Material Properties acc. to DIN EN ISO 10350		Norm ISO (IEC)	Unit Einheit	**Polytron PMMA XT**
Used Test Method[x)]				*IE*
Material[1)]	-	-	-	PMMA
Fillers/Modification[1)]	-	-	-	extrudiert/extruded
Color[2)]	-	-	-	clear-transparent
Density	ρ	1183	g/cm³	1,19
Water Absorption (saturation in water)[3)]	Ww	62	%	2,1
Moisture Absorption (saturation at 23°C/50% RH)[3)]	WH	62	%	-
MECHANICAL PROPERTIES*)				
Tensile Test[4)]				
Modulus of Elasticity	E_t	527-1/2	MPa	3300
Tensile Stress at Yield	σ_Y	527-1/2	MPa	72
Tensile Stress at Break	σ_B	527-1/2	MPa	-
Tensile Stength	$\sigma_{Y\,max}$	527-1/2	MPa	-
Yield Strain	ε_Y	527-1/2	%	-
Strain at Break	ε_B	527-1/2	%	4,5
Flexural Modulus[6)]	E_f	178	MPa	-
Flexural Strength[6)]	$\sigma_{Y\,max}$	178	MPa	105
Compressive Strength[7)]				
Compressive Stress @ 1% Strain	σ_{d1}	604	MPa	-
Compressive Stress @ 2% Strain	σ_{d2}	604	MPa	-
Compressive Stress @ 10% Strain	σ_{d10}	604	MPa	-
Impact Strength[8)]				
Charpy-Impact-Strength	acU	179	KJ/m²	15
Charpy-Notched-Impact-Strength	acN	179	KJ/m²	-
Izod-Impact-Strength	aiU	180	KJ/m²	-
Izod-Notched-Impact-Strength	aiN	180	KJ/m²	1,6
Hardness				
Ball Indentation[9)]	H	2039-1	MPa	175
Rockwell[9)]	R	2039-2	-	-
Shore[10)]	-	868	-	-
Tribology Properties[11)]				
Coefficient of Friction, dynamic	μ_{dyn}	7148-2	-	0,50 - 0,80
Wear Rate	-	7148-2	µm/km	-
THERMAL PROPERETIES				
Melting Point[12)]	Tm	11357-1 u. 3	°C	-
Glastransition Temperature[12)]	Tg	11357-1 u. 2	°C	112
Specific Heat @ 23°C	c	-	J/(g x K)	1,47
Heat-Deflection-Temperature (HDT-A)[13)]	Tf 1,8	75-1/2	°C	95
Vicat-Softening-Temperature (VST-B50)[14)]	Tv	306	°C	103
Thermal Conductivity	λ	-	W/(m x K)	0,19
Relative Temperature Index acc. UL746B Str	RTI	-	°C	90
Continous Service Temperature[15)]				
Min.	-	-	°C	-30
Max. short time	-	-	°C	75
Max. continously 5.000/20.000 h	-	-	°C	70/60
Coefficient of Linear Thermal Expansion[16)]				
between 23 and 55 °C	α	11359-1/2	K^{-1} x 10^{-6}	70
between 23 and 150 °C	α	11359-1/2	K^{-1} x 10^{-6}	-
above 150 °C	α	11359-1/2	K^{-1} x 10^{-6}	-
Flamability[17)]				
acc. to DIN 4102	-	-	Class	B2/-
acc. to UL 94 @ 3 mm thickness	-	9772 u. 9773	Class	-
Oxygene Index[18)]	O/23	4589-1/2	%	-
ELECTRICAL PROPERTIES[19) *)]				
Dielectric Constant @ 100 Hz	εr 100	IEC 60250	-	2,8
Dielectric Constant @ 1 MHz	εr 1M	IEC 60250	-	-
Dissipation Factor @ 100 Hz	tan δ 100	IEC 60250	-	0,03
Dissipation Factor @ 1 MHz	tan δ 1M	IEC 60250	-	-
Volume Resistivity	ρe	IEC 60093	Ωcm	> 10E15
Surface Resistivity	σe	IEC 60093	Ω	> 10E13
Dielectric Strength	EB 1	IEC 60243-1	kV/mm	30
Resistance to Tracking	CTI	IEC 60112	-	600
MISCELLANEOUS PROPERTIES[*)]				
Resistance against Acids	-	-	-	B
Resistance against Alkalies	-	-	-	B
UV-Resistance	-	-	-	A
Hydrolysis-Resistance	-	-	-	B
Food Contact	-	-	-	+

