Celazole® PBI U-60
Moisture Management Guide

PBI and Moisture – An Overview

Polybenzimidazole (PBI) is a linear amorphous polymer, which in an unconstrained wet or humid environment will sorb but not react with water (Table 1).

Table 1

Water Absorption – ASTM D-570 (2" disk x 1/8")	Celazole® PBI U-60
24 hr immersion (73F)	0.4%

In the moist environment, water will move into the unconstrained polymer matrix between polymer chains, spreading them and stretching the dimensions of the shape or part. Water does not bond or react with PBI but will move freely in and out of an unconstrained matrix. In contrast, if PBI is constrained, the polymer chains will not spread and the water will not penetrate. Absorbed water can be desorbed by changing PBI to a dry environment, wherein the matrix returns to the original size and condition.

The effect of water absorption for PBI is the same as for other thermoplastics; the physical manifestation is threefold: it will change part dimensions, it can exacerbate the effects of thermal and pressure shock, and it will reduce mechanical strength.

Additionally, sorbed moisture will impact electrical insulation resistance and dielectric properties. In many situations, these undesired effects can be eliminated or mitigated if properly managed. This guide is designed for that purpose.

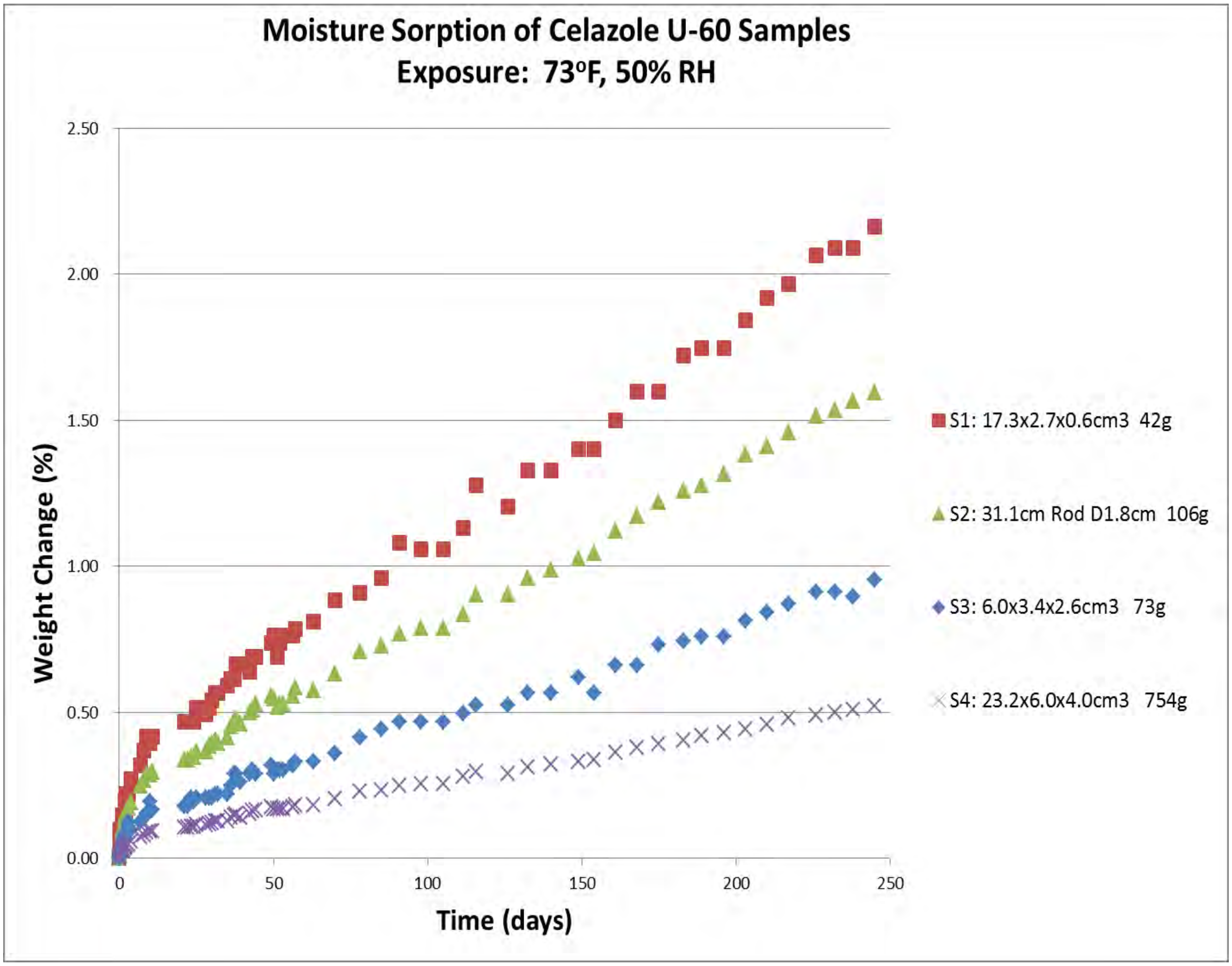
PBI and Moisture Absorption – The Fundamentals

