CARBON-GRAPHITE PRODUCTS
PERMA-FOIL™
Graphite Sheet

(1) PERMA-FOIL™ Roll Products
(2) PERMA-FOIL™ Punching Processed Product Samples
(3) PERMA-FOIL™ Punching Processed Product Samples
Features of PERMA-FOIL™

PERMA-FOIL™ is a generic term for the flexible graphite sheet that Toyo Tanso developed through our original manufacturing technology. It is a sheet graphite product that is formed using select acid treated natural graphite, which is then compressed after undergoing high temperature expansion. Only natural graphite is used as a raw material, which yields highly flexible carbon with excellent heat resistance and chemical resistance. Other features include a high compressibility recovery rate, excellent airtightness, and a high thermal conductivity.

- **Excellent Self-Lubrication**
  PERMA-FOIL™ has self-lubricating properties due to its layered crystal structure, making it appropriate for use in high-temperature atmospheres and in fields where fluids and lubricants are avoided. In particular, its coefficient of friction in an un lubricated condition is low compared with other materials, making adhesion difficult to occur.

- **Stable in the wide range of temperature**
  Since PERMA-FOIL™ is produce only from natural graphite without using a binder, it is stable in the wide range of temperature (-200°C to 3200°C inert atmosphere) enabling it to be used.

- **Flexibility, Compressibility recovery properties**
  This graphite sheet has flexibility and high recovery from compressive stress, which previously unobtainable with existing graphite products. Good matching with counter materials make it ideal for use as a sealing material.

- **Excellent Chemical Resistance**
  PERMA-FOIL™ has excellent chemical resistance (acid, base) and is chemically stable.

- **Excellent Thermal and Electrical Conductivity**
  Thermal and electrical conductivity are excellent parallel to surface, and PERMA-FOIL™ is optimum as a heat release material and as a heat transfer material.
  * Patent Number 3691836 (JP)

- **Excellent Purity**
  High purity products that have undergone high temperature treatment with halogen gas have a very high purity. Since it has extremely high purity, it is optimum for components in semiconductor, IT, or nuclear energy industry application.
  * Patent Number 2620606 (JP)
Manufacturing Process

Through heat treatment, acid treated graphite becomes expanded graphite.

Acid Treated Graphite
(Acid treated graphite is natural graphite that has undergone acid treatment)

Expanded Graphite

Expansion Treatment

Preforming

Expanded Graphite

Rolling

Winding

Bulk Roll

Inspection

No information in this catalog may be used or reproduced without the prior consent of Toyo Tanso.
PERMA-FOIL™ has excellent sealing properties, durability, and machinability. Our high purity products have gone through our unique purification process and are optimum as components in the nuclear energy industry, as spacers and packing used in the semiconductor industry, as radiator plates used in the electronics industry, and as other such components. Grades are arranged for all kinds of applications including: automotive gaskets, general industrial packing, parts for semiconductor equipment, corrosion resistant seals, IT industry applications, and a wide range of other applications. We produce this product in a wide array of sizes and shapes including rolls, cut sheets and custom