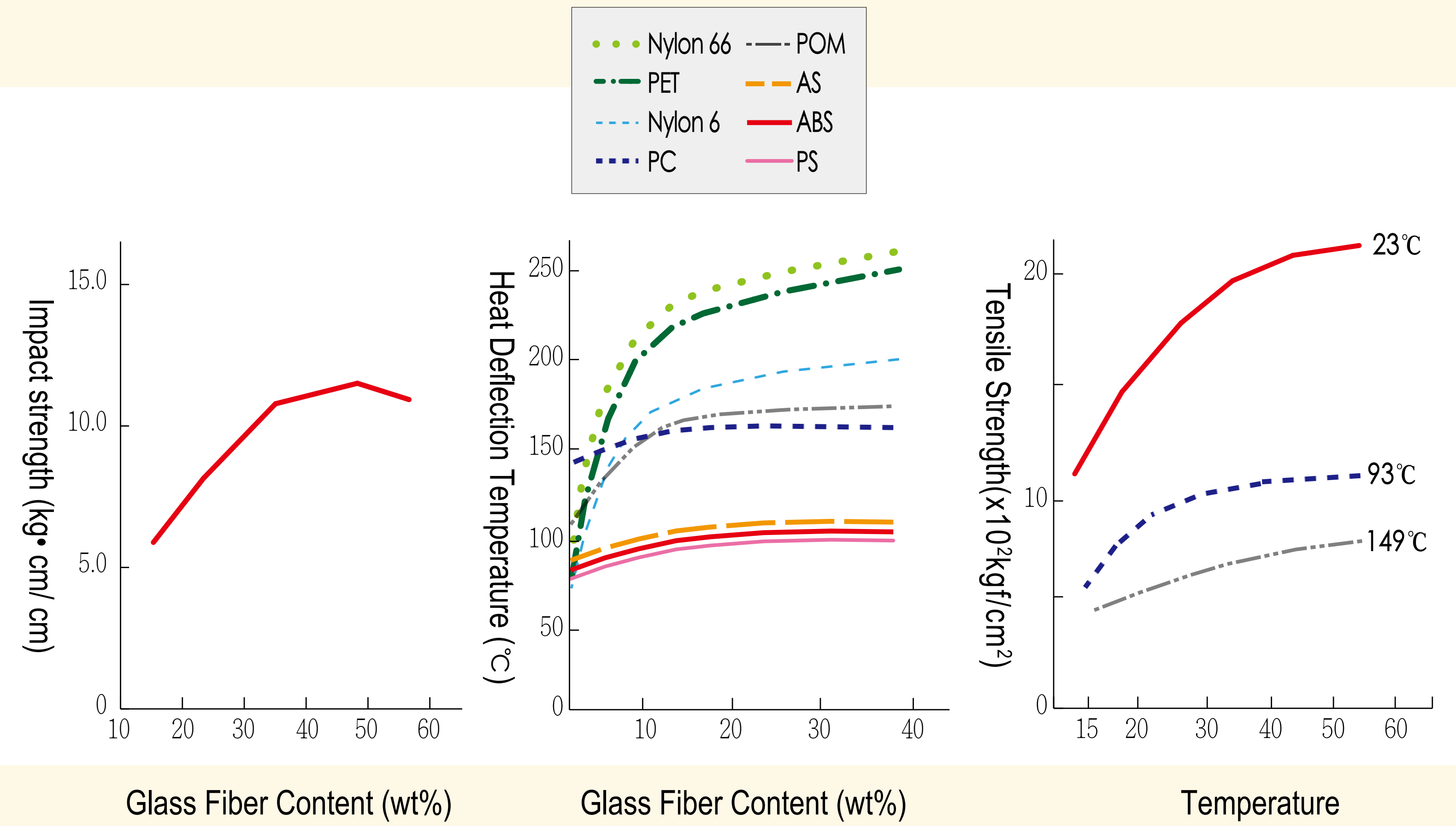
Models		No addition of Glass Fiber	Addition of 30% Glass Fiber
Glass Fiber Content	%	0	30
Specific Gravity		1.38	1.56
Tensile Strength	kg/ cm^2	540	1,620
Elongation	%)	200	2.7
Flexural Strength	kg/ cm^2	Not damaged	2,600
Flexural Modulus	kg/ cm^2	24,000	91,400
NI Impact	kg•cm/ cm	4	10.3
Heat Deflection Temperature	18.6kg/ cm^2	85	224
Rockwell Hardness	ROCKWELL	M106	M100

PHYSICAL PROPERTIES

Graphs 1, 2 and 3 show the increase of PET Impact Strength, Heat Deflection Temperature and Tensile Strength, respectively after addition of glass fiber.

