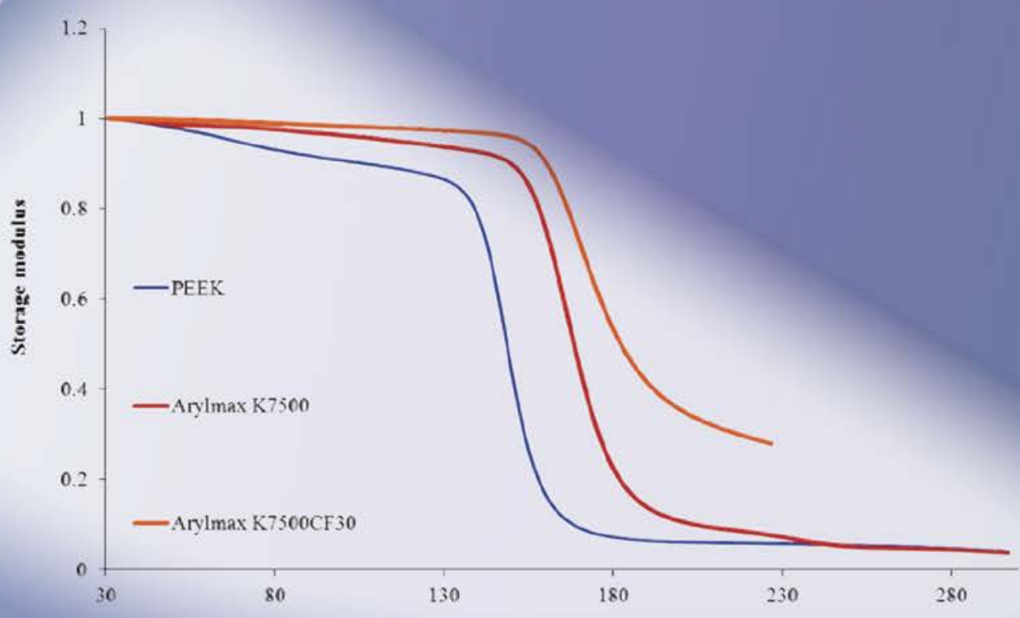
Polymics
Concept to Solution®

Arylmax® K

PEEK & Beyond™



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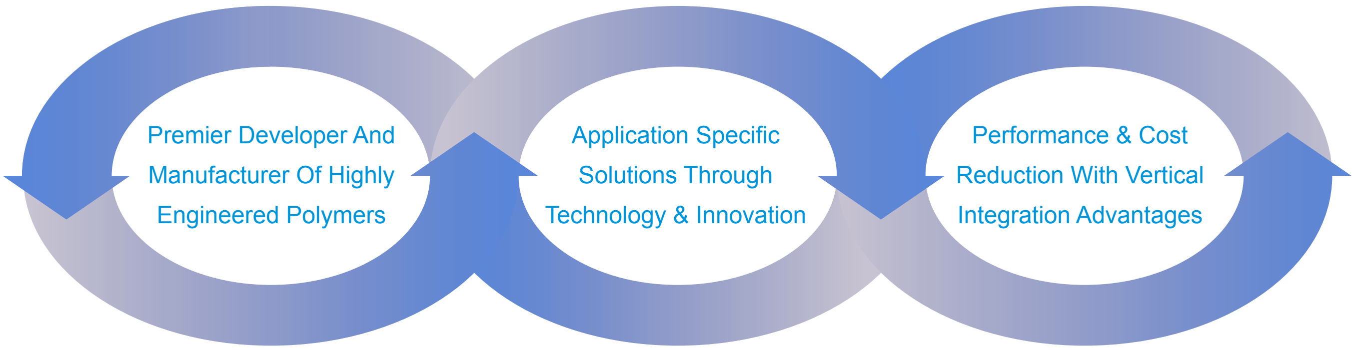
1. Company Profile

Polymics,® Ltd. is the world's premier developer and manufacturer of ultra-high performance engineering polymers. With a wide range of manufacturing capabilities and our vertically integrated supply chain, Polymics offers a variety of products and services, for an infinite variety of engineered uses.

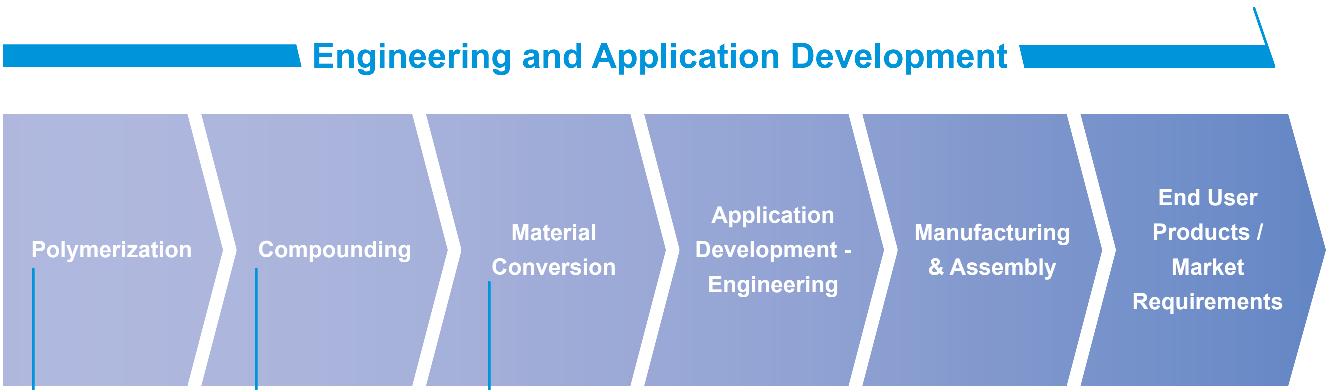
Polymics® is proud to work with customers to develop ideal custom solutions for virtually any issue. Our core competency is the custom formulation of compounds uniquely designed to match the needs of our customers' specific applications. Regardless of the industry or end-use, we have the expertise to quickly and economically create the ideal polymer for the job.

Mission for Polymics - Concept to Solution®



Polymics Products & Services

Integrated Solution Provider And High Performance Components



Polymer:
PEEK
PAEK's
PAES's
TPI
PBI

Compounds:
Carbon fiber
Glass fiber
Mineral fillers

Stock Shapes:
Tubes
Bushings
Sheet
Rod
Films

2. Polymics® Standard PEEK Product Lines

Resin	Series	Product Code	Description
PEEK	Pyramid™	**Unfilled**	
		KD2000	Standard Flow
		KD4000	High Flow
		GF	
		KD2120	PEEK+15%GF
		KD2150	PEEK+30%GF
		KD215x	PEEK with special glass package
		CF	
		KD2220	PEEK+15%CF
		KD2230	PEEK+20%CF
		KD2250	PEEK+30%CF
		KD2270	PEEK+40%CF
		KD2219	Wear Grade for standard PV values
		CC100	60% Chopped CF Reinforced
		CC200	60% Woven CF Reinforced
		CC300	60% Long CF Reinforced
		CC400	60% UD Crossply CF Reinforced
		Ceramic	
		KD2420	PEEK+15% Ceramic
		KD2430	PEEK+20% Ceramic
		KD2450	PEEK+30% Ceramic
		PTFE	
		KD2520	PEEK+15% PTFE
		KD2530	PEEK+20% PTFE
		KD2540	PEEK+25% PTFE
	PBI		
	Celazole® T-series	TU60	Injection moldable unfilled PBI
		TL60	Injection moldable Wear Grade PBI
		TF60C	Injection moldable CF Reinforced PBI
		TF60V	Injection Moldable GF Reinforced PBI

3. Arylmax® K --- A New Tier of Higher Performance Solutions

Polymics® Combines Versatile Performance and Value into Arylmax® K

Arylmax® K is a family of proprietary polymers that supply tailor-made formulations designed to meet specific application requirements where PEEK falls short on performance or value.

