# **TORLON®**

## Polyamide-imide (PAI)

## **Main Characteristics:**

- Very high max. allowable service temperature in air (250°C continuously)
- Excellent retention of mechanical strength, stiffness and creep resistance over a wide range of temperatures
- Extremely low coefficient of linear thermal expansion up to 250°C
- Excellent wear and frictional behaviour (particularly TORLON® 4301 PAI)
- · Excellent UV resistance
- · Inherent low-flammability
- Exceptional resistance against high energy radiation (gamma and X rays)

The TORLON® PAI grades, combining excellent retention of mechanical strength, stiffness and creep resistance over a wide temperature range with extremely low thermal expansion up to 250°C, are top-rank materials for high temperature applications.

We distinguish five grades:

## **TORLON® 4501 PAI**

(PAI + graphite + PTFE)

Colour: Black

This compression moulded material is similar in composition to TORLON® 4301 PAI, and is selected when larger shapes are required.

### TORLON® 5530 PAI

(PAI + GF30) Colour: Khaki grey

This compression moulded, 30% glass fibre reinforced grade offers higher stiffness, mechanical strength and creep resistance than TORLON® 4203 PAI and TORLON® 4503 PAI. It is well suited for structural applications supporting static loads for long periods of time at high temperatures. The suitability of TORLON® 5530 PAI for sliding parts, however, is to be carefully examined since the glass fibres tend to abrade the mating surface.

### **TORLON® 4203 PAI**

(PAI)

Colour: Yellow ochre

TORLON® 4203 PAI offers the best toughness and impact strength of all TORLON® PAI grades. Because of its intrinsic high temperature resistance, high dimensional stability and good machinability, this extruded TORLON® PAI grade is very popular for precision parts in high-tech equipment. In addition, its good electrical insulating ability provides numerous possibilities in the field of electrical components.

## TORLON® 4503 PAI

(PAI)

Colour: Yellow ochre

This compression moulded material is similar in composition to TORLON® 4203 PAI, and is selected when larger shapes are required.

### TORLON® 4301 PAI

(PAI + graphite + PTFE)

Colour: Black

The addition of graphite and PTFE provides higher wear resistance and lower coefficient of friction compared to the unfilled grade as well as little or no stick-slip in use. This extruded grade excels in severe wear applications such as non-lubricated bearings, seals, bearings cages and reciprocating compressor parts.

#### TORLON® 4203 PAI Polyamide-imide (PAI)

TORLON® 4203 PAI offers the best toughness and impact strength of all TORLON® PAI grades. Because of its intrinsic high temperature resistance, high dimensional stability and good machinability, TORLON® PAI grade is very popular for precision parts in high-tech equipment. In addition, its good electrical insulating ability provides numerous possibilities in the field of electrical components.

- High maximum service temperature (250°C)
- Inherent low flammability
- Outstanding dimensional stability (to +250°C) Excellent dielectric and insulating properties
- · Excellent resistance against high energy radiation
- Exceptional wear resistance
- Excellent retention of mechanical strength / stiffness over a wide range of temperatures

#### **Common Applications:**

Connectors; Switches; Relays; Thrust washers; Valve seats; Piston rings; Mechanical linkages; Bushes; Electrical and thermal insulators.

| Delivery Programme                                |             |      |  |
|---|-------------|------|--|
|   | min         | max  |  |
| Rod 2440mm long diameter (mm)                     | 2.38        | 50.8 |  |
| Plate 1220mm long<br>width (mm)<br>thickness (mm) | 305<br>6.35 | 25.4 |  |
| Colour: Yellow ochre                              |             |      |  |