PBI sorbs water in direct proportion to the prevailing water partial pressure, i.e. percent Relative Humidity (% R.H.) and its equilibrium saturation level varies with % R.H. obeying Henry's Law. At 30% R.H. equilibrium saturation is about 4.5%; at 50% R.H. it's about 7%. At 80% R.H. and above, the maximum equilibrium saturation of 11.7% is reached. Sorption capacity is not affected by temperature except to the extent that it affects the % R.H.

The rate of water sorption is limited by the rate of water diffusion into the PBI part. Fickian diffusion is observed as the rate of diffusion is driven by the water concentration gradient in the polymer. This rate of diffusion is a linear function of the square root of exposure time and is determined by temperature, % R.H. and part geometry. Since the rate is a function of the square root of exposure time, the rate of absorption starts out fast and slows with time. Geometry affects the rate of water sorption as the diffusion distance changes. Diffusion is dominant through exposed large planar surfaces and is minimal through exposed edges. It naturally follows then, that equilibrium concentration is achieved more readily with exposure of films and thin-walled shapes versus bulky three-dimensional shapes – all else equal.

An illustration of PBI's water absorption trend for four Celazole PBI U-60 samples is shown in Figure 1. In this example, four dried samples (S1 – S4) of Celazole U-60 were simultaneously exposed to conditioned air at 50% R.H., 73F for 250 days. Noteworthy is the difference in the rate of absorption for the various geometries.

Figure 1



The Effects of Water in PBI

An unconstrained PBI specimen exposed to a humid or wet environment will sorb water (constrained, it will not). In many cases, the effect of sorbed moisture is very small and goes un-noticed with use; however, there are situations where it's a factor that must be considered. Users should be aware of three ways in which moisture can have detrimental effects on PBI parts' physical performance: dimensional changes, cracking/blistering and strength loss.

Dimensional Changes

One effect of sorbed moisture in PBI is a temporary change in part dimensions. It is temporary to the extent that the condition is reversible when the PBI is dried. Table 2 illustrates the effect of sorbed moisture on part dimensions. As part geometries vary widely, this table should be used as a guideline only.
Also note that if a shape has not reached moisture equilibrium with its environment, there will be a moisture gradient in the part attributable to the slow moisture diffusion, wherein the surface could be moister or dryer than the core. It is equally possible for moisture concentration to be anisotropic, resulting from moisture exposure to one side of the part. Machining of a part from a stock shape in such condition could lead to warping or thickness variation. Therefore, be sure to properly dry the shape as described later in this document prior to machining.

Table 2

Dimensional Change of U-60 PBI Disk w/ Sorbed Water				
% Water Absorption	1/8"T x 2.5" Diam. Disk		3/8"T x 2.5" Diam. Disk	
	% change Thickness	% change Diameter	% change Thickness	% change Diameter
0	0	0	0	0
0.25	~0	~0	~0	~0
0.5	0.05	0.02	~0	0.02
1	0.15	0.05	0.1	0.05
2	0.6	0.1	0.7	0.15
3	1.2	0.2	1.3	0.35
4	1.9	0.3	1.5	0.45

Cracking or Blistering

While it is not common, serious part damage can result from severe environmental shocks when PBI parts have sorbed moisture. This may occur when a moisture-containing PBI part experiences a rapid and extreme change in temperature and/or pressure. For example, a part containing 4% moisture at ambient temperature and pressure which is then placed in full vacuum at 300C may crack or blister as the moisture escapes. Likewise, a PBI part saturated in steam and then rapidly decompressed may crack or blister. To avoid these situations, users must understand how to store and dry PBI parts and should refer to the guidelines herein.