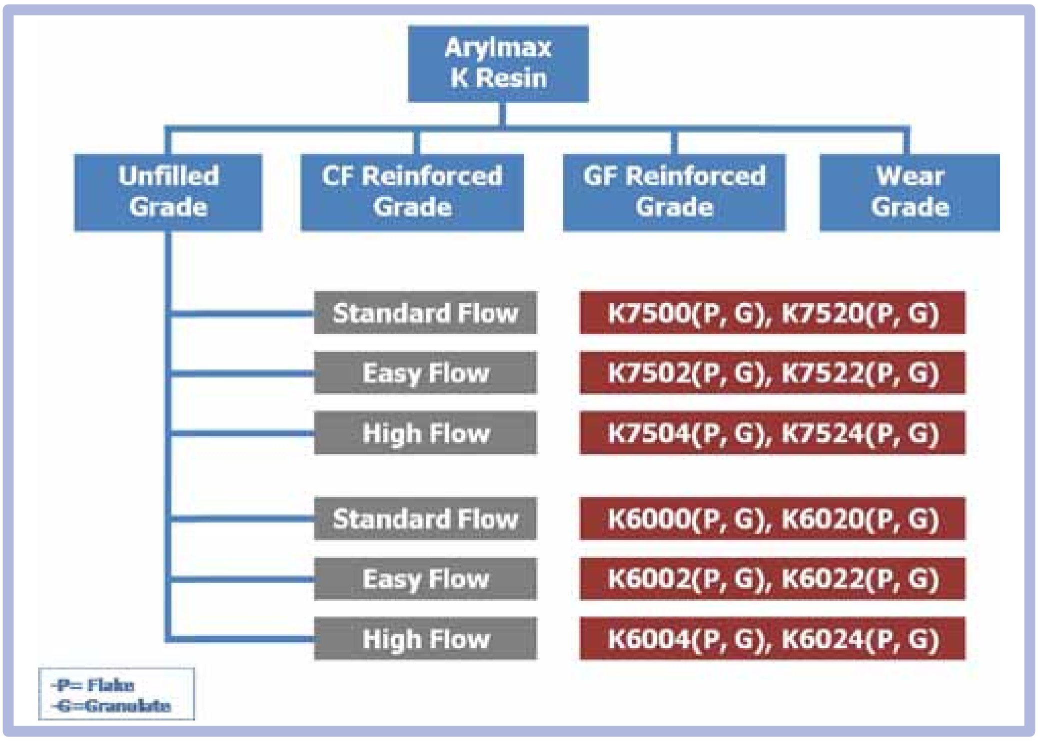
Polymics® currently offers and manufactures Arylmax® K (Polyaryletherketone family) in resin and compound forms. Arylmax® K polymers were introduced in 2010 to provide a material that would excel in harsh operating conditions at temperatures too high for standard PEEK material. In addition to the standard offerings, they can also be customized to meet the requirements of many difficult applications.

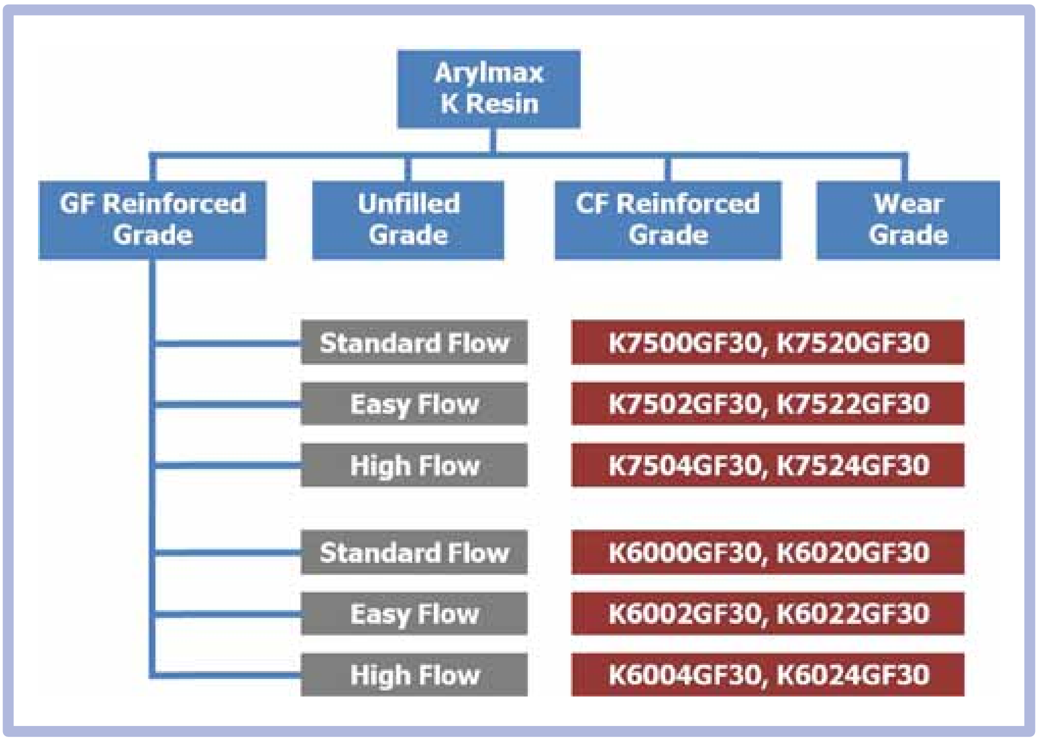
Polymics®, Ltd. utilizes its vertically integrated supply capabilities to offer Arylmax® K as resin, compounded pellets for extrusion or injection molding, and fine powders for compression molding or coating. In addition, standard molded and extruded shapes and components are available in different formulations. Arylmax® K is currently available in standard unfilled, glass-filled, carbon-filled, wear package, and many other custom formulations.