♦ Heat Resistance

Glass Fiber reinforced PET Engineering Plastic (FR-PET) has excellent heat resistance feature. As shown in Table 4, FR-PET has higher melting points and heat deflection temperatures. Table 5 shows that flame resistant grade FR-PET has a higher long-term working temperature than other flame-resistant grade engineering plastics.



Graph 1:
Influence of glass fiber content on PET impact strength

Graph 2:
Influence of Glass Fiber Content on PET Heat Deflection Temperature

Graph 3:
Influence of Glass Fiber on PET Tensile Strength

Table 4: Thermal Characteristics of FR-PET Engineering Plastics

% of Glass Fiber Added		30	35	35
Melting point	℃	254	254	254
Heat Distortion Temperature	18.6kg/ cm^2	224	226	229
	4.6kg/ cm^2	247	248	249
Thermal Conductivity	W/m.K	0.29	0.32	0.33
Linear Expansion Index	10^{-5}/m/m/℃	2.7	2.3	1.1

Table 5: Long-term Working Temperature of Flame Resistant Grade Engineering Plastics

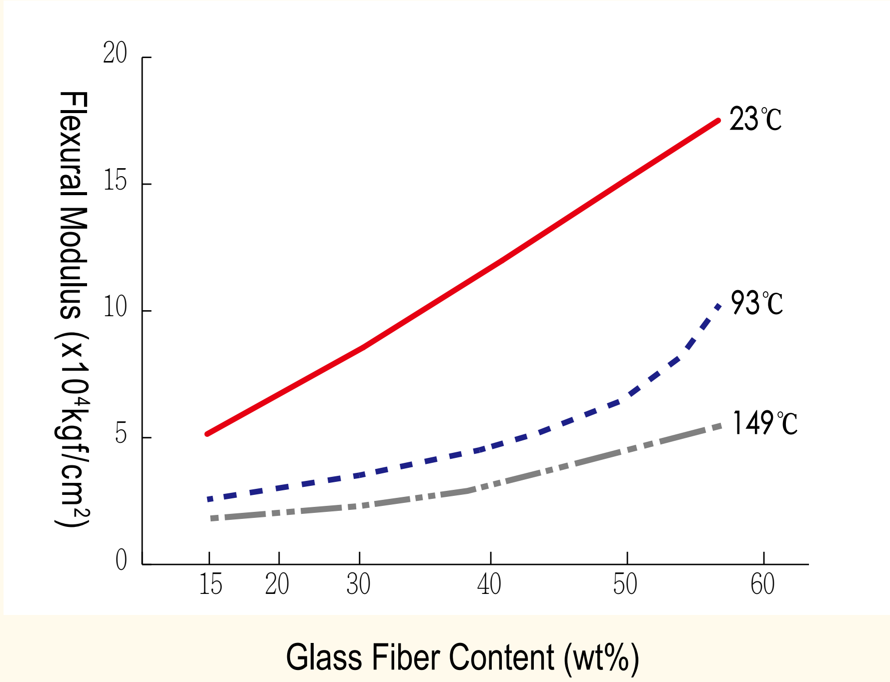
Engineering Plastic Type	UL Long-term Working Temperature		
	Electrical Characteristics	Mechanical Properties	
		With Impact	Without Impact
FR-PET	150	150	150
PBT	140	130	140
Nylon 66	130	115	115
Modified PPE	110	105	110
PSF	160	140	160
PEI	170	170	170
PPS	200	200	220

♦ Rigidity

High rigidity is another characteristic of FR-PET besides heat resistance. When compared to PBT engineering plastics of similar nature, rigidity of FR-PET is higher than PBT with similar glass fiber content by 30%. Due to its rigidity, it is acknowledged as one of the materials suitable for producing products with smaller thickness. The higher the Flexural Modulus, the higher rigidity will be. Taking 55% glass fiber reinforced FR-PET for example, its Flexural Modulus can reach 180,000kg/cm2, about ¼ of aluminum alloy. Other commonly used engineering plastics are unable to reach this rigidity without adding ore fibers.