| Density   | Technical Specification                             |            |                   |                     |
|---|---|------------|-------------------|---------------------|
| Water absorption*1       • after 24h immersion in water (23°C)       62       mg       29         • Saturation in air (23°C/50% RH)       ~       %       2.5         • Saturation in water (23°C)       ~       %       4.4         Melting temperature       ~       °C       N/A         Glass transition temperature       ~       °C       280         Thermal conductivity at 23°C       ~       W/(K.m)       0.26         Coefficient of linear thermal expansion       •       werage value between 23 · 100°C       ~       m/(m-K)       30.10°6         • average value between 23 · 150°C       ~       m/(m-K)       30.10°6       average value above 150°C       ~       m/(m-K)       30.10°6         • average value above 150°C       ~       m/(m-K)       30.10°6       m/(m-K)       30.10°6         • average value above 150°C       ~       m/(m-K)       30.10°6       m/(m-K)       30.10°6         • average value above 150°C       ~       m/(m-K)       30.10°6       *         • Temperature of deflection under load       *       *       °       C       280         Max allowable service temperature in air       •       •       °       °       2       2       2  | Property  | ISO Method | Units             | Values              |
| - after 24h immersion in water (23°C) 62  |   | 1183       | g/cm <sup>3</sup> | 1.41                |
| Saturation in air (23°C/50% RH)   | Water absorption*1                                  |            |                   |                     |
| · Saturation in air (23°C/50% RH)         ~         %         2.5           · Saturation in water (23°C)         ~         %         4.4           Melting temperature         ~         °C         N/A           Glass transition temperature         ~         °C         280           Thermal conductivity at 23°C         ~         W/(K.m)         0.26           Coefficient of linear thermal expansion         .         werage value between 23 · 100°C         m/(m-K)         30.10°6           · average value between 23 · 150°C         ~         m/(m-K)         30.10°6           · average value above 150°C         ~         °         2         20   | after 24h immersion in water (23°C)                 | 62         | mg                | 29                  |
| • Saturation in water (23°C)         ~         %         4.4           Melting temperature         ~         °C         N/A           Glass transition temperature         ~         °C         280           Thermal conductivity at 23°C         ~         W/(K.m)         0.26           Coefficient of linear thermal expansion         .         w/(K.m)         0.26           coefficient of linear thermal expansion         .         m/(m-K)         30.10°6           .         average value between 23 - 150°C         ~         m/(m-K)         30.10°6           .         average value between 23 - 150°C         ~         m/(m-K)         30.10°6           .         average value above 150°C         ~         m/(m-K)         30.10°6           .         average value above 150°C         ~         m/(m-K)         30.10°6           .         average value between 23 - 150°C         ~         m/(m-K)         30.10°6           .         average value above 150°C         ~         m/(m-K)         30.10°6           .         average value above 150°C         ~         m/(m-K)         30.10°6           .         average value above 150°C         ~         C         280           Max allowable service temper  |   | 62         | %                 | 0.35                |
| Melting temperature         ~         °C         N/A           Glass transition temperature         ~         °C         280           Thermal conductivity at 23°C         ~         W/(K.m)         0.26           Coefficient of linear thermal expansion         .         werage value between 23 · 100°C         ~         m/(m-K)         30.10°6           . average value between 23 · 150°C         ~         m/(m-K)         30.10°6           . average value between 23 · 150°C         ~         m/(m-K)         30.10°6           . average value between 23 · 150°C         ~         m/(m-K)         30.10°6           . average value between 23 · 150°C         ~         m/(m-K)         30.10°6           . average value between 23 · 150°C         ~         m/(m-K)         30.10°6           . average value between 23 · 150°C         ~         m/(m-K)         30.10°6           . average value between 23 · 150°C         ~         m/(m-K)         30.10°6           . average value between 23 · 150°C         ~         m/(m-K)         30.10°6           . average value between 23 · 150°C         ~         m/(m-K)         30.10°6           . average value between 23 · 150°C         ~         280           Max 180         60°C         250   | Saturation in air (23°C/50% RH)                     | ~          | %                 | 2.5                 |
| Glass transition temperature $\sim$ °C 280 Thermal conductivity at 23°C $\sim$ W/(K.m) 0.26 Coefficient of linear thermal expansion $\cdot$ average value between 23 · 100°C $\sim$ m/(m-K) 30.10°6 $\cdot$ average value between 23 · 150°C $\sim$ m/(m-K) 30.10°6 Temperature of deflection under load $\cdot$ method A: 1.8 MPa 75 °C 280 Max allowable service temperature in air $\cdot$ for short periods*2 $\sim$ °C 270 continuously for 20,000 hrs*3 $\sim$ °C 250 Flammability*4 $\cdot$ "Oxygen Index" 4589 % 45 $\cdot$ according to UL94 (1.5/3mm thickness) $\sim$ $\sim$ V-O/V-O Tension Test*5 $\cdot$ Stress at yield*6 527 MPa 120 $\cdot$ Strain at break*6 527 MPa 4500 Compression Test*8 $\cdot$ Stress at 1/2% nominal strain*7 604 MPa 27/53 Impact $\cdot$ Charpy*9 179/1eU kJ/m² no break Impact $\cdot$ Charpy notched 179/1eA kJ/m² 10 Ball Indentation hardness*10 2039-1 N/mm² 200 Hardness Rockwell*10 2039-2 $\sim$ E80 M120 Electric Strength*11 60243 KV/mm 24 Volume resistivity 60093 $\Omega$ cm $>$ 10 <sup>13</sup> Relative Permittivity at 1 Mhz 60250 $\sim$ 3.9  | Saturation in water (23°C)                          | ~          | %                 | 4.4                 |
| Thermal conductivity at $23^{\circ}\text{C}$ $\sim$ W/(K.m) 0.26 Coefficient of linear thermal expansion $\cdot$ average value between $23 \cdot 100^{\circ}\text{C}$ $\sim$ m/(m-K) $30.10^{-6}$ $\cdot$ average value between $23 \cdot 150^{\circ}\text{C}$ $\sim$ m/(m-K) $30.10^{-6}$ $\cdot$ average value above $150^{\circ}\text{C}$ $\sim$ m/(m-K) $30.10^{-6}$ Temperature of deflection under load $\cdot$ method A: 1.8 MPa $75$ °C $280$ Max allowable service temperature in air $\cdot$ for short periods*2 $\sim$ °C $250$ Flammability*4 $\cdot$ "Oxygen Index" $4589$ % $45$ $\cdot$ according to UL94 (1.5/3mm thickness) $\sim$ $\sim$ V-O/V-O Tension Test*5 $\cdot$ Stress at yield*6 $\cdot$ 527 MPa $\cdot$ 10 $\cdot$ 11 $\cdot$ 10 $\cdot$ 10 $\cdot$ 11 $\cdot$ 10 $\cdot$ 11 $\cdot$ 10 $\cdot$ 11 $\cdot$ 10 $\cdot$ 11 $\cdot$ 10 $\cdot$ 12 $\cdot$ 10 $\cdot$ 11 | Melting temperature                                 | ~          | °C                | N/A                 |