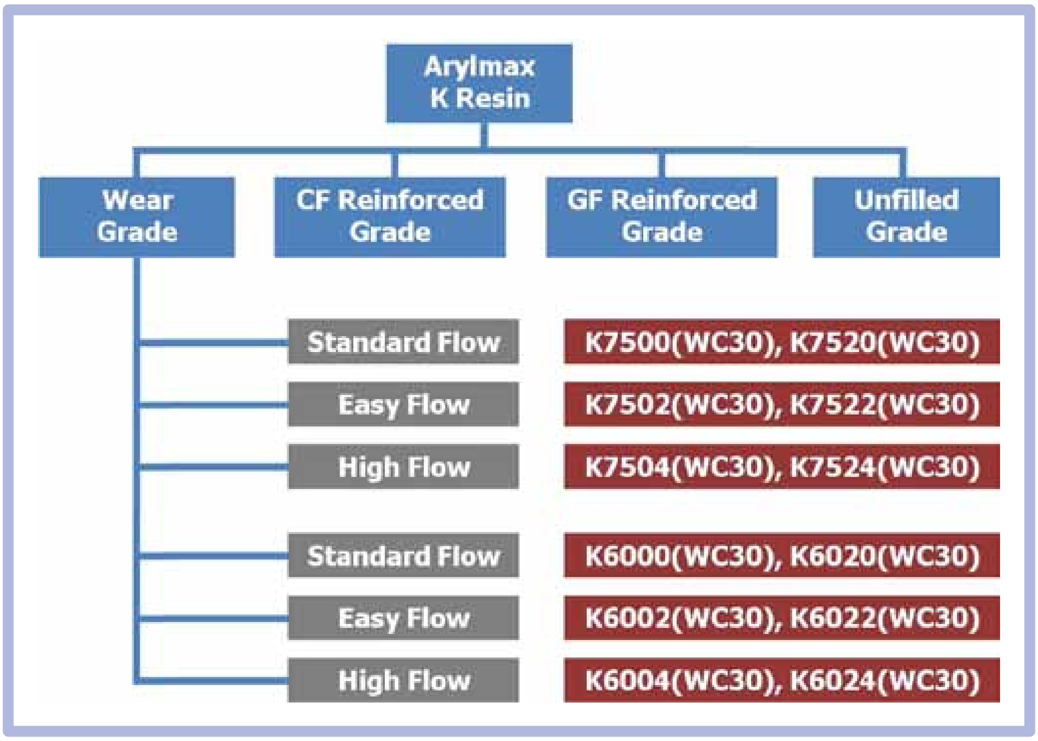
4. Why Arylmax® K?

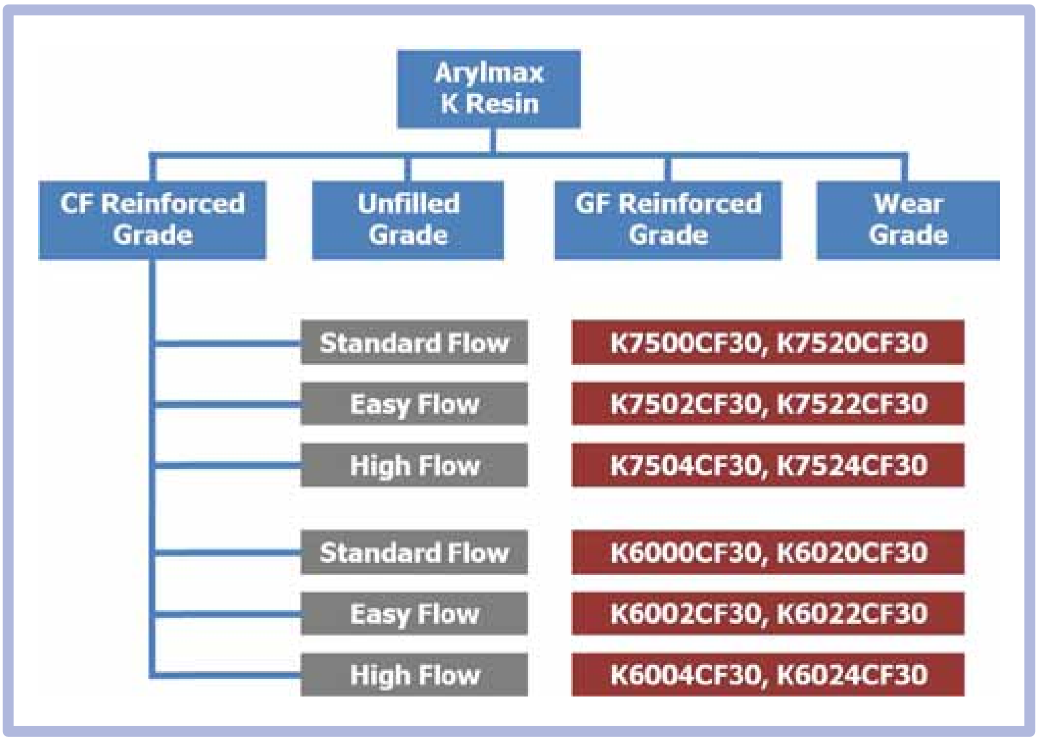
- ***Best value performance ratio***
- ***Simple selection process for diverse properties that matches unique application requirements***
- ***Easily processable with conventional equipment***
- ***Conforms to global standards and material specifications***
- ***Reliable, vertically integrated supply chain assurance***
- ***Served by expert technical teams globally***

5. Arylmax® K Product Line





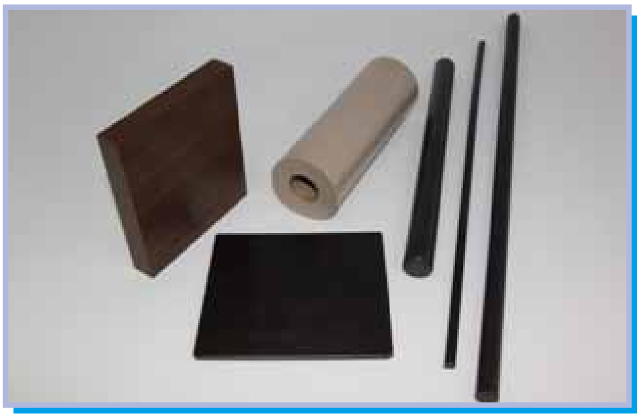

Arylmax K Resin
Wear Grade
CF Reinforced Grade
GF Reinforced Grade
Unfilled Grade
Standard Flow
Easy Flow
High Flow
Standard Flow
Easy Flow
High Flow
K7500(WC30), K7520(WC30)
K7502(WC30), K7522(WC30)
K7504(WC30), K7524(WC30)
K6000(WC30), K6020(WC30)
K6002(WC30), K6022(WC30)
K6004(WC30), K6024(WC30)


Arylmax K Resin
CF Reinforced Grade
Unfilled Grade
GF Reinforced Grade
Wear Grade
Standard Flow
Easy Flow
High Flow
Standard Flow
Easy Flow
High Flow
K7500CF30, K7520CF30
K7502CF30, K7522CF30
K7504CF30, K7524CF30
K6000CF30, K6020CF30
K6002CF30, K6022CF30
K6004CF30, K6024CF30

6.Understanding Arylmax® K Products

Arylmax® K60xx Series: Unique, Superior Performance

Arylmax® K60xx polymer is a semi-crystalline polymer designed with less crystallinity than PEEK and most other commercial PAEK polymers. As a result, the resulting molded parts has lower shrinkage and warpage while offering improved ductility typically shown by amorphous engineering polymers. Additionally, it exhibits excellent bonding to most metal that offers unique advantage for insert molding and is especially useful in Nano Molding Technology(NMT).



- Offers the chemical and wear resistance of a semi-crystalline polyketone but with the benefits of low warpage and the high ductility of typical amorphous materials
- Lower processing temperature than comparable PEEK grades
- Superior processing characteristics over PEEK
- Higher glass transition temperature than PEEK
- Potential cost reduction compared to PEEK
- Compatibility with other commercial high performance polymers in blends and compounds
- Superior bonding properties with metal
- Exclusively suitable for the Nano Molding Technology(NMT) process

Arylmax® K75xx Series: Reliable Solutions in Extreme Environments

The Arylmax® K75xx series products offer higher modulus and mechanical property retention than PEEK at high temperatures as shown in the cover page.