♦ Excellent Electrical Resistance

FR-PET has similar electrical resistance as PBT and is used as insulation material for electrical and electronic appliances (as shown in Table 6).



Graph 4: Relation of glass fiber content in FR-PET and flexural modulus

Table 6: FR-PET Electrical Properties

Electrical Properties	Units	4210G6 (GF 30%)	4210G9 (GF 45%)
Volume Resistivity	Ω.cm	10^{15}	10^{15}
Surface Resistivity	Ω/sq	10^{14}	10^{13}
Dielectric strength (1.59mm)	Kv/mm	23	22
Dielectric Constant			
10^3Hz	–	3.8	4.1
10^6Hz	–	3.7	4.0
Dielectric Tangent			
10^3Hz	–	0.011	0.009
10^6Hz	–	0.018	0.017
Arc Resistance	s	125	125
High Voltage Tracking Resistance	mm/min	22.3	12.7

♦ Chemical Resistance:

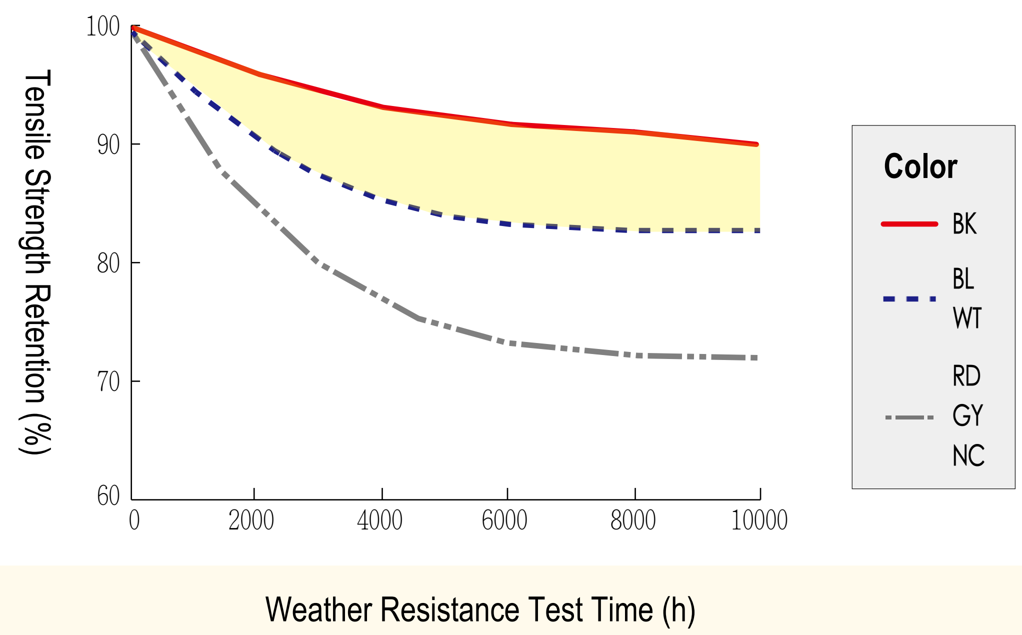
As reinforced PET resin belongs to the polyester class, it will react with strong acids, alkaline and water vapor in hydrolysis reactions. This is a common symptom in all polyesters. But reinforced PET resins have excellent resistance against organic solvents and oils. (Shown in Table 7)

♦ Weather Resistance:

FR-PET resin has excellent weather resistance. Graph 5 shows that after 10,000 hour test in the weather test simulator, the colored FR-PET retains tensile strength better than the non-colored version.

Table 7: FR- PET Chemical Resistance

Medicament	Aluminum	Zinc Alloy	PC	GR-PC	GR-PET
Acid	X	X	○	○	○
Alkali	X	X	X	X	X
Hot Water	○	○	X	X	X
Vegetable Oil	○	○	○	○	○
Seawater	X	○	○	○	○
Organic Acids	X	○	○	○	○
Aromatic Hydrocarbons	○	○	X	X	○
Halogen Hydrocarbons	○	○	X	X	○
Alcohol	X	○	○	○	○