| Coefficient of linear thermal expansion  · average value between 23 · 100°C ~ m/(m-K) 30.10°6  · average value between 23 · 150°C ~ m/(m-K) 30.10°6  · average value above 150°C ~ m/(m-K) 30.10°6  Temperature of deflection under load  · method A: 1.8 MPa 75 °C 280  Max allowable service temperature in air  · for short periods*2 ~ °C 270  · continuously for 20,000 hrs*3 ~ °C 250  Flammability*4  · "Oxygen Index" 4589 % 45  · according to UL94 (1.5/3mm thickness) ~ ~ V-0/V-0  Tension Test*5  · Stress at yield*6 527 MPa 120  · Strain at break*6 527 % 10  · Tensile modulus of elasticity*7 527 MPa 4500  Compression Test*8  · Stress at 1/2% nominal strain*7 604 MPa 27/53  Impact - Charpy *9 179/1eU kJ/m² no break Impact - Charpy notched 179/1eA kJ/m² 10  Ball Indentation hardness*10 2039-1 N/mm² 200  Hardness Rockwell*10 2039-2 ~ E80 M120  Electric Strength*11 60243 KV/mm 24  Volume resistivity 60093 Ω.cm >10¹4  Surface resistivity 60093 Ω.cm >10¹3  Relative Permittivity at 1 Mhz 60250 ~ 3.9   | Glass transition temperature                        | ~          | °C                | 280                 |
| · average value between 23 · 100°C       ~       m/(m-K)       30.10°6         · average value between 23 · 150°C       ~       m/(m-K)       30.10°6         · average value above 150°C       ~       m/(m-K)       30.10°6         Temperature of deflection under load       .       method A: 1.8 MPa       75       °C       280         Max allowable service temperature in air       .       for short periods*2       ~       °C       270         · continuously for 20,000 hrs*3       ~       °C       250         Flammability*4       .       "0xygen Index"       4589       %       45         · according to UL94 (1.5/3mm thickness)       ~       ~       V-0/V-0         Tension Test*5       .       Stress at yield*6       527       MPa       120         · Strain at break*6       527       MPa       4500         Compression Test*8       .       Stress at 1/2% nominal strain*7       604       MPa       27/53         Impact - Charpy*9       179/1eU       kJ/m²       no break         Impact - Charpy notched       179/1eA       kJ/m²       10         Ball Indentation hardness*10       2039-1       N/mm²       200         Hardness Rockwell*10       2039-2 <td< td=""><td>Thermal conductivity at 23°C</td><td>~</td><td>W/(K.m)</td><td>0.26</td></td<>  | Thermal conductivity at 23°C                        | ~          | W/(K.m)           | 0.26                |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$  | Coefficient of linear thermal expa                  | nsion      |                   |                     |
| · average value above 150°C   | average value between 23 - 100°C                    | ~          | m/(m-K)           | 30.10 <sup>-6</sup> |
| Temperature of deflection under load $ \begin{array}{ccccccccccccccccccccccccccccccccccc$   | average value between 23 - 150°C                    | ~          | m/(m-K)           | 30.10 <sup>-6</sup> |
| $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | average value above 150°C                           | ~          | m/(m-K)           | 30.10 <sup>-6</sup> |
| Max allowable service temperature in air $ \cdot \text{ for short periods}^{*2}  \sim \qquad ^{\circ}\text{C} \qquad 270 \\ \cdot \text{ continuously for 20,000 hrs}^{*3}  \sim \qquad ^{\circ}\text{C} \qquad 250 \\ \text{Flammability}^{*4} \\ \cdot \text{ "Oxygen Index"} \qquad 4589 \qquad \% \qquad 45 \\ \cdot \text{ according to UL94 (1.5/3mm thickness)}  \sim \qquad \sim \qquad \text{V-O/V-O} \\ \text{Tension Test}^{*5} \\ \cdot \text{ Stress at yield}^{*6} \qquad 527 \qquad \text{MPa} \qquad 120 \\ \cdot \text{ Strain at break}^{*6} \qquad 527 \qquad \text{MPa} \qquad 4500 \\ \text{Compression Test}^{*8} \\ \cdot \text{ Stress at 1/2% nominal strain}^{*7} \qquad 604 \qquad \text{MPa} \qquad 27/53 \\ \text{Impact - Charpy}^{*9} \qquad 179/1eU \qquad \text{kJ/m}^2 \qquad \text{no break Impact - Charpy notched} \qquad 179/1eA \qquad \text{kJ/m}^2 \qquad 10 \\ \text{Ball Indentation hardness}^{*10} \qquad 2039-1 \qquad \text{N/mm}^2 \qquad 200 \\ \text{Hardness Rockwell}^{*10} \qquad 2039-2 \qquad \sim \qquad \text{E80 M120} \\ \text{Electric Strength}^{*11} \qquad 60243 \qquad \text{KV/mm} \qquad 24 \\ \text{Volume resistivity} \qquad 60093 \qquad \Omega.\text{cm} \qquad >10^{14} \\ \text{Surface resistivity} \qquad 60093 \qquad \Omega \qquad >10^{13} \\ \text{Relative Permittivity at 1 Mhz} \qquad 60250 \qquad \sim \qquad 3.9 \\ \end{cases}$   | Temperature of deflection under le                  | oad        |                   |                     |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$  | method A: 1.8 MPa                                   | 75         | °C                | 280                 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$  |   | e in air   |                   |                     |
| Flammability*4   • "Oxygen Index"   • 4589  |   | ~          | •                 |                     |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$   |   | ~          | °C                | 250                 |
| $\begin{array}{c ccccccccccccccccccccccccccccccccccc$   | ,   | 4589       | %                 | 45                  |
| Tension Test*5  • Stress at yield*6  • Strain at break*6  • Tensile modulus of elasticity*7  • Stress at 1/2% nominal strain*7  Impact - Charpy*9  Impact - Charpy notched  Ball Indentation hardness*10  Hardness Rockwell*10  Electric Strength*11  Surface resistivity  Relative Permittivity at 1 Mhz  Stress at yield*6  527  MPa  120  MPa  4500  MPa  27/53  MPa  4500  MPa  27/53  Impact - Charpy*9  179/1eU  kJ/m²  no break  Impact - Charpy notched  179/1eA  kJ/m²  10  2039-1  N/mm²  200  E80 M120  E80 M120   | , , ,   |            |                   |                     |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$  |   |            |                   | V 0/ V 0            |
| $ \begin{array}{llllllllllllllllllllllllllllllllllll$   | Stress at yield*6                                   | 527        | MPa               | 120                 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$  | Strain at break*6                                   | 527        | %                 | 10                  |
| $\begin{array}{llllllllllllllllllllllllllllllllllll$  |   | 527        | MPa               | 4500                |
| $\begin{array}{llllllllllllllllllllllllllllllllllll$  | Compression Test*8                                  |            |                   |                     |
| $\begin{array}{llllllllllllllllllllllllllllllllllll$  | <ul> <li>Stress at 1/2% nominal strain*7</li> </ul> | 604        | MPa               | 27/53               |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$  | Impact - Charpy*9                                   | 179/1eU    | kJ/m <sup>2</sup> | no break            |
| $\begin{array}{llllllllllllllllllllllllllllllllllll$  | Impact - Charpy notched                             | 179/1eA    |                   | 10                  |
| Electric Strength* $^{*11}$ 60243 KV/mm 24<br>Volume resistivity 60093 $\Omega$ .cm > $^{10^{14}}$<br>Surface resistivity 60093 $\Omega$ > $^{10^{13}}$<br>Relative Permittivity at 1 Mhz 60250 ~ 3.9   | Ball Indentation hardness*10                        | 2039-1     | N/mm <sup>2</sup> | 200                 |
| Volume resistivity60093 $\Omega$ .cm>1014Surface resistivity60093 $\Omega$ >1013Relative Permittivity at 1 Mhz60250~3.9   |   | 2039-2     | ~                 | E80 M120            |
| Surface resistivity 60093 $\Omega$ >10 <sup>13</sup> Relative Permittivity at 1 Mhz 60250 ~ 3.9   | _   |            | ,                 |                     |
| Relative Permittivity at 1 Mhz 60250 ~ 3.9  | -   |            | $\Omega.cm$       |                     |
| ·   | -   |            | Ω                 |                     |
| Dielectric dissipation factor " 60250 ~ 0.031   | ·   |            | ~                 |                     |
|   | Dielectric dissipation factor "                     | 60250      | ~                 | 0.031               |