The data contained herein are average values and partly taken from the information of the raw material suppliers. It is quite possible, however, that in some cases the material properties differ significantly from the information given in this document! Reinforced plastics in particular are often anisotropic and consequently show parallel and perpendicular to the flow direction different characteristics. Tests with injection molded specimens which often are used by raw material suppliers may result in clearly distinctive values. [*) #)]

Comparing the material properties of different companies, one must see to it that the test procedures are similar. Test procedures may considerably differ in respect to conditions, parameters and applied standards which might lead to evident different property values. In general, POLYTRON determines the material properties according to commonly valid ISO standards. [x)]

Please pay attention to the remarks hereinafter:

Unless otherwise stated the material properties were obtained in standard climate, at room temperature with 23°C and 50 % relative humidity.

1) Material designation as well as indication of probable fillers is done with reference to ISO 1043 part I and II.

2) Only common colors for semi-finished shapes are indicated here. Other colorations are quite possible if the quantity is sufficient. However, colorants may influence the material properties to some extent considerably!

3) As the data for the water/moisture absorption depends on the chosen size of test specimen as well as on test parameters, values are only given for saturation but not on time.

   Remark: In liquid or gaseous state, water as well as other liquids with their ingredients may penetrate the material structure and influence the molecular system. Hereby the material properties may be changed considerably. In normal cases these processes are reversible. In theory, substances can be eliminated from the material or the material structure material can be influenced (for example by re-crystallization), which would change the properties persistently. In general, goes the water/moisture absorption along with a change of volume. The dimensional change of isotropic plastics can be up to 30% of the moisture absorption. The dimensional change of reinforced plastics depends on the fiber orientation.

4) The tension speeds applied are chosen from the standards for the materials to be tested. In general, the tensile strength of engineering plastics is determined at 20 mm/min of fiber reinforced and high performance plastics at 5 mm/min and of the relatively soft materials (for instance PE) at 50 mm/min. The tension e-modulus is always determined at a tension speed of 1 mm/min. Test specimens are described in ISO 3167 standard (in general type 1B with a thickness of 4 mm is used).

   Remark: A high yield stress or stress at break refer to a solid, strong material. Materials with high strain are tough those with low brittle. The e-modulus in turn supplies information on the rigidity of materials.

5) Creep strength limit gives information on creep strength under tensile load, i.e., the given value describes the deformation of the test specimen under load over the time. Practically the initial stress is reflected which after 1,000 hours of load leads to a tension of 1%.

6) The test speeds are prescribed in ISO 178 and comparable with those of the tension test. Test specimen is of rectangular shape with a size of 4 x 10 x 80 mm.

   Remark: The correlation between tension and elongation of plastics is in general nonlinear. Therefore, in case of doubt does the flexural modulus result in higher test values than that of the tension test. In case the load exceeds the limit of the e-modulus, one has to count with an irreversible damage of the material structure. Therefore, the value of the obtained flexural test is only of limited use.

7) The compressive stress at strain describes the material performance under compressive load. A strain value is given which includes a 1 % compression of the test specimen. For this a cylindrical test specimen is used of which the ratio of diameter and length is at least 0.4 (for instance: Ø 12 x 30 mm).

8) ISO 179 and 180 provide quite a number of test specimens and possible directions of application for force. Apart from the exceptions listed in the ISO, test specimens of type 1 (4 x 10 x 80 mm) are used. Due to the size of test equipment for Izod impact tests also test specimens of type 2 (12.7 x 12.7 x 63.5 mm) are used. Except for laminated plastics, vertical direction of force application is preferred on the small sides of the test specimens. For notched test specimens the groove ground radius is specified in the ISO. The preferred is the radius A with 45°. The size of the chosen pendulum hammer is specified by the ISO. The work input W for breaking the test specimen must be within 10 and 80 % of the pendulum work power E (nominal value). In most cases a pendulum of 5 J nominal efficiency is used for the notch impact strength test.