Graph 5: FR-PET Weather Resistance Test

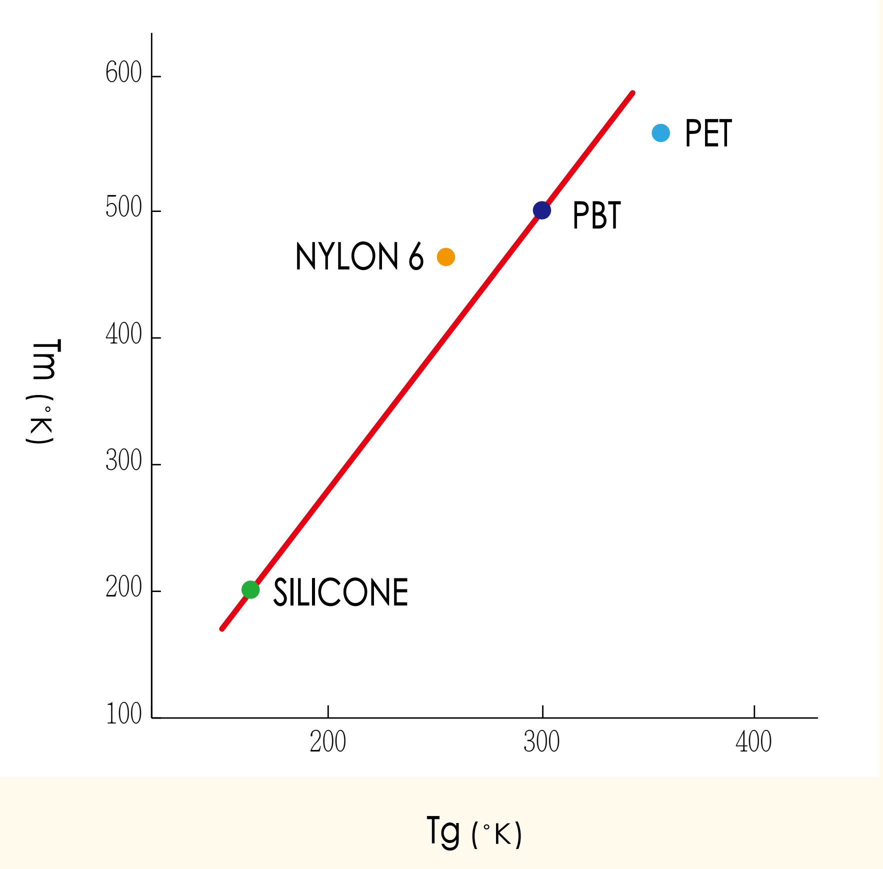
♦ Crystallization:

Both FR-PET and PBTare crystalline macromolecules. As the glass transition temperature (Tg) of PBT is only 22℃ , so PBT can also be completely crystallized at low temperature ranges. On the other hand, the glass transition temperature (Tg) of FR- PET is 69℃ , so FR- PET will require temperatures of above 100℃ to be crystallized. From a heat resistance perspective, the high melting point of FR- PET allows excellent heat resistance but the high Tg value also causes a slow crystallization rate, affecting the molding speed of FR- PET. Graph 6 shows the relation between Tg and the melting points (Tm) of other macromolecules.

Although FR- PET has high heat resistance, chemical resistance, electrical resistance, and weather resistance, the molding speed is affected by the slow crystallization speed as mentioned previously, hence FR- PET demands are unable to increase.
To improve on the crystallization speed of FR- PET, 2 main methods are used :

1. Research for methods to reduce the Glass Transition temperature of FR- PET. When synthesizing FR- PET, a third compound is added to the reaction to reduce the Tg. During molding, a third compoundwith close chemical affinity is added to reduce the glass transition temperature.

2. Use of nucleating agents to improve crystallization speed. through research, the addition of suitable nucleating agents may improve the crystallization speed of FR- PET. Experiments have revealed that suitable nucleating agents are graphite, carbon black, zinc oxide, magnesium oxide, calcium silicate, magnesium silicate, barium sulfate, talc, calcium oxalate, calcium benzoate, magnesium stearate, and calcium tartrate dehydrate.



Graph 6: Relation between Tg and Tm of macromolecules

PHYSICAL PROPERTIES

♦ Water Absorption

FR-PET water absorption is as illustrated in Graph 7. Under normal conditions, FR-PET water absorption is between 0.4~0.6%, lower than Nylon. When immersed in water at room temperature, FR-PET physical property changes are not significant, but in boiling water, FR-PET will undergo hydrolysis and polymerization degree will decrease, causing a significant decrease in physical properties.