 $<sup>^{*1}</sup>$  - According to method 1 of ISO62 and done on discs Ø 50 x 3mm

<sup>-</sup> Only for short time exposure (a few hours) in applications where no or only a very low load is applied to the material

<sup>\*3 -</sup> Temperature resistance over a period of min. 20,000 hours. After this there is a decrease in tensile strength of about 50% as compared with the original value. The temperature value given here is thus based on the thermal-oxidative degradation which takes place and causes a reduction in properties. Note however, that the max. allowable service temp. depends in many cases essentially on the duration and the magnitude of the mechanical stresses to which the material is subjected.

<sup>\*4 -</sup> These mostly estimated ratings, derived from raw material supplier data, are not intended to reflect hazards presented by the materials under actual fire conditions. There is no UL yellow card available for TORLON 4203 stock shapes.

<sup>-</sup> Test specimens: Type 1B

<sup>\*6 -</sup> Test Speed: 5mm/min

<sup>-</sup> Test specimens: cylinders ø 12 x 30mm

<sup>\*10 -</sup> Test specimens: 10mm thick

<sup>\*7 -</sup> Test Speed: 1mm/min

<sup>\*9 -</sup> Pendulum used: 4 J

<sup>\*11 -</sup> Test specimens: 1mm thick

#### TORLON® 4503 PAI Polyamide-imide (PAI)

This compression moulded material is similar in composition to TORLON® 4203 PAI, and is selected when larger shapes are required.

- High maximum service temperature (250°C)
- Excellent resistance against high energy radiation

Inherent low flammability

- Exceptional wear resistance
- Outstanding dimensional stability (to +250°C) Excellent dielectric and insulating properties
- Excellent retention of mechanical strength / stiffness over a wide range of temperatures

#### **Common Applications:**

Connectors; Switches; Relays; Thrust washers; Valve seats; Piston rings; Mechanical linkages; Bushes; Electrical and thermal insulators.