Strength Loss

Finally, water absorption will affect strength. In the extreme case, PBI can lose up to 45% of its strength when fully saturated with water/steam. Tables 3 and 4 illustrate this point. Conversely, a part saturated with water and then dried will see strength, modulus, elongation and hardness restored to original values (Table 4).

Table 3

PBI U-60 Strength Change after Steam Exposure (650F, 2200 psi)		
	Tensile Strength (kpsi)	Hardness Shore D
Baseline	23	95
Steam 1 day	13	93
Steam 7 days	12	91

Table 4

PBI U-60 Strength Change after Boiling in Water							
	Tensile Strength (kpsi)	Elongation (%)	Tensile Modulus (kpsi)	Compressive Strength @ 10% Strain (kpsi)	Compressive Modulus (kpsi)	Hardness Rockwell K	Hardness Shore D
Baseline	22	2.4	840	56	860	115	99
Boiling 1 day	18	2.6	780			90	
7 days	17	2.9	720			60	95
30 days	14	2.6	680	32	610	55	93
Boiling 7 days; dried	24	3.2	860			104	97

Controlling Moisture in PBI Parts

For predictable machined part fit and performance, stock shapes and finished parts should be stored in a dry environment. Both stock shapes and finished parts should be packed in moisture barrier packaging. Open packaging just prior to use. In the event that a part may have adsorbed so much moisture as to risk shocking it when placing it in high temperature or vacuum service, consider drying the material prior to use or re-use.

Celazole parts are dried by putting them in a low Relative Humidity environment. For quick and safe drying, dry the parts in a vacuum oven at 150C. Alternately, where vacuum is not available, one can use dry heat at 200C. For best practice, always place the part in oven at ambient temperature and ramp oven heating and cooling as prescribed below. See Table 5 below for complete drying instructions.

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Table 5

Drying Cycle and Ramp Rates
1. Take part from room temperature to 130C, at rate of 50 C/hr. 2. Hold temperature at 130C for 1~2 hrs. 3. Increase temperature from 130C to 200C, at rate of 25 C/hr. If vacuum is used, stop at 150C. 4. Hold at 200C (150C with vacuum) for 4 to 72 hours depending upon part size, original moisture content and application temperature and pressure. In general, 4 hour hold time is sufficient for most parts used below 300C For large parts, parts with high moisture content, and application environments with rapid heating above 400C one should consider a 72 hour hold cycle. 5. Cool from 200C (150C with vacuum) to 130C at rate of 10C/hr. 6. Turn dryer off when temperature reaches 130C. Allow to slowly cool until safe to package.

Packaging Materials

Manufacturers of laminated packing films offer a variety of products that serve as excellent moisture barriers for PBI with high tear and burst strengths (Table 6). The best moisture barriers and most cost effective packing films are the aluminized laminates of oriented polypropylene and polyethylene, or in extra heavy duty construction – aluminized laminates of nylon, polyethylene and ethylene-vinyl alcohol copolymer (EVOH). These opaque heat sealable laminates are available in durable puncture resistant constructions. If transparency is not important, these aluminized laminates are the best choice as they have the lowest water vapor transmission rate, are very durable, and cost less than high performing transparent films.

If package transparency is important, be sure to check the film's specification for water vapor transmission. Biaxially oriented films are more effective than monoaxial films as barriers to water vapor transmission and are also very tough and resistant to tears. Transparent films with very low water vapor transmission rates include (in order of preference) PCTFE, Polyvinylidene chloride (Saran), PTFE, and HDPE. Most heat sealable films contain a polyethylene layer for making the heat seal.

Finally, be sure to follow the film manufacturer's recommendations for seal width, as well as sealing temperature, pressure and dwell time.

Table 6

Recommend Packaging Films		
Product	**Description/ Use**	**Water Vapor Transmission Rate ($g/100in^2/24hrs$)**
Protect 470 Foil (OPP/PI/Foil/PE) MIL-PRF-131K	Most small to medium sized parts or stock shapes	<0.0005
Protect HD100 Foil (Biax Nylon/PE/ Foil/FE/Hvy Duty Coex) MIL-PRF-131K	Large stock shapes with sharp edges	0.0005
Protect VF191 Clear MIL-PRF-22191F	Most parts requiring see-through packaging	<0.03
Protect HD200 Clear (Biax Nylon/PE/ EVOH Coex)	Extra heavy and sharp edged parts	0.15