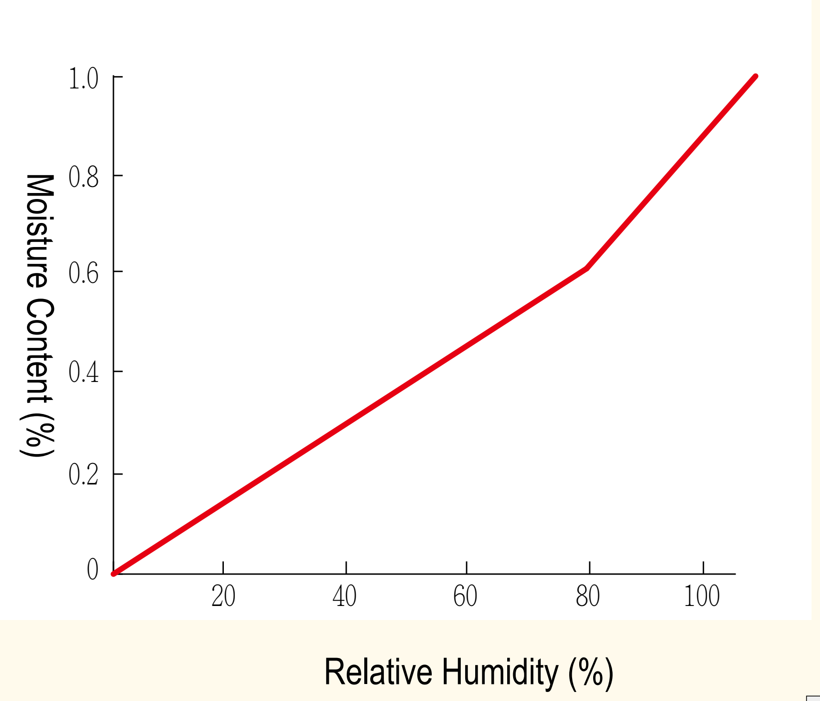
♦ Melting Viscosity

FR-PET has better flowability than reinforced PBT. Suitable processing temperature is between 280~320℃ . This is similar to Nylon 66. Graph 8 shows the relation between FR-PET melting viscosity and temperature. The melting viscosity and flowability will change with the amount of additive and flame retardant chemicals added.