**Technical Specification** 

| Delivery Programme   |                 |                  |  |  |
|--|-----------------|------------------|--|--|
|  | min             | max              |  |  |
| Rod 153mm long diameter (mm)                                 | 57.15           | 381.0            |  |  |
| Tube 203m long<br>outer diameter (mm)<br>inner diameter (mm) | 42.86<br>19.05  | 193.68<br>107.95 |  |  |
| Tube 153m long<br>outer diameter (mm)<br>inner diameter (mm) | 196.85<br>50.80 | 882.65<br>736.6  |  |  |
| Colour: Yellow ochre   |                 |                  |  |  |

| Toomingan opcomouncin                               |            |                   |                     |
|---|------------|-------------------|---------------------|
| Property  | ISO Method | Units             | Values              |
| Density   | 1183       | g/cm <sup>3</sup> | 1.41                |
| Water absorption*1                                  |            |                   |                     |
| after 24h immersion in water (23°C)                 | 62         | mg                | 29                  |
|   | 62         | %                 | 0.35                |
| Saturation in air (23°C/50% RH)                     | ~          | %                 | 2.5                 |
| Saturation in water (23°C)                          | ~          | %                 | 4.4                 |
| Melting temperature                                 | ~          | °C                | N/A                 |
| Glass transition temperature                        | ~          | °C                | 280                 |
| Thermal conductivity at 23°C                        | ~          | W/(K.m)           | 0.26                |
| Coefficient of linear thermal expa                  | nsion      |                   |                     |
| average value between 23 - 100°C                    | ~          | m/(m-K)           | 30.10 <sup>-6</sup> |
| average value between 23 - 150°C                    | ~          | m/(m-K)           | 30.10 <sup>-6</sup> |
| average value above 150°C                           | ~          | m/(m-K)           | 30.10 <sup>-6</sup> |
| Temperature of deflection under I                   | oad        |                   |                     |
| · method A: 1.8 MPa                                 | 75         | °C                | 280                 |
| Max allowable service temperatu                     | re in air  |                   |                     |
| · for short periods*2                               | ~          | °C                | 270                 |
| · continuously for 20,000 hrs*3                     | ~          | °C                | 250                 |
| Flammability *4                                     |            |                   |                     |
| · "Oxygen Index"                                    | 4589       | %                 | 45                  |
| according to UL94 (1.5/3mm thickness)               | ~          | ~                 | V-O/V-O             |
| Tension Test*5                                      |            |                   |                     |
| · Stress at yield*6                                 | 527        | MPa               | 120                 |
| · Strain at break*6                                 | 527        | %                 | 10                  |
| <ul> <li>Tensile modulus of elasticity*7</li> </ul> | 527        | MPa               | 4500                |
| Compression Test*8                                  |            |                   |                     |
| Stress at 1/2% nominal strain*7                     | 604        | MPa               | 27/53               |
| Impact - Charpy*9                                   | 179/1eU    | kJ/m²             | no break            |
| Impact - Charpy notched                             | 179/1eA    | kJ/m²             | 10                  |
| Ball Indentation hardness*10                        | 2039-1     | N/mm <sup>2</sup> | 200                 |
| Hardness Rockwell*10                                | 2039-2     | ~                 | E80 M120            |
| Electric Strength*11                                | 60243      | KV/mm             | 24                  |
| Volume resistivity                                  | 60093      | $\Omega.cm$       | >1014               |
| Surface resistivity                                 | 60093      | Ω                 | >1013               |
| Relative Permittivity at 1 Mhz                      | 60250      | ~                 | 3.9                 |
| Dielectric dissipation factor "                     | 60250      | ~                 | 0.031               |
|   |            |                   |                     |

 $<sup>^{*1}</sup>$  - According to method 1 of ISO62 and done on discs Ø 50 x 3mm

<sup>-</sup> Only for short time exposure (a few hours) in applications where no or only a very low load is applied to the material

<sup>\*3 -</sup> Temperature resistance over a period of min. 20,000 hours. After this there is a decrease in tensile strength of about 50% as compared with the original value. The temperature value given here is thus based on the thermal-oxidative degradation which takes place and causes a reduction in properties. Note however, that the max. allowable service temp. depends in many cases essentially on the duration and the magnitude of the mechanical stresses to which the material is subjected.

<sup>\*4 -</sup> These mostly estimated ratings, derived from raw material supplier data, are not intended to reflect hazards presented by the materials under actual fire conditions. There is no UL yellow card available for TORLON 4503 stock shapes.

<sup>-</sup> Test specimens: Type 1B

<sup>-</sup> Test Speed: 5mm/min

<sup>-</sup> Test specimens: cylinders ø 12 x 30mm

<sup>\*10-</sup> Test specimens: 10mm thick

 $<sup>^{*}12</sup>_{\text{-}}$  It has to be noted that the figures given for the properties of this TORLON grade have been derived form tests run on test specimens from extruded material.

<sup>\*7-</sup> Test Speed: 1mm/min

<sup>\*9 -</sup> Pendulum used: 4 J \*11- Test specimens: 1mm thick

## TORLON® 4301 PAI

Polyamide-imide (PAI + graphite+PTFE)

The addition of graphite and PTFE provides higher wear resistance and lower coefficient of friction compared to the unfilled grade as well as little or no stick-slip in use. This extruded grade excels in severe wear applications such as non-lubricated bearing, seals, bearings cages and reciprocating compressor parts.

- High maximum service temperature (250°C)
- Excellent resistance against high energy radiation

Inherent low flammability

- Exceptional wear and frictional behaviour
- Outstanding dimensional stability (to +250°C) Excellent dielectric and insulating properties
- Excellent retention of mechanical strength / stiffness over a wide range of temperatures

#### **Common Applications:**

Bearings; Seals; Bearing cages; Reciprocating compressor parts; Thrust washers; Valve seats; Piston rings; vanes; Wear pads.