Distribution

BIEGLO GmbH, Germany
info@bieglo.com
+49 40 401130000

BARplast LLC, USA
info@barplast.com
+1 713 5171938

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Celazole® PBI U-60

Typical Properties

PROPERTIES	ASTM METHOD	ENGLISH VALUE	METRIC VALUE
MECHANICAL			
Tensile Strength	D-638	23 kpsi	160 MPa
Modulus		850 kpsi	5900 MPa
Elongation		3.0%	3.0%
Tensile Fatigue, % of stress to failure at 1,000,000 cycles, 1 Hz	D-638	35% (8.1 kpsi)	35% (56 MPa)
Flexural Strength	D-790	32 kpsi	220 MPa
Modulus		950 kpsi	6500 MPa
Compressive Strength (Yield)	D-695	57 kpsi	390 MPa
Compressive Strength (10% Strain)	D-695	50 kpsi	340 MPa
Compressive Modulus	D-695	850 kpsi	5900 MPa
Hardness – Rockwell M	D-785	>125	>125
– Rockwell E	D-785	104	104
– Shore D	D-2240	95	95
Izod Impact Strength (notched)	D-256	.53 ft-lb/in	30 J/m
(unnotched)		11 ft-lb/in	590J/m
THERMAL			
Heat Deflection Temp. (264 psi; 1.8 MPa)	D-648	815°F	435°C
Glass Transition	DMA	800°F	427°C
Coefficient of Linear Thermal Expansion			
75-300°F (25-150°C)	TMA	13 X 10^{-6} in/in°F	23 µm/m°C
390-570°F (200-300°C)	TMA	18 X 10^{-6} in/in°F	33 µm/m°C
Limiting Oxygen Index	D-2863	58%	58%
Thermal Conductivity 77°F (25°C)		2.8 Btu-in/hr-ft^2°F	0.41 W/m°C
ELECTRICAL			
Dielectric Strength	D-149	580 V/mil	23 KV/mm
Volume Resistivity	D-257	2 X 10^{15} ohm-cm	2 X 10^{15} ohm-cm
Dissipation Factor			
1 kHz	D-150	0.000	0.000
10 kHz	D-150	0.003	0.003
0.1 MHz	D-150	0.034	0.034
Dielectric Constant			
1 kHz	D-150	3.4	3.4
10 kHz	D-150	3.4	3.4
0.1 MHz	D-150	3.3	3.3
Arc Resistance	D-495	185 sec.	185 sec.

PBI Performance Products, Inc.
9800 Southern Pine Blvd Suite D
Charlotte, NC 28273 USA
704.554.3378
www.CelazolePBI.com

Celazole® PBI U-60

Typical Properties – Continued

PROPERTIES	ASTM METHOD	ENGLISH VALUE	METRIC VALUE
OTHER			
Specific Gravity		1.3	1.3
Coef. of Friction, Static			
Aluminum		0.14	0.14
Steel		0.15	0.15
Brass		0.16	0.16
Coef. of Friction, Dynamic			
Aluminum		0.16	0.16
Steel		0.16	0.16
Brass		0.18	0.18
Water Adsorption, 24 hrs at 73F	D-570	0.4%	0.4%

U-60 grade Celazole® polybenzimidazole (PBI) resin is a unique organic polymer which does not burn in air and has extraordinary high temperature resistance, along with excellent stability to chemicals and hydrolysis.

The data shown here describe an unfilled high-performance part molded of Celazole PBI, with many outstanding properties:

- ♦Highest compressive strength of any unfilled resin
- ♦Excellent tensile and flexural strength
- ♦Good fatigue properties
- ♦Excellent hardness
- ♦Low coefficient of friction
- ♦Outstanding Tg and heat deflection temperature
- ♦Relatively low coefficient of thermal expansion
- ♦High volume resistivity
- ♦Very good plasma resistance

Celazole PBI is ideal for applications where requirements cannot be met by other resins—in extreme high temperatures, in harsh chemical or plasma environments, or in applications where durability and wear resistance are important. Parts molded of Celazole PBI are being used in semiconductor and flat panel display manufacture, electrical insulating parts, heat insulating applications, as well as seals, bearings and wear plates in various industrial applications. They are also being evaluated in demanding aerospace applications requiring outstanding strength and short-term high temperature resistance.

PBI Performance Products, Inc.
9800 Southern Pine Blvd Suite D
Charlotte, NC 28273 USA
704.554.3378
www.CelazolePBI.com

Celazole® PBI U-60 (Molded)

Environmental Resistance Ratings

Parts are molded of U-60 grade Celazole® polybenzimidazole (PBI) resin, a unique organic polymer which does not burn in air and has extraordinary high-temperature resistance, along with excellent stability to chemicals and hydrolysis.