UV Resistant Roller & Bushings

Supporting Pin & External Fixator

- Higher stiffness than comparable PEEK grades across full temperature range
- Equal or better wear and chemical resistance than PEEK
- Up to 30°C higher glass transition temperature than PEEK
- Potential cost reduction compared to PEEK
- Compatible with other commercial high performance polymers in blends and compounds

7.Typical Arylmax® K Properties

7.1 Unfilled Arylmax® K Grades

Property	ASTM	Unit	K6000	K7500	PEEK
General					
Form	-	-	Pellets	Pellets	Pellets
Composition (Polyetherketoneketone)	-	-	Neat Resin	Neat Resin	Neat Resin
Specific Gravity	D792	g/ml	1.28	1.3	1.3
Linear Mold Shrinkage	D935	%	1.3	1.6	1.5
Moisture Absorption @24hr	D570	%	0.3	0.2	0.5
Mechanical					
Tensile Strength (Break)	D638	MPa	90	100	96
Tensile Modulus	D638	GPa	4.1	4.5	3.5
Elongation (Break)	D638	%	60	10	40
Flexural Strength (Yield)	D790	MPa	130	160	158
Flexural Modulus	D790	GPa	3.4	4.4	4.1
Izod, Notched	D256	J/m	80	75	70
Compressive Strength	D695	MPa	115	135	120
Hardness	D2240	Shore D	86	90	88
Thermal					
Melting Point	D3418	^{o}C	330	353	343
Tg (Glass Transition)	D3418	^{o}C	165	170	143
Flammability Rating@1.5mm thickness	UL 94	-	V-0	V-0	V-0
Thermal Conductivity	C177	W/m-K	0.28	0.28	0.25
CTE, linear (<Tg)	D696	µm/m-°C	30	50	47
UL Cont. Use Temp	UL 764B	^{o}C	250	270	250
Electrical					
Dielectric Strength	D149	KV/mm	25	25	25
Dielectric Constant	D150	1KHz	3.1	3.1	3.3
Dissipation Factor	D150	1KHz	0.004	0.004	0.004
Volume Resistivity	D257	>Ohm-cm x 10^{16}	1	1	1
Surface Resistivity	D257	>Ohm-sq x 10^{16}	2	2	2

7.2 Typical Properties of Arylmax® K GF Grades

Property	ASTM	Unit	K6000GF30	K7500GF30	PEEKGF30
General					
Form	-	-	Pellets	Pellets	Pellets
Composition (Polyetherketoneketone)	-	-	Glassfiber filled	Glassfiber filled	Glassfiber filled
Specific Gravity	D792	g/ml	1.51	1.53	1.51
Linear Mold Shrinkage	D935	%	0.6	0.7	0.6
Moisture Absorption @24hr	D570	%	0.1	0.1	0.1
Mechanical					
Tensile Strength (Break)	D638	MPa	168	179	166
Tensile Modulus	D638	GPa	11.2	11.9	9.7
Elongation (Break)	D638	%	3.9	3.5	2.6
Flexural Strength (Yield)	D790	MPa	257	266	262
Flexural Modulus	D790	GPa	11	11.5	11
Izod, Notched	D256	J/m	66	72	66
Compressive Strength	D695	MPa	238	248	243
Hardness	D2240	Shore D	90	94	92
Thermal					
Melting Point	D3418	^{o}C	330	353	343
Tg (Glass Transition)	D3418	^{o}C	165	170	143
Flammability Rating@1.5mm thickness	UL 94	-	V-0	V-0	V-0
Thermal Conductivity	C177	W/m-K	0.29	0.3	0.43
CTE, linear (<Tg)	D696	µm/m-°C	18	16	18
UL Cont. Use Temp	UL 764B	^{o}C	230	260	240
Electrical					
Dielectric Strength	D149	KV/mm	25	25	25
Dielectric Constant	D150	1KHz	3.2	3.3	3.2
Dissipation Factor	D150	1KHz	0.004	0.005	0.005
Volume Resistivity	D257	>Ohm-cm x 10^{16}	1	1	1
Surface Resistivity	D257	>Ohm-sq x 10^{16}	2	2	2

7.3 Typical Properties of Arylmax® K CF Grades

Property	ASTM	Unit	K6000CF30	K7500CF30	PEEKCA30
General					
Form	-	-	Pellets	Pellets	Pellets
Composition (Polyetherketoneketone)	-	-	Carbonfiber filled	Carbonfiber filled	Carbonfiber filled
Specific Gravity	D792	g/ml	1.41	1.42	1.41
Linear Mold Shrinkage	D935	%	0.4	0.3	0.3
Moisture Absorption @24hr	D570	%	0.1	0.1	0.1
Mechanical					
Tensile Strength (Break)	D638	MPa	250	260	253
Tensile Modulus	D638	GPa	23.8	25.1	22.3
Elongation (Break)	D638	%	3.4	3.2	2.0
Flexural Strength (Yield)	D790	MPa	357	386	369
Flexural Modulus	D790	GPa	21.6	24	19
Izod, Notched	D256	J/m	62	70	67
Compressive Strength	D695	MPa	276	298	290
Hardness	D2240	Shore D	88	92	90
Thermal					
Melting Point	D3418	°C	330	353	343
Tg (Glass Transition)	D3418	°C	165	170	143
Flammability Rating@1.5mm thickness	UL 94	-	V-0	V-0	V-0
Thermal Conductivity	C177	W/m-K	0.28	0.28	0.38
CTE, linear (<Tg)	D696	µm/m-°C	9	8	8
UL Cont. Use Temp	UL 764B	°C	240	260	240
Electrical					
Volume Resistivity	D257	>Ohm-cm	$10^{3\sim5}$	$10^{3\sim5}$	$10^{3\sim5}$
Surface Resistivity	D257	>Ohm-sq	$10^{3\sim5}$	$10^{3\sim5}$	$10^{3\sim5}$

7.4 Typical Properties of Arylmax® K WC Grades

Property	ASTM	Unit	K6000WC30	K7500WC30	PEEKWG30
General					
Form	-	-	Pellets	Pellets	Pellets
Composition (Polyetherketoneketone)	-	-	CF + Graphite + PTFE		
Specific Gravity	D792	g/ml	1.43	1.45	1.45
Linear Mold Shrinkage	D935	%	0.7	0.6	0.6
Moisture Absorption @24hr	D570	%	0.1	0.1	0.1
Mechanical					
Tensile Strength (Break)	D638	MPa	130	142	136
Tensile Modulus	D638	GPa	12	12.8	12.3
Elongation (Break)	D638	%	3.4	3.9	2.2
Flexural Strength (Yield)	D790	MPa	218	230	224
Flexural Modulus Mpsi	D790	GPa	11	11.9	11.2
Izod, Notched	D256	J/m	48	52	50
Compressive Strength	D695	MPa	158	170	165
Hardness	D2240	Shore D	80	86	85
Thermal					
Melting Point	D3418	^{o}C	320	353	343
Tg (Glass Transition)	D3418	^{o}C	162	170	143
Flammability Rating@1.5mm thickness	UL 94	-	V-0	V-0	V-0
Thermal Conductivity	C177	W/m-K	0.28	0.28	0.29
CTE, linear (<Tg)	D696	µm/m-°C	30	50	45
UL Cont. Use Temp	UL 764B	^{o}C	240	260	240
Electrical					
Volume Resistivity	D257	>Ohm-cm x 10^{16}	$10^{6\sim9}$	$10^{6\sim9}$	$10^{6\sim9}$
Surface Resistivity	D257	>Ohm-sq x 10^{16}	$10^{6\sim9}$	$10^{6\sim9}$	$10^{6\sim9}$

8. Arylmax® K Thermal & Mechanical Properties

Arylmax® K polymers have glass transition (Tg) and crystalline melting temperatures (Tm) in the range shown in Figure 1. Due to the semi-crystalline nature of these polymers, a high degree of mechanical properties are retained close to their melting temperatures.