Technical Specification

| Delivery Programme                                |             |       |  |
|---|-------------|-------|--|
|   | min         | max   |  |
| Rod 2400mm long diameter (mm)                     | 6.35        | 50.80 |  |
| Plate 1220mm long<br>width (mm)<br>thickness (mm) | 305<br>6.35 | 25.40 |  |
| Colour: Black                                     |             |       |  |

| 150 Method 1183 62 62 ~ ~ ~ ~ sion ~ ~ ad      | Units g/cm <sup>3</sup> mg % % % °C °C W/(K.m) m/(m-K) m/(m-K) m/(m-K)    | Values 1.45 26 0.3 1.9 3.8 N/A 280 0.54 25.10-6 25.10-6   |
|--|---|---|
| 62<br>62<br>~<br>~<br>~<br>~<br>sion<br>~<br>~ | mg % % % °C °C W/(K.m) m/(m-K) m/(m-K)                                    | 26<br>0.3<br>1.9<br>3.8<br>N/A<br>280<br>0.54<br>25.10 <sup>-6</sup><br>25.10 <sup>-6</sup>                             |
| 62<br>~<br>~<br>~<br>~<br>sion<br>~<br>~       | % % % °C °C W/(K.m) m/(m-K) m/(m-K)                                       | 0.3<br>1.9<br>3.8<br>N/A<br>280<br>0.54<br>25.10 <sup>-6</sup><br>25.10 <sup>-6</sup>                                   |
| 62<br>~<br>~<br>~<br>~<br>sion<br>~<br>~       | % % % °C °C W/(K.m) m/(m-K) m/(m-K)                                       | 0.3<br>1.9<br>3.8<br>N/A<br>280<br>0.54<br>25.10 <sup>-6</sup><br>25.10 <sup>-6</sup>                                   |
| ~<br>~<br>~<br>~<br>sion<br>~<br>~<br>~        | % % % °C °C W/(K.m) m/(m-K) m/(m-K)                                       | 1.9<br>3.8<br>N/A<br>280<br>0.54<br>25.10 <sup>-6</sup><br>25.10 <sup>-6</sup>  |
| ~<br>~<br>~<br>sion<br>~<br>~<br>~             | % °C °C W/(K.m) m/(m-K) m/(m-K)   | 3.8<br>N/A<br>280<br>0.54<br>25.10 <sup>-6</sup><br>25.10 <sup>-6</sup>   |
| sion<br>~<br>~<br>~<br>ad                      | °C<br>°C<br>W/(K.m)<br>m/(m-K)<br>m/(m-K)                                 | N/A<br>280<br>0.54<br>25.10 <sup>-6</sup><br>25.10 <sup>-6</sup>  |
| sion<br>~<br>~<br>~<br>ad                      | °C<br>W/(K.m)<br>m/(m-K)<br>m/(m-K)                                       | 280<br>0.54<br>25.10 <sup>-6</sup><br>25.10 <sup>-6</sup>   |
| sion<br>~<br>~<br>~<br>ad                      | W/(K.m)  m/(m-K)  m/(m-K)   | 0.54<br>25.10 <sup>-6</sup><br>25.10 <sup>-6</sup>  |
| sion<br>~<br>~<br>~<br>ad                      | m/(m-K)<br>m/(m-K)  | 25.10 <sup>-6</sup><br>25.10 <sup>-6</sup>  |
| ~<br>~<br>~<br>ad                              | m/(m-K)   | 25.10 <sup>-6</sup>   |
| ~<br>~<br>ad                                   | m/(m-K)   | 25.10 <sup>-6</sup>   |
| ~<br>ad  |   |   |
|  | m/(m-K)   |   |
|  |   | 25.10 <sup>-6</sup>   |
|  |   |   |
| 75   | °C  | 280   |
| in air   |   |   |
| ~  | °C  | 270   |
| ~  | °C  | 250   |
|  |   |   |
| 4589   | %   | 44  |
| ~  | ~   | V-0/V-0   |
|  |   |   |
| 527  | MPa   | 80  |
| 527  | %   | 5   |
| 527  | MPa   | 5800  |
|  |   |   |
| 604  | MPa   | 31/58   |
| 179/1eA  | kJ/m <sup>2</sup>   | 4   |
| 2039-1   | N/mm <sup>2</sup>   | 200   |
| 2039-2   | ~   | M105  |
| 60093  | $\Omega.\mathrm{cm}$  | >1013   |
| 60093  | Ω   | >1013   |
| 60250  | ~   | 5.4   |
| 60250  | ~   | 0.042   |
|  | 527<br>527<br>527<br>504<br>.79/1eA<br>.039-1<br>.039-2<br>50093<br>50093 | MPa  527 MPa  527 MPa  527 MPa  527 MPa  604 MPa  79/1eA kJ/m²  2039-1 N/mm²  2039-2 ~  60093 Ω.cm  60093 Ω.cm  60093 Ω |

 $<sup>^{</sup>c1}$  - According to method 1 of ISO62 and done on discs Ø 50 x 3mm

<sup>\*2 -</sup> Only for short time exposure (a few hours) in applications where no or only a very low load is applied to the material

<sup>\*3 -</sup> Temperature resistance over a period of min. 20,000 hours. After this there is a decrease in tensile strength of about 50% as compared with the original value. The temperature value given here is thus based on the thermal-oxidative degradation which takes place and causes a reduction in properties. Note however, that the max. allowable service temp. depends in many cases essentially on the duration and the magnitude of the mechanical stresses to which the material is subjected.

<sup>\*4 -</sup> These mostly estimated ratings, derived from raw material supplier data, are not intended to reflect hazards presented by the materials under actual fire conditions. There is no UL yellow card available for TORLON 4301 stock shapes.