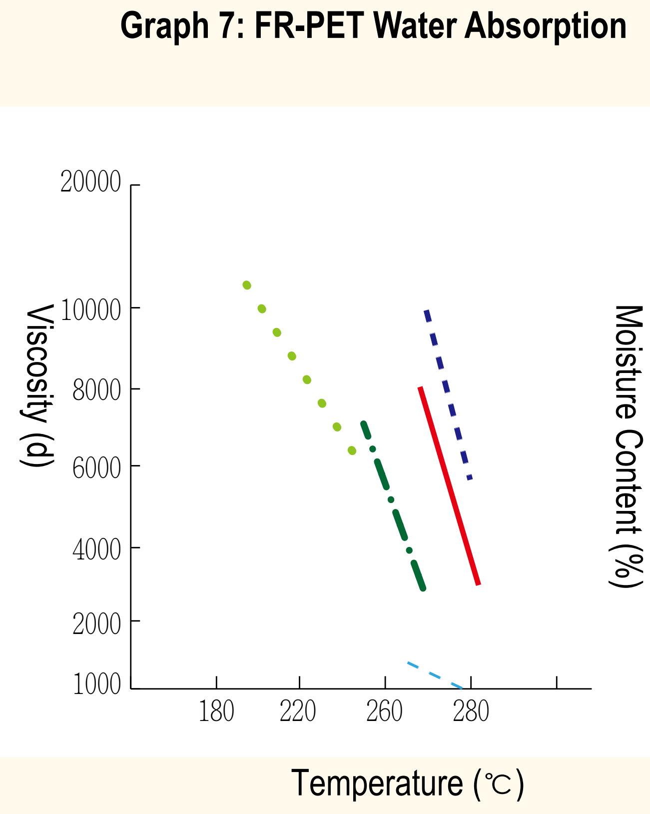
PRECAUTIONS FOR PRODUCT PROCESSING

♦ Drying

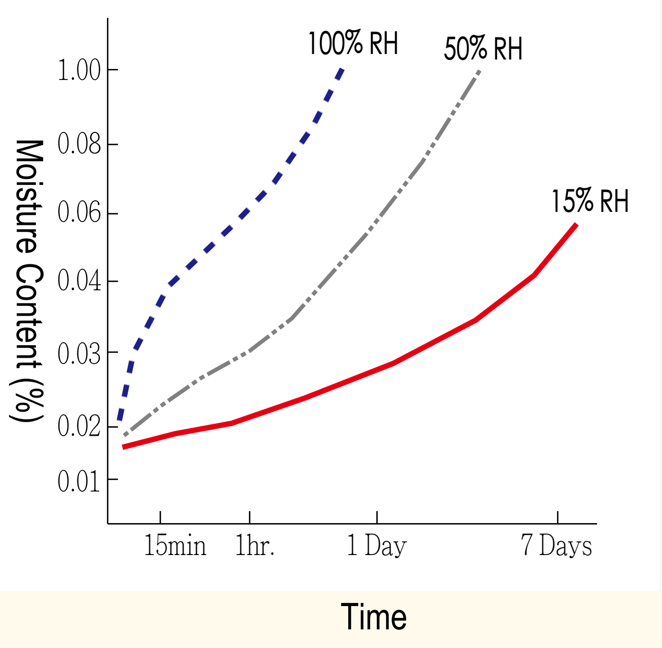
Like Nylon, PC, and PBT, FR-PET is a type of polyester. During injection molding, if the melting flow of plastic has more water content than allowed levels, the plastic will undergo hydrolysis and cause the degree of polymerization to decrease. Although it is hard to tell from product surfaces, mechanical and physical properties such as impact strength will decline significantly. During injection molding, FR-PET water content should be controlled below 0.02%.If the FR-PET is heated at 130℃ *5hrs or 150℃ *4hrs before injection molding, the water content may be reduced to below 0.01%, as shown in Graph 9.



Graph 7: FR-PET Water Absorption



Graph 8: Relation between FR- PET melting viscosity and temperature



Graph 9: Graph of FR- PET water absorption under different humidity

♦ Molding Conditions

FR-PET Injection Molding reference conditions are listed in Table 10. In order to ensure the physical properties of products, residence time should be constrained towithin 10 minutes.

♦ Mold Temperature

To allow FR-PET products to retain dimensional stability and heat resistance, molding conditions should use high temperature molds. In the production of solder-resisting electrical and electronic components, ordinary FR-PET mold temperature should be calibrated between 120~140℃ while crystallization improved models can be calibrated between 90~100℃ . In most conditions, the use of high temperature molds allows a greater degree of crystallization and higher rigidity. But the downside is it will require a longer production cycle and affect productivity. Products manufactured at high temperatures also cause more frequent product warpage. On the other hand, when using low temperature molds, the degree of crystallization in the product is low but it has a shorter production cycle and thus greater productivity. For products with low warpage, models with ore fibers may be used and the low temperature mold should be calibrated at temperatures under 65℃ .

♦ Product Shrinkage

As the degree of crystallization increases, FR-PET density will also increase, and show signs of shrinkage. When glass fiber is added, the product shrinkage will show directionality due to different plastic flow directions. When designing molds, the shrinkage rates in Table 11 may be taken into consideration.

♦ Use of Recycled Materials

When FR-PET is molded, the residue material in the Spru and Runner may be collected for reuse. But to ensure physical properties, the ratio of recycled materials should be contained to within 25%. The ratio of the mixture should take into consideration client requirements for physical properties, colors, and flame retardant agents.

Table 10: FR-PET Injection Molding Reference Conditions

	Ordinary Grade	Flame Resistant Grade
Cylinder Temperature		
Rear (℃)	260~295	260~290
Center (℃)	260~300	260~295
Front (℃)	260~295	265~295
Optimal Material Temperature (℃)	275~300	275~300
Maximum Temperature Limit (℃)	305	305

Table 11: FR-PET Product Shrinkage

Unit %

Product Thickness	Low Temperature Mold	High Temperature Mold	
	Glass Fiber 30%	Glass Fiber 15%	Glass Fiber 30%
1~2mm	0.2~0.3	0.5~0.6	0.4~0.5
2~3	0.3~0.4	0.7~0.9	0.5~0.6
3~4	0.4~0.5	0.8~1.0	0.6~0.7
4~5	0.5~0.6	0.9~1.1	0.8~0.9

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