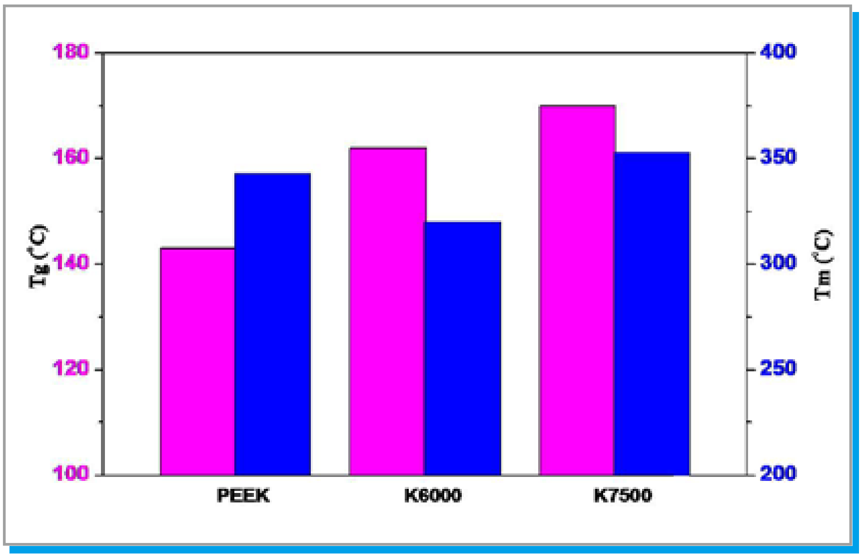


Figure 1. Glass Transition(Tg) and Melting Temperature(Tm) for Arylmax® K and Commercial PEEK

Heat Deflection Temperature

Heat Deflection Temperature(HDT) values are used to compare the elevated temperature performance of materials under load at the stated test conditions. The short-term thermal performance of polymers may be predicted by determining the HDT at which a defined deformation is observed in a sample under constant applied stress (1.8MPa, ASTM D648) at constant heating rate, however, they do not represent the upper temperature limit for a specific material or application.

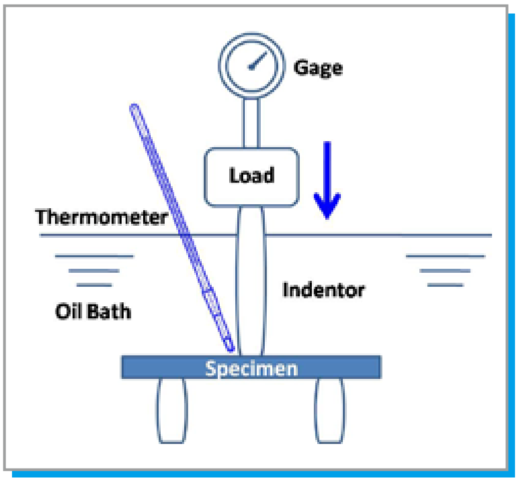


Figure 2. Heat Deflection Temperature Testing Schematic

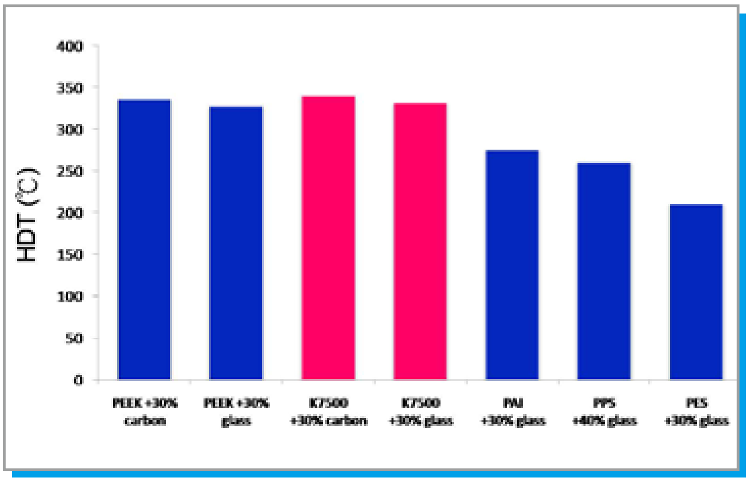


Figure 3. HDT(at 1.8MPa) for Arylmax® K and other High Performance Polymers

Relative Thermal Index

Polymers are subject to thermal degradation at elevated temperatures. These effects may be evaluated by measuring the relative thermal index (RTI) as defined by Underwriters Laboratories (UL746B) also known as the continuous use temperature, gives values for approximate temperature limits for continuous use in air and without additional external loading. This test determines the temperature at which 50% of a particular material property is retained compared to a control material whose RTI is already known (RTI typically corresponds to extrapolated times between 60,000 and 100,000 hours).The UL RTI rating for Arylmax® K materials compared to other high performance polymers are shown in Figure 4 below.

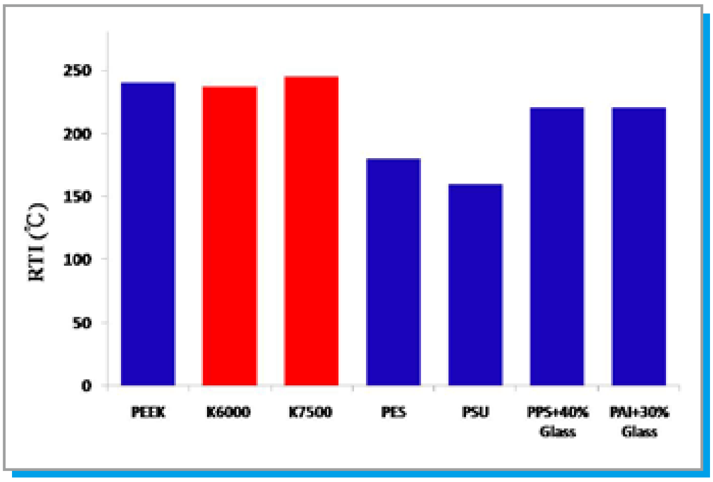


Figure 4. RTI of Arylmax® K and other High Performance Polymers

Figure 5. Arylmax® K Injection Molded Tubes with Versatile Compositions and Dimensions

Tensile Properties

Tensile properties, important in structural design, are used to compare the relative strength and stiffness of plastics. The standard tensile tests for rigid thermoplastics(ASTM D638) involve clamping a standard molded tensile bar into the test device (Figure 6).