<sup>-</sup> Test specimens: Type 1B

<sup>-</sup> Test Speed: 5mm/min

<sup>\*8 -</sup> Test specimens: cylinders ø 12 x 30mm

Test Speed: 1mm/min

<sup>\*9</sup> Test specimens: 10mm thick

#### TORLON® 4501 PAI Polyamide-imide (PAI + graphite+PTFE)

This compression moulded material is similar in composition to TORLON® 4301 PAI, and is selected when larger shapes are required.

- High maximum service temperature (250°C)
- Excellent resistance against high energy radiation

Inherent low flammability

- Exceptional wear and frictional behaviour
- Outstanding dimensional stability (to +250°C) Excellent dielectric and insulating properties
- Excellent retention of mechanical strength / stiffness over a wide range of temperatures

#### **Common Applications:**

Bearings; Seals; Bearing cages; Reciprocating compressor parts; Thrust washers; Valve seats; Piston rings; vanes; Wear pads.

| Delivery Programme   |                 |                  |  |  |
|--|-----------------|------------------|--|--|
|  | min             | max              |  |  |
| Rod 153mm long<br>diameter (mm)                              | 50.8            | 381.00           |  |  |
| Tube 203m long<br>outer diameter (mm)<br>inner diameter (mm) | 42.86<br>19.05  | 193.68<br>107.95 |  |  |
| Tube 153m long<br>outer diameter (mm)<br>inner diameter (mm) | 196.85<br>50.80 | 882.65<br>736.6  |  |  |
| Plate 305mm long<br>width (mm)<br>thickness (mm)             | 305<br>9.53     | 50.80            |  |  |
| Plate 610mm long<br>width (mm)<br>thickness (mm)             | 305<br>9.53     | 38.10            |  |  |
| Colour: Black  |                 |                  |  |  |

| Technical Specification               |            |                   |                     |
|---------------------------------------|------------|-------------------|---------------------|
| Property                              | ISO Method | Units             | Values              |
| Density                               | 1183       | g/cm <sup>3</sup> | 1.45                |
| Water absorption*1                    |            |                   |                     |
| after 24h immersion in water (23°C)   | 62         | mg                | 26                  |
|                                       | 62         | %                 | 0.3                 |
| Saturation in air (23°C/50% RH)       | ~          | %                 | 1.9                 |
| Saturation in water (23°C)            | ~          | %                 | 3.8                 |
| Melting temperature                   | ~          | °C                | N/A                 |
| Glass transition temperature          | ~          | °C                | 280                 |
| Thermal conductivity at 23°C          | ~          | W/(K.m)           | 0.54                |
| Coefficient of linear thermal expa    | nsion      |                   | _                   |
| average value between 23 - 100°C      | ~          | m/(m-K)           | 25.10 <sup>-6</sup> |
| average value between 23 - 150°C      | ~          | m/(m-K)           | 25.10 <sup>-6</sup> |
| average value above 150°C             | ~          | m/(m-K)           | 25.10 <sup>-6</sup> |
| Temperature of deflection under le    |            |                   |                     |
| method A: 1.8 MPa                     | 75         | °C                | 280                 |
| Max allowable service temperatur      | e in air   |                   |                     |
| • for short periods*2                 | ~          | °C                | 270                 |
| · continuously for 20,000 hrs*3       | ~          | °C                | 250                 |
| Flammability*4                        |            |                   |                     |
| "Oxygen Index"                        | 4589       | %                 | 44                  |
| according to UL94 (1.5/3mm thickness) | ~          | ~                 | V-0/V-0             |
| Tension Test*5                        |            |                   |                     |
| Stress at break*6                     | 527        | MPa               | 80                  |
| • Strain at break*6                   | 527        | %                 | 5                   |
| • Tensile modulus of elasticity*7     | 527        | MPa               | 5800                |
| Compression Test*8                    |            |                   |                     |
| • Stress at 1/2% nominal strain*7     | 604        | MPa               | 31/58               |
| Impact - Charpy notched               | 179/1eA    | kJ/m <sup>2</sup> | 4                   |
| Ball Indentation hardness*9           | 2039-1     | N/mm <sup>2</sup> | 200                 |
| Hardness Rockwell*9                   | 2039-2     | ~                 | M105                |
| Volume resistivity                    | 60093      | $\Omega$ .cm      | >10 <sup>13</sup>   |
| Surface resistivity                   | 60093      | Ω                 | >1013               |
| Relative Permittivity at 1 Mhz        | 60250      | ~                 | 5.4                 |
| Dielectric dissipation factor "       | 60250      | ~                 | 0.042               |
|                                       |            |                   |                     |

 $<sup>^{*1}</sup>$  - According to method 1 of ISO62 and done on discs Ø 50 x 3mm

<sup>-</sup> Only for short time exposure (a few hours) in applications where no or only a very low load is applied to the material

<sup>\*3 -</sup> Temperature resistance over a period of min. 20,000 hours. After this there is a decrease in tensile strength of about 50% as compared with the original value. The temperature value given here is thus based on the thermal-oxidative degradation which takes place and causes a reduction in properties. Note however, that the max. allowable service temp. depends in many cases essentially on the duration and the magnitude of the mechanical stresses to which the material is subjected.

<sup>-</sup> These mostly estimated ratings, derived from raw material supplier data, are not intended to reflect hazards presented by the materials under actual fire conditions. There is no UL yellow card available for TORLON 4501 stock shapes.