   Remark: The details next to the ISO supply information on the chosen test specimens and directions of application for force; 1eU therefore means: test specimen type 1, force applied along the small side, unnotched. Would an N be indicated instead of the U, the test specimen would be notched, with a groove ground radius N = A, B or C.

9) The ISO proposes a smooth and even plate of 50 x 50 mm surface with 4 mm thickness for the specimen. The test load for the ball pressure hardness can range from 49, 132, 358 or 961 N, the one for Rockwell hardness is determined to be 980 N.

10) The shore hardness test has a particular measuring scale and therefore is recommendable for softer materials, like PE, PTFE or elastomers. The ISO provides two test scales, Shore A and Shore D. In case the values obtained with the durometer type A should exceed 90° then it is recommended to use the durometer type D. Generally, it is recommended to use measuring per ball indentation or Rockwell for harder thermoplastics.

11) The tribology properties were tested on a pin on disk tribo system. The test setup follows the instructions of the ISO 7148-2. For this purpose, a pin of Ø 6 mm from the material to be tested is pressed with 3 MPa on a rotating C35 steel disk of Ø 160 mm, roughness Ra = 0.7 – 0.9 µm. The disk rotates with a speed of 0.33 m/s over a distance of 28,000 meters. The results from the above described test setup, however, are not universally valid, as other test setups as well are allowed which may result in deviating values. The American test procedure according to ASTM D 3702 for example is already in its test setup extremely different to the pin on disk test and therefore may yield in totally different test results.

   Remark: The dynamic coefficient of friction indicates the frictional resistance of a moving glide element. Contrary to this does the static coefficient of friction reflect the initial resistance of a glide element to be put in motion. The bigger the difference between *both values, the bigger is the so-called slip-stick, i.e. the blocking up in the very beginning of the start. For applications where the motion is interrupted frequently, and high rotation exactness is required materials have to be chosen with very low slip-stick susceptibility.*

12) The melting temperature declares the value at which the thermoplastic materials get to their viscous status. A critical point for amorphous plastic materials respectively for the amorphous parts of the semi-crystalline plastics is the glass transition temperature as above this temperature the amorphous parts become thermo-elastic. Of thermosetting plastics respectively plastics with thermosetting characteristics (for instance PTFE, PI, PBI), however a melting temperature cannot be determined. The temperature resistance of these materials is limited only by the thermal oxidative decomposition.

<u>Remark</u>*: Reaching the glass transition temperature, the semi-crystalline materials can already lose a considerable part of their strength although the real melting temperature, where the crystalline parts reach their plastic condition, is much higher. Helpful for the evaluation the fact of this matter is the heat deflection temperature or the Vicat softening temperature explained hereafter.*

13) The heat deflection temperature describes the temperature where the test specimen achieves a bowing specified in the standard spec. under a defined load (edge fibre or flexural stress). The ISO 75-2 provides three methods for this load: A with 1.8 MPa, B with 0.45 MPa or C with 8 MPa. In common practice a load of 1.8 MPa (method A) is applied.

14) By means of the Vicat procedure the temperature is determined at which a defined entering body under specified load and specified temperature increase gets 1 mm deep into the surface of the test specimens. This standard provides four variants: Procedure A with a load of 10 N and a temperature increase of 50°C/h (A50) or 120°C/h (A120) respectively and procedure B with a load of 50 N and a temperature increase of 50°C/h (B50) or 120°C/h (B120) respectively.

15) On determination of the continuous operating temperature, a heavy impact load is provided as plastics often become brittle when exposed to coldness. The minimum continuous operating temperature shows the value at which the material still possesses at least 50 % of its standard impact strength. The maximum continuous operating temperature however describes the temperature at which the material after the indicated operation time still possesses 50 % of its strength. Short-time means in this context that the material is exposed to the temperature for some hours only.