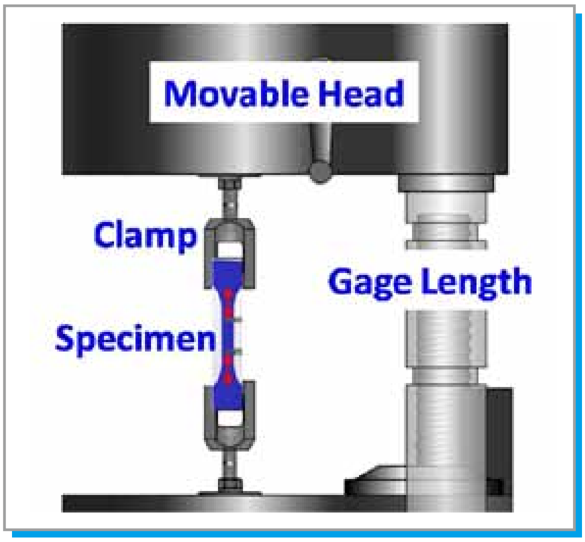


Figure 6. Tensile Properties Testing Diagraph of Arylmax® K

Flexural Properties

Flexural properties relate to a plastic's ability to bend or resist bending under load. In the tests for most flexural properties (ASTM D790),a test bar placed across two supports is deflected in the middle at a constant rate, usually 2 mm/min. For glass-reinforced materials it is 20 mm/min.

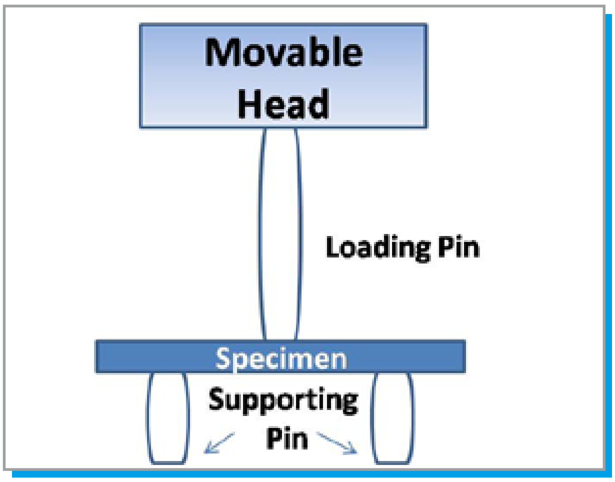


Figure 7. Flexural Properties Testing Diagraph of Arylmax® K

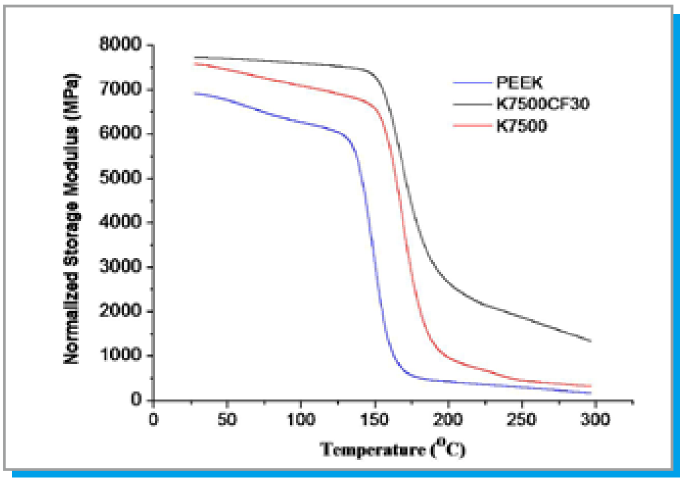


Figure 8. DMA curves comparisons of Arylmax® K and PEEK

It can be seen from Figure 8 that the high temperature mechanical properties retention of Arylmax® K materials are at least 20% higher than those of PEEK which indicated better application values at high temperature and especially in harsh environments.

Compressive Properties

In the standard tests for compressive properties (ASTM D695), a specimen is compressed at a constant strain rate between two parallel platens until it ruptures or deforms by a certain percentage (Figure 9).

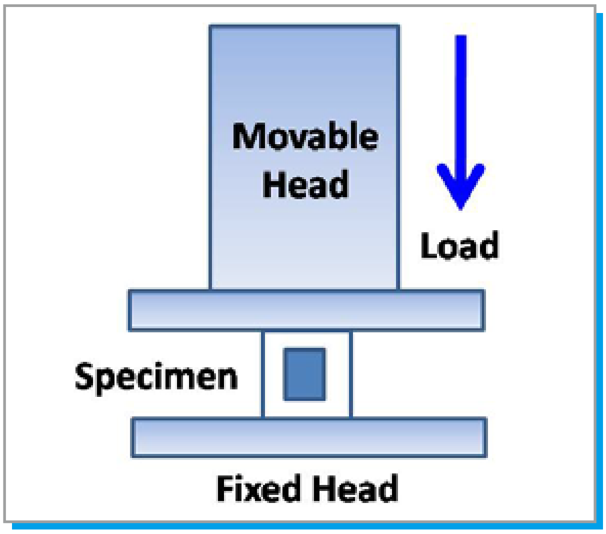


Figure 9. Compressive Properties Testing Diagraph of Arylmax® K

Impact Properties

Important in a variety of applications, impact properties, particularly impact strength, will help you select the proper material. Impact strength, a plastic part's ability to absorb and dissipate energy, varies with its shape, thickness and temperature. While impact properties can be critical in some applications, test results are among the most difficult to relate to actual part performance. Variables such as part geometry, temperature, stress concentration points, molding stresses, and impact speed reduce the accuracy of general impact data for quantitative calculations. The complex and dynamic nature of resin performance during impact has led to the development of a variety of tests that more closely represent different in-use conditions. The most common of these tests are described in this section.

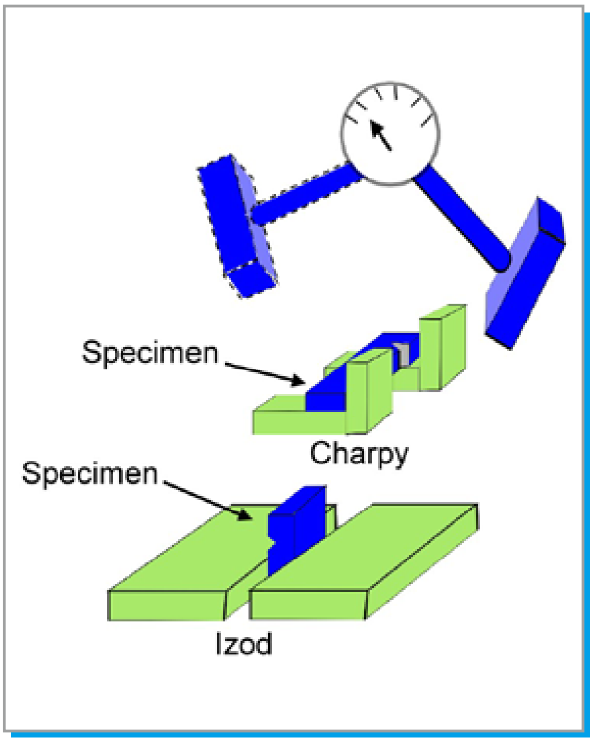


Figure 10. Impact Properties Testing Diagraph of Arylmax® K

Hardness Properties

The hardness properties of plastics, mainly used to compare indentation resistance, may not correlate to the material's actual abrasion, scratch, or wear resistance. The most common tests for comparing relative hardness are Rockwell Hardness (ASTM D785) and Shore Hardness (ASTM D2240).

Due to their strong retention of mechanical properties over a wide range of temperatures and conditions, Arylmax® Materials are widely regarded among the highest performing thermoplastic polymers.