In high-temperature exposure to organic chemicals, Celazole® molded parts offer outstanding chemical resistance and property retention, even after extended exposures. In hot caustic, Celazole parts out-perform other high-performance resins. And Celazole U-60 parts have been used successfully in a variety of harsh environments, ranging from oil fields to aerospace applications. In the field, Celazole parts have performed well when exposed to hydraulic and heat-transfer fluids, chlorinated solvents, polyester, nylon, PEEK, and PES molten polymers, and metal-corrosion inhibitors – conditions too severe for most plastics.

Celazole parts are hydrolytically stable after exposure to high pressure steam or boiling water. Moisture absorption of Celazole U-60 resin reaches equilibrium at 10-14% and, through solvation, some strength loss and swelling occur. However, Celazole parts typically regain their original properties after dehydration. When constrained, as in valve assemblies, Celazole U-60 parts have been used successfully in high-temperature, high-pressure steam environments.

Molded Celazole U-60 Environmental Resistance Ratings

Chemical	Temp. (°F)	Pressure (psi)	Rating @ Days 1	7	30
Hydrocarbons					
Xylene	Reflux	Ambient	--	A	--
Toluene	Reflux	Ambient	--	A	--
Kerosene	200	Ambient	--	A	--
Gasoline	200	Ambient	--	A	--
Ketones/Aldehydes					
Methyl Ethyl Ketone	Reflux	Ambient	--	A	--
Chlorinated Solvents					
Methylene Chloride	Reflux	Ambient	--	A	--
Organic Acids					
Acetic Acid (Glacial)	200	Ambient	--	A	--
Phenol	200	Ambient	A	A	A
Polar Aprotic Solvents					
Dimethylacetamide	200	Ambient	C	D	--
Alcohols					
Methanol	Reflux	Ambient	A	A	B
Triethylene glycol	200	Ambient	A	A	A
Triethylene glycol	450	Ambient	A	A	A
Strong **Bases**					
Sodium Hydroxide (Caustic (15%))	200	Ambient	A	B	C
Weak **Bases**					
Sodium Carbonate (10%)	200	Ambient	A	A	A
Strong Acids					
Sulfuric Acid (30%)	200	Ambient	A	C	D
Hydrochloric Acid (10%)	200	Ambient	A	C	D
Hydrochloric Acid (37%)	200	Ambient	B	C	D
Nitric Acid (10%)	200	Ambient	B	D	D
Phosphoric Acid (35%)	200	Ambient	A	B	D

Rating System: A = No Effect, B = Small Effect, C = Large Effect, D = Severe Effect

PBI Performance Products, Inc.
9800 Southern Pine Blvd Suite D
Charlotte, NC 28273 USA
704.554.3378
www.CelazolePBI.com

Celazole® PBI U-60 (Molded)

Environmental Resistance Ratings - Continued

Use of Celazole parts may be less beneficial in exposures to polar, aprotic solvents or in high-temperature exposures to strong, oxidizing, aqueous acids. Although Celazole U-60 parts are affected by powerful oxidizing agents in high concentrations, tests show good resistance to organic acids. Performance in acid envi-ronments should be evaluated vs. application requirements.

In addition, tests have shown no noticeable change in strength or appearance of Celazole U-60 parts after 200 megarad exposure to Cobalt 60 gamma radiation (1.17 and 1.33 MeV). These tests were conducted in air at room temperature.

Celazole U-60 parts have excellent resistance to a range of extreme environments that degrade most plastics. Other high-performance materials, such as polyetherimide, polyimide, polyamideimide, polyetherether-ketone, and polyphenylene sulfide are severely affected by many of these harsh conditions.