<sup>-</sup> Test specimens: Type 1B

<sup>-</sup> Test Speed: 5mm/min

<sup>-</sup> Test specimens: cylinders ø 12 x 30mm

<sup>-</sup> Test Speed: 1mm/min

<sup>\*9 -</sup> Test specimens: 10mm thick

<sup>\*10-</sup> It has to be noted that the figures given for the properties of this TORLON grade have been derived form tests run on test specimens from extruded material.

#### TORLON® 5530 PAI Polyamide-imide (PAI+GF30)

This compression moulded, 30% glass fibre reinforced grade offers higher stiffness, mechanical strength and creep resistance than TORLON® 4203 PAI and TORLON® 4503 PAI. It is well suited for structural applications supporting static loads for long periods of time at high temperatures. The suitability of TORLON® 5530 PAI for sliding parts, however, is to be carefully examined since the glass fibres tend to abrade the mating surface.

- High maximum service temperature (250°C)
- · Excellent resistance against high energy radiation

Inherent low flammability

- Exceptional wear and frictional behaviour
- - Outstanding dimensional stability (to +250°C) Excellent dielectric and insulating properties
- Excellent retention of mechanical strength / stiffness over a wide range of temperatures

#### **Common Applications:**

Bearings; Seals; Bearing cages; Reciprocating compressor parts; Thrust washers; Valve seats; Piston rings; vanes; Wear pads.

| Delivery Programme   |                 |                  |  |  |
|--|-----------------|------------------|--|--|
|  | min             | max              |  |  |
| Rod 153mm long<br>diameter (mm)                              | 50.80           | 381.0            |  |  |
| Tube 203m long<br>outer diameter (mm)<br>inner diameter (mm) | 42.86<br>19.05  | 193.68<br>107.95 |  |  |
| Tube 153m long<br>outer diameter (mm)<br>inner diameter (mm) | 196.85<br>50.80 | 882.65<br>736.6  |  |  |
| Plate 305mm long<br>width (mm)<br>thickness (mm)             | 305<br>9.53     | 50.80            |  |  |
| Plate 610mm long<br>width (mm)<br>thickness (mm)             | 305<br>9.53     | 38.10            |  |  |
| Colour: Khaki grey   |                 |                  |  |  |

| Technical Specification  |   |                          |   |
|--|---|--------------------------|---|
| Property   | ISO Method  | Units                    | Values  |
| Density Water absorption*1   | 1183  | g/cm <sup>3</sup>        | 1.61  |
| after 24h immersion in water (23°C)  | 62<br>62  | mg<br>%                  | 25<br>0.26  |
| Saturation in air (23°C/50% RH)     Saturation in water (23°C)   | ~ ~   | %<br>%                   | 1.7<br>3.0  |
| Melting temperature Glass transition temperature   | ~ ~   | °C                       | N/A<br>280  |
| Thermal conductivity at 23°C Coefficient of linear thermal expan   | ~<br>nsion  | W/(K.m)                  | 0.36  |
| <ul><li>average value between 23 - 100°C</li><li>average value between 23 - 150°C</li></ul>  | ~ ~   | m/(m-K)<br>m/(m-K)       | 25.10 <sup>-6</sup> 25.10 <sup>-6</sup>                 |
| · average value above 150°C  Temperature of deflection under lo  | ~<br>oad  | m/(m-K)                  | 25.10 <sup>-6</sup>                                     |
| · method A: 1.8 MPa  Max allowable service temperatur  | 75<br>e in air                                    | °C                       | 280   |
| for short periods*2     continuously for 20,000 hrs*3  Flammability*4  | ~ ~   | °C                       | 270<br>250  |
| "Oxygen Index"     according to UL94 (1.5/3mm thickness)   | 4589<br>~   | %<br>~                   | 50<br>V-0/V-0   |
| Tension Test*5  • Stress at break*6  | 527   | MPa                      | 95  |
| Strain at break*6     Tensile modulus of elasticity*7 Impact - Charpy notched Hardness Rockwell*8 Electric Strength*9 Volume resistivity | 527<br>527<br>179/1eA<br>2039-2<br>60243<br>60093 | % MPa kJ/m² ~ KV/mm Ω.cm | 3<br>6200<br>3.5<br>E85 M125<br>28<br>>10 <sup>13</sup> |
| Surface resistivity Relative Permittivity at 1 Mhz Dielectric dissipation factor "   | 60093<br>60250<br>60250                           | Ω<br>~<br>~              | >10 <sup>13</sup> 4.2 0.050                             |

 $<sup>^{*1}</sup>$  - According to method 1 of ISO62 and done on discs Ø 50 x 3mm

<sup>\*2 -</sup> Only for short time exposure (a few hours) in applications where no or only a very low load is applied to the material

<sup>\*3 -</sup> Temperature resistance over a period of min. 20,000 hours. After this there is a decrease in tensile strength of about 50% as compared with the original value. The temperature value given here is thus based on the thermal-oxidative degradation which takes place and causes a reduction in properties. Note however, that the max. allowable service temp. depends in many cases essentially on the duration and the magnitude of the mechanical stresses to which the material is subjected.

<sup>\*4 -</sup> These mostly estimated ratings, derived from raw material supplier data, are not intended to reflect hazards presented by the materials under actual fire conditions. There is no UL yellow card available for TORLON 5530 stock shapes.

<sup>-</sup> Test specimens: Type 1B

<sup>-</sup> Test Speed: 5mm/min

<sup>\*8 -</sup> Test specimens: 10mm thick

<sup>\*7 -</sup> Test Speed: 1mm/min

<sup>\*9 -</sup> Test specimens: 1mm thick