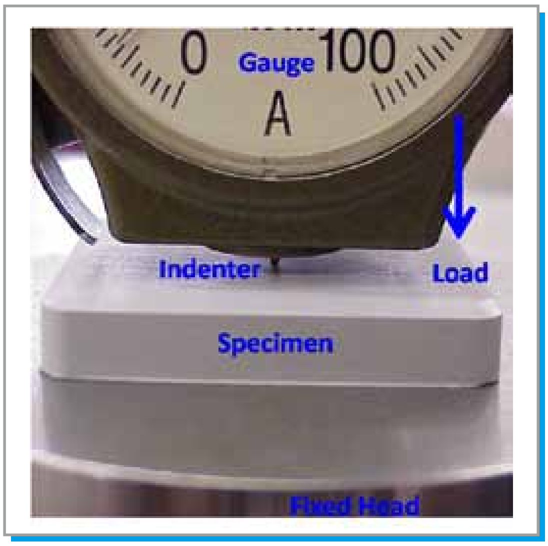


Figure 11. Hardness Properties Testing Diagraph of Arylmax® K

9. Arylmax® K Electrical Properties

Arylmax® K materials are often used as an electrical insulator due to their outstanding thermal and environmental resistance, and mechanical performance.

Volume Resistivity

A measure of the material's electrical insulating property provides a means to compare plastics used as insulators. Volume resistivity should be at least 10^8 ohm*cm to be considered an insulating material. While polymers generally have excellent insulating properties, their electrical resistance decreases with increasing temperature and moisture content, sometimes by orders of magnitude within a part's given service range. Component geometry and time may also be significant and must be evaluated when designing for operating conditions. A measure of the electrical resistance between opposite faces of a unit cube of material, volume resistivity indicates current-leakage resistance through an insulating body. The tests for volume resistivity (ASTM D257 or IEC93) measure resistance in ohms between electrodes mounted on opposite specimen faces (Figure 11). This resistance is multiplied by the electrode's area then divided by the sample thickness, which gives the volume resistivity in ohms-cm.

Surface Resistivity

The electrical resistance between two electrodes on the surface of the specimen of a material is defined as the surface resistivity which is the ratio of the potential difference between two electrodes forming a square geometry on the surface of a specimen and the current which flows between them. Arylmax® K materials have a surface resistivity typical of insulative high performance polymers.

Because test results are sensitive to humidity, surface contamination, and surface contour, accurate and reliable measurements are difficult to obtain. In the tests (ASTM D257 or IEC93), the resistance between two straight conductors pressed onto opposite edges of the test specimen determine the current leakage along the surface of a 0.4-inch (1-cm) square of the insulating material. Because the length and width of the path are the same, the centimeter terms cancel, leaving ohms as the standard measurement unit.

Material Base	Type	Grade	Specifications(Ω)
Arylmax® K	ESD (Electrostatic Discharge)	500	10^1~10^3
		510	10^4~10^6
		520	10^6~10^8
		530	10^8~10^{12}
		540	10^{15}~10^{16}

Figure 11. Standard Grades of ESD Arylmax® K

Polymics can supply consistent surface and volume resistivity formulations for the Arylmax® K series products. These products had been widely used in test socket areas and semiconductor industries.

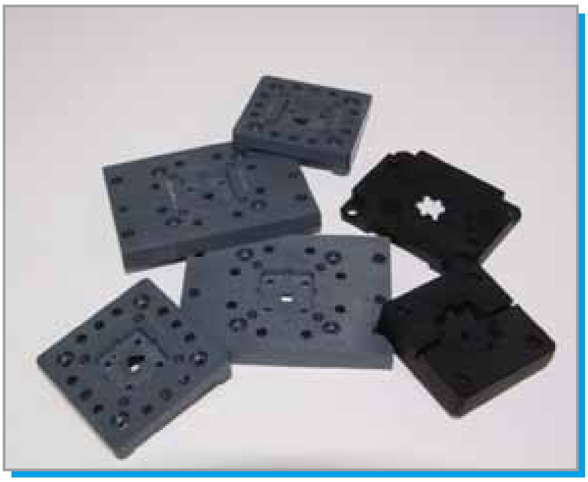


Figure 12. End Test Sockets made of Arylmax® K ESD Products

Dielectric Constant

An important factor in high-power and/or high-frequency applications, the dielectric constant is dimensionless and varies with temperature, moisture levels, frequency, and part thickness. Specifically, the dielectric constant is the ratio of the capacitance of a plate electrode system with a test specimen as the dielectric to the capacitance of the same system with a vacuum as the dielectric. A schematic of the standard tests for measuring dielectric constants (ASTMD150 or IEC250) is shown in Figure 13. Lower values indicate better insulating characteristics.

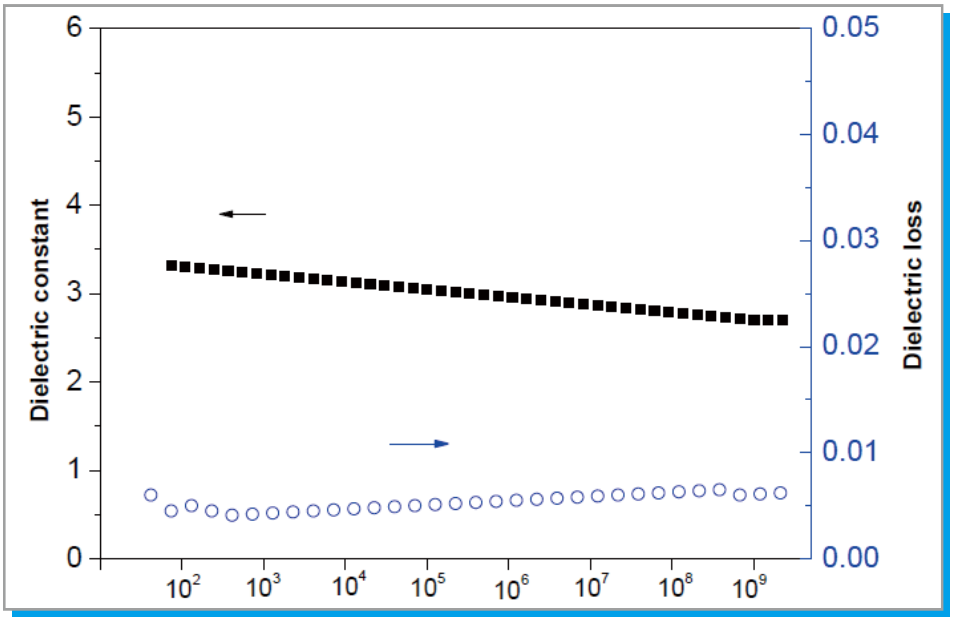


Figure 13. Dielectric Constant and Dielectric Loss of Arylmax® K over Wide Frequency Range