Environmental Resistance Ratings, Continued

Chemical	Temp. (°F)	Pressure (psi)	Rating @ Days 1	7	30
Weak Acids					
Acetic Acid (10%)	200	Ambient	A	B	B
Aqueous Oxidants					
5% Sodium Hypochlorite	200	Ambient	A	B	B
Water					
Boiling Water	212	Ambient	A	B	B
Steam	650	2200	B	B	B
End Use Specific					
"Mobile Bay" Sourgas (Hydrogen sulfide, carbon dioxide, methane)	450	2000	--	A	--
NACE "A" (amine, water-based) Corrosion Inhibitor	200	Ambient	--	A	--
NACE "B" (amine, oil-based) Corrosion Inhibitor	200	Ambient	--	A	--
Brine (Zn and Ca Bromide) 15-20 lb/gal	200	Ambient	--	A	--
Skydrol B Hydraulic Fluid	200	Ambient	A	A	A
Monsanto Therminol-66 Heat Transfer Fluid	520	Ambient	--	A	--
Texaco Havoline Supreme 30W Motor Oil	200	Ambient	A	A	A

Rating System: A = No Effect, B = Small Effect, C = Large Effect, D = Severe Effect

Chemical Resistance testing is conducted on tensile and compression test specimens using methodology derived from ASTM D 543. Ratings include tensile and compressive strength retention, weight gain or loss, swelling, and hardness changes.

PBI Performance Products, Inc.
9800 Southern Pine Blvd Suite D
Charlotte, NC 28273 USA
704.554.3378
www.CelazolePBI.com

Distribution
BIEGLO GmbH, Germany
info@bieglo.com
+49 40 401130000

BARplast LLC, USA
info@barplast.com
+1 713 5171938

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Celazole® PBI U-60 CF

Typical Properties

PROPERTIES	ASTM METHOD	ENGLISH VALUE	METRIC VALUE
MECHANICAL			
Tensile Strength (break)	D638	32 kpsi	220 MPa
Modulus		1740 kpsi	12000 MPa
Elongation (break)		2.5 %	2.5 %
Flexural Strength (yield)	D790	42 kpsi	290 MPa
Modulus		1885 kpsi	13000 MPa
Compressive Strength	D695	65 kpsi	450 MPa
Compressive Modulus	D695	1595 kpsi	11000 MPa
Izod Impact Strength (notched 1/8")	D256	0.6 ft-lb/in	0.32 J/cm
Hardness – Shore D	D2240	98	98
THERMAL			
Glass Transition	DMA	800°F	427°C
Coefficient of Linear Thermal Expansion			
75-300°F (25-150°C)	TMA	6.7×10^{-6} in/in°F	12 μm/m°C
390-570°F (200-300°C)	TMA	10×10^{-6} in/in°F	18 μm/m°C
ELECTRICAL			
Surface Resistivity	D257	$10^{1} – 10^{3}$ ohm/sq	$10^{1} – 10^{3}$ ohm/sq
OTHER			
Specific Gravity	D792	1.42	1.42
Carbon Fiber content (nominal)		25 %	25 %

U-60CF is an ultra-high strength carbon fiber reinforced compression molded PBI variant available as stock shape.

PBI Performance Products, Inc.
9800 Southern Pine Blvd Suite D
Charlotte, NC 28273 USA
704.554.3378
www.CelazolePBI.com

Distribution
BIEGLO GmbH, Germany
info@bieglo.com
+49 40 401130000

BARplast LLC, USA
info@barplast.com
+1 713 5171938

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Celazole® PBI U-60 ESD E5

Typical Properties

PROPERTIES	ASTM METHOD	ENGLISH VALUE	METRIC VALUE
MECHANICAL			
Tensile Strength (break)	D638	29 kpsi	200 MPa
Modulus		1300 kpsi	9000 MPa
Elongation (break)		2.5 %	2.5%
Flexural Strength (yield)	D790	37 kpsi	260 MPa
Flexural Modulus		1400 kpsi	9700 MPa
Compressive Strength	D695	62 kpsi	430 MPa
Izod Impact Strength (notched 1/8")	D256	0.55 ft-lb/in	0.29 J/cm
Hardness – Shore D	D2240	96	96
THERMAL			
Glass Transition	DMA	800°F	427°C
Coefficient of Linear Thermal Expansion			
75-300°F (25-150°C)	D696	9×10^{-6} in/in°F	16 µm/m°C
ELECTRICAL			
Surface Resistivity	D257	$10^4 – 10^6$ ohm/sq	$10^4 – 10^6$ ohm/sq
OTHER			
Specific Gravity	D792	1.38	1.38
Carbon Fiber content (nominal)		15 %	15 %

U-60ESD is an electrostatic dissipative compression molded PBI variant available as a stock shape. ESD characteristic can be tailored to need.