<u>Remark</u>*: The continuous operating temperature in general depends on the time and height of the mechanical load applied during the induction period of temperature. This means that at lower or without mechanical load the materials can also be used at lower or higher temperatures than those indicated.*

16) The coefficient of linear thermal expansion indicates the linear extension of a material depending on the changing temperature load per unit. The expansion may be different in parallel and perpendicular direction, particularly for reinforced material.

17) The details on flammability and extinction are taken from the data sheets of our raw material suppliers and are neither based on own testing nor on testing of semi-finished shapes. Therefore, they do not represent reliable information on actual material behavior nor on that of a part made hereof in case of fire.

<u>Remark</u>*: The performance under fire describes the properties of plastics under specified heating/firing rates, depending on the thickness of specimens. The grading is specified in a so-called flammability classification.*
DIN 4102 distinguishes between non-inflammable (A class) and inflammable (B class) materials, i.e. B1 means hardly inflammable, B2 normal inflammable, B3 easily inflammable. Similar to this is the classification of the American Underwriter Laboratories (UL), following the ISO 9772 and 9773 on a scale from HB which is the worst up to 5V which is the best grade (*HB ➔ V-2 ➔ V-1 ➔ V-0 ➔ 5V*), likewise depending on the thickness of the test specimens as well on the duration/time of heating/firing.

18) The oxygen index shows the minimum oxygen concentration in an oxygen-nitrogen-composition/mixture which is needed for burning a material.

19) The tests for the electrical properties were made with natural test specimens (without color). The properties of colored, in particular black test specimens may be lower up to 50 % of those of natural materials, as the color particles may have a conducting influence. Micro porosity, voids as well as high moisture content may also have a considerable adverse effect on the insolating properties of plastic materials.

*) Due to the moisture absorption of polyamide (PA) do the properties vary partly considerably for which reason value sections have to be given for mechanical as well as for electrical properties.

#) Materials reinforced with fibers as a rule are anisotropic. These materials may show partly considerable property variances in parallel or perpendicular to the flow direction.

+) Following standards and test specimens were used for determining the data:

AE *Properties were obtained on specimens machined from semi-finished shapes as per valid ASTM Standards.*

AS *Properties were obtained on injection molded specimens as per valid ASTM standards.*

DE *Properties were obtained on specimens machined from semi-finished shapes as per valid DIN standards.*

DS *Properties were obtained on injection molded specimens as per valid DIN standards.*

IE *Properties were obtained on specimens machined from semi-finished shapes as per valid ISO standards.*

IS *Properties were obtained on injection molded specimens as per valid ISO standards (ISO 294).*

°) All other property dates base on data sheets of raw material suppliers and are not confirmed by own testing nor testing of semi-finished shapes. Therefore, they do not give reliable information on actual material performance respectively performance of a fabricated part made of this material under service condition.

The symbols and figures have the following meaning:

- *A* *Application is possible; material is usable.*
- *B* *Application is limited; short-term use possible or only under low mechanical load; the material's performance is limited.*
- *C* *Application is not possible; material swells severely or decomposes already after a short time.*
- *+* *Material is reliable respectively can be used for the indicated application.*
- *-* *Material is instable respectively unsuitable for the intended application.*
- *(+)* *Material is not yet tested.*
- *OR* *on Request*
- *swz.* *black*
- *0,0* *The value given with the radiation resistance shows the Radiation Index (RI) which is defined as the logarithm, base 10, of the absorbed radiation dose in Grays at which the mechanical properties (here flexural strength) is reduced to 50% of its initial value.*

Properties shown in this table may help to make the right material choice and to compare the different plastic materials. However, these properties are not legally binding! Data must not be used for specifications nor be used as sole basis for designing purpose! The user or buyer is obligated to control the quality and properties of the recommendations on its own always by testing under practical service conditions. Any infringements of patents, copyrights or other rights in the possession or under the administration of third parties by the application, use, processing or other use of their recommendations, information, data or products are at the user's own risk!

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