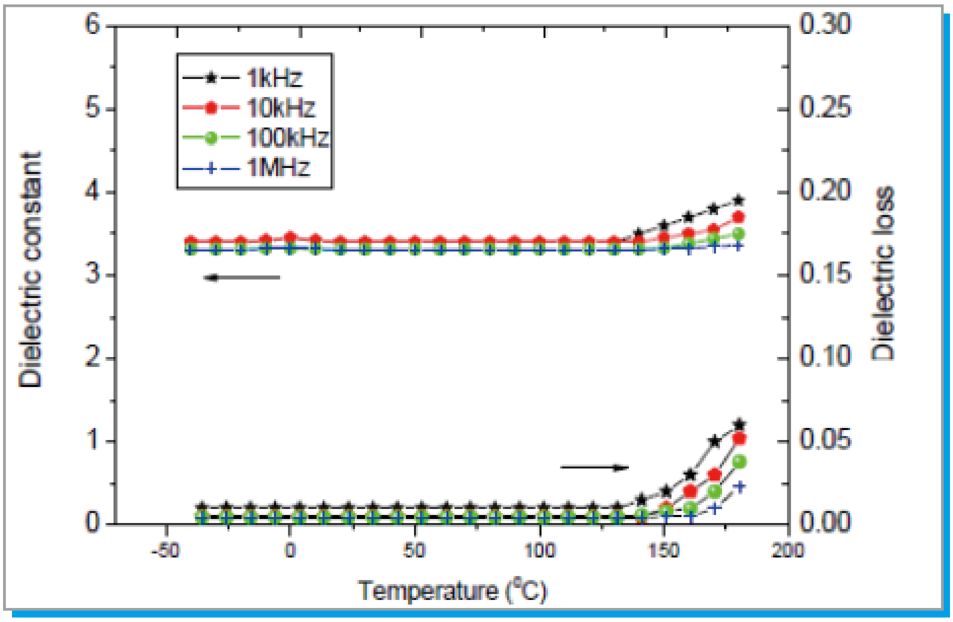


Figure 14. Dielectric Constant and Dielectric Loss of Arylmax® K under Wide Frequency vs. Temperature

From Figure 14 we can see that Arylmax® K series product maintains a relatively consistent Dielectric Constant and Dielectric Loss from 1KHz to 2GHz below 150°C.

Dielectric Dissipation Factor

Measuring a resin's tendency to convert current into heat, the dissipation factor, is particularly important in applications such as radar and microwave equipment that run at high frequencies. The loss tangent (dissipation factor) is expressed as the ratio of the power loss in a dielectric material to the power transmitted through it.

Some resins subjected to these reversing fields convert a high percentage of the energy to heat, making the process inefficient and possibly leading to part failure.

The excellent stability of Arylmax®K's dielectric constant across virtually the whole tested frequency makes it uniquely suitable in the signal transmission area, especially for applications involving smart phone antennas.

10. Arylmax® K Flammability Properties

Flammability can be defined as the ability of a material to support combustion. A flammable material is one which is easily ignited and burns rapidly. Arylmax® K materials are inherently resistant to combustion, and when they do burn, they produce no toxic or corrosive gases compared with other polymers. The addition of fillers (such as glass or carbon fiber) further improve Arylmax® K materials inherent resistance to combustion.

Flammability

Unfilled Arylmax® K achieves UL94 V-0 rating at 0.060". Glass or carbon fiber-filled grades achieve UL94 V-0 ratings at 0.020" over a wide range of filler levels.

Underwriters Laboratories has established flammability classes for plastics (UL 94). Classes range from “HB,” the least flame resistant, through more resistant ratings of “V-2,” “V-1”and “V-0.” Additionally materials can receive a “5VA” or “5VB” rating based upon a separate test covered under UL 94 for the more stringent flammability requirements in electrical and electronic enclosures. The vertical-flame test and horizontal test will be used when running a flammability test in accordance with UL 94.

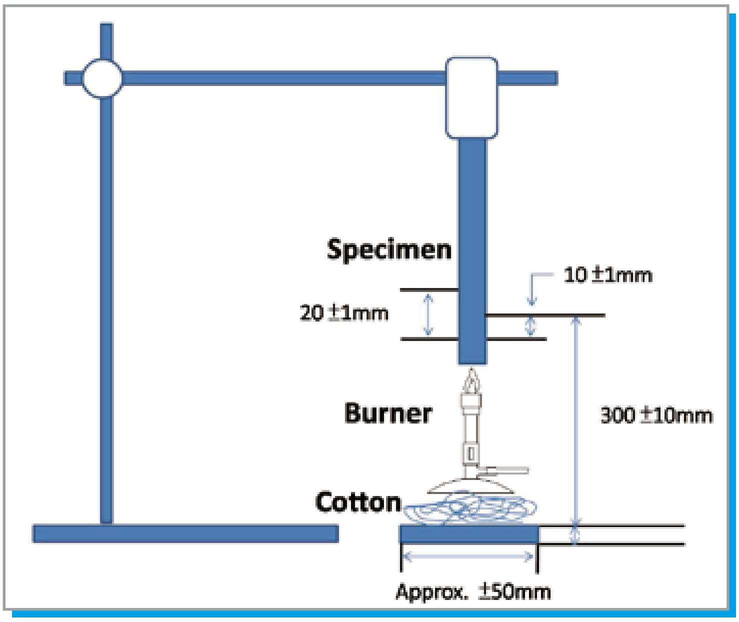


Figure 15. Vertical Burning Test for UL Flammability

11. Arylmax® K Tribological Properties

Tribology is the science and engineering of interacting surfaces in relative motion which includes the study and application of the principles of friction, lubrication and wear. Tribology is a branch of mechanical engineering and materials science that deals with the interaction of contacting surfaces in relative motion under applied load; their design, friction, wear and lubrication. Arylmax® K materials are used for tribological components due to their outstanding resistance to wear under high pressure and velocity conditions.

Wear

Wear is related to interactions between surfaces and more specifically the removal and deformation of material on a surface as a result of mechanical action of the opposite surface. Wear may make the surface smoother or rougher, due to a range of processes including surface fatigue, abrasive wear, and adhesive wear. The lower the wear rate, the better the resistance to wear in that specific wear scenario. The wear rate is defined as the rate of height loss in a specific wear environment, but is often reported as specific wear rate or wear factor = wear rate/(pressure x velocity).

The wear rate is influenced by the test conditions(pressure and velocity). It is therefore vital to know whether the wear factor is from high speed / low pressure or from low speed / high pressure testing.

Figure 16. Bushings made of Arylmax® K Products

12.Selection Guides

As the potential of high performance engineering polymers evolves, components and parts made from these polymers are replacing those made from stainless steel, aluminum, ceramic, and bronze. These replacements are becoming more prevalent due to the superior properties of high performance engineering plastics such as:

- ***Longer part life***
- ***Elimination of lubrication***
- ***Reduced wear on mating parts***
- ***Faster operation of equipment / line speeds***
- ***Less power needed to run equipment***
- ***Corrosion resistance and inertness***

Though the advantages are obvious, selecting the best material may not be. The following outlines some guidelines that may be helpful while selecting a material.

Step 1 – Determine what type of forces are present during operation

If the forces are mainly frictional, it is a "Bearing and Wear Application"

If the forces are static and dynamic, it is a "Structural Application"

Step 2 – Determine the thermal requirements of your application

Consider both typical and extreme operating conditions

The two factors that determine a material's heat resistance are its heat deflection temperature (HDT) and continuous service temperature.

Step 3 – Determine chemical exposure

Consider chemicals present in the operating environment

Consider chemicals or chemical processes used to clean the equipment

Step 4 – Consider additional material characteristics including:

Relative Impact Resistance/Toughness

Dimensional Stability

Regulatory/Agency Compliance

Step 5 – Determine the best shape and manufacturing method for value

Polymics offers many processing options such as compression molding, extrusion, CAM, and injection molding capabilities. Selecting the best method will enable the least amount of material to be used during manufacturing. This reduces fabrication costs, increases the turn-over rate, and reduces scrap material.

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Only Polymics products have the high performance and material properties listed in this brochure.

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