PBI Performance Products, Inc.
9800 Southern Pine Blvd Suite D
Charlotte, NC 28273 USA
704.554.3378
www.CelazolePBI.com

Distribution
BIEGLO GmbH, Germany
info@bieglo.com
+49 40 401130000

BARplast LLC, USA
info@barplast.com
+1 713 5171938

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Celazole® PBI U-60 ESD E8

Typical Properties

PROPERTIES	ASTM METHOD	ENGLISH VALUE	METRIC VALUE
MECHANICAL			
Tensile Strength (break)	D638	26 kpsi	180 MPa
Modulus		1100 kpsi	7600 MPa
Elongation (break)		2.5 %	2.5 %
Flexural Strength (yield)	D790	35 kpsi	240 MPa
Flexural Modulus		1300 kpsi	9000 MPa
Compressive Strength	D695	60 kpsi	410 MPa
Izod Impact Strength (notched 1/8")	D256	0.5 ft-lb/in	0.27 J/cm
Hardness – Shore D	D2240	95	95
THERMAL			
Glass Transition	DMA	800°F	427°C
Coefficient of Linear Thermal Expansion			
75-300°F (25-150°C)	D696	11 X 10^{-6} in/in°F	20 µm/m°C
ELECTRICAL			
Surface Resistivity	D257	10^6 – 10^9 ohm/sq	10^6 – 10^9 ohm/sq
OTHER			
Specific Gravity	D792	1.36	1.36
Carbon Fiber content (nominal)		10 %	10 %

U-60ESD is an electrostatic dissipative compression molded PBI variant available as a stock shape. ESD characteristic can be tailored to need.

PBI Performance Products, Inc.
9800 Southern Pine Blvd Suite D
Charlotte, NC 28273 USA
704.554.3378
www.CelazolePBI.com

Distribution
BIEGLO GmbH, Germany
info@bieglo.com
+49 40 401130000

BARplast LLC, USA
info@barplast.com
+1 713 5171938

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Celazole® PBI U-60

HIGHER-PERFORMANCE CONTACT PART MATERIALS FOR SENSITIVE GLASS HANDLING NEEDS

Celazole PBI (polybenzimidazole) is a high strength, highly stable linear hetrocyclic polymer.

Broadly resistant to hydrocarbons, alcohols, weak acids, weak bases, hydrogen sulfide, chlorinated solvents, oils, heat transfer fluids and many other organic chemicals, it can be used in air up to 315°C (600°F) and up to 375°C (700°F) in vacuum and inert environments.

EXTREME **HIGH TEMPERATURE** RESISTANCE: 425° C glass temperature (Tg)

- Will not melt at ambient pressure
- Glass transition temperature of 800°F (427°C) means stability at high temperatures
- Will not scratch glass
- Mohs Hardness of 3 cannot scratch glass with Mohs Hardness 7
- Used in technical glass manufacturing – glass contact applica-tions for this reason
- Excellent wear resistance
- The highest compressive strength of any unfilled plastic
- Excellent thermal and electrical insulator
- Machinable into intricate parts
- Available in electrostatic discharge grade (ESD) to alleviate arc tracking when electrical charges are present

APPLICATIONS:

Glass panel guides, clamps, lifting pins, insulating contacts, etc. – in 600F (315°C) environments

Glass handling, conveying, LCD panel sputtering, chemical vapor deposition (CVD) and physical vapor deposition (PVD) processes

COMPARISONS:

2x	≤	✕
Twice the strength of a Polyimide	Less brittle than ceramic or quartz	Won't scratch glass like ceramics

PBI Performance Products, Inc.
9800 Southern Pine Blvd. Suite D, Charlotte, NC 28273
T: 704-554-3378 F: 704-554-3101
www.pbiproducts.com

PBI CELAZOLE U-60 PROPERTIES

	ASTM METHOD	ENGLISH VALUE	METRIC VALUE
COMPRESSIVE STRENGTH (YIELD)	D-695	57 kpsi	390 MPa
MODULUS	D-695	850 kpsi	5,900 MPa
HEAT DEFLECTION TEMP. (264 psi; 1.8 MPa)	D-648	815°F	435°C
GLASS TRANSITION	DMA	800°F	427°C
CLTE 75-300°F (25-150°C)	TMA	13 x 10^{-6} in/in°F	23 µm/m°C
THERMAL CONDUCTIVITY 77°F (25°C)		2.8 Btu-in/hr-ft^2°F	0.41 W/m°C
DIELECTRIC STRENGTH	D-149	580 V/mil	23 KV/mm
VOLUME RESISTIVITY	D-257	2 x 10^{15} ohm-cm	2 x 10^{15} ohm-cm
ARC RESISTANCE	D-495	185 sec.	185 sec.
COEF. OF FRICTION, STATIC VS STEEL		0.15	0.15

For more information, contact:

Debra Robinson
Inside Sales Manager

(704) 554-2744

PBI Performance Products, Inc
9800-D Southern Pine Boulevard
Charlotte, NC 28273
E-mail: debra.robinson@pbiproducts.com
celazolePBI.com

PBI PERFORMANCE PRODUCTS, INC.
A member of The Inter Tech Group, Inc.

Distribution
BIEGLO GmbH, Germany
info@bieglo.com
+49 40 401130000

BARplast LLC, USA
info@barplast.com
+1 713 5171938

Disclaimer

Celazole® PBI U-60 SD

Typical Properties

PROPERTIES	ASTM METHOD	ENGLISH VALUE	METRIC VALUE
MECHANICAL			
Tensile Strength	D638	23 kpsi	160 MPa
Modulus		850 kpsi	5900 MPa
Elongation		3.0%	3.0%
Tensile Fatigue, % of stress to failure at 1,000,000 cycles, 1 Hz	D638	35% (8.1 kpsi)	35% (56 MPa)
Flexural Strength	D790	32 kpsi	220 MPa
Modulus		950 kpsi	6500 MPa
Compressive Strength (Yield)	D695	57 kpsi	390 MPa
Compressive Strength (10% Strain)	D695	50 kpsi	340 MPa
Compressive Modulus	D695	850 kpsi	5900 MPa
Hardness – Rockwell M	D785	>125	>125
– Rockwell E	D785	104	104
– Shore D	D2240	95	95
Izod Impact Strength (notched)	D256	0.53 ft-lb/in	0.28 J/cm
(unnotched)		11 ft-lb/in	5.9 J/cm
THERMAL			
Heat Deflection Temp. (264 psi; 1.8 MPa)	D648	815°F	435°C
Glass Transition	DMA	800°F	427°C
Coefficient of Linear Thermal Expansion			
75-300°F (25-150°C)	TMA	13 X 10^{-6} in/in°F	23 µm/m°C
390-570°F (200-300°C)	TMA	18 X 10^{-6} in/in°F	33 µm/m°C
Limiting Oxygen Index	D2863	58%	58%
Thermal Conductivity 77°F (25°C)		2.8 Btu-in/hr-ft^2°F	0.41 W/m°C
ELECTRICAL			
Dielectric Strength	D149	580 V/mil	23 KV/mm
Volume Resistivity	D257	2 X 10^{15} ohm-cm	2 X 10^{15} ohm-cm
Dissipation Factor			
1 kHz	D150	0.000	0.000
10 kHz	D150	0.003	0.003
0.1 MHz	D150	0.034	0.034
Dielectric Constant			
1 kHz	D150	3.4	3.4
10 kHz	D150	3.4	3.4
0.1 MHz	D150	3.3	3.3
Arc Resistance	D495	185 sec.	185 sec.

PBI Performance Products, Inc.
9800 Southern Pine Blvd Suite D
Charlotte, NC 28273 USA
704.554.3378
www.CelazolePBI.com

Celazole® PBI U-60 SD

PROPERTIES	ASTM METHOD	ENGLISH VALUE	METRIC VALUE
PURITY			
Metals – Typical maximum (ppm)			
Fe	ICP	1	1
Ni	ICP	1	1
Cr	ICP	1	1
Cu	ICP	1	1
OTHER			
Specific Gravity		1.3	1.3
Coef. of Friction, Static			
Aluminum		0.14	0.14
Steel		0.15	0.15
Brass		0.16	0.16
Coef. of Friction, Dynamic			
Aluminum		0.16	0.16
Steel		0.16	0.16
Brass		0.18	0.18
Water Adsorption, 24 hrs at 73F	D570	0.4%	0.4%

U-60SD grade Celazole® polybenzimidazole (PBI) is a high purity/ ultra-low metal form of Celazole PBI; recommended for use in semiconductor dry etch, sputter, chemical vapor deposition and physical vapor deposition systems; and other purity sensitive applications.

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Charlotte, NC 28273 USA
704.554.3378
www.CelazolePBI.com

Distribution
BIEGLO GmbH, Germany
info@bieglo.com
+49 40 401130000

BARplast LLC, USA
info@barplast.com
+1 713 5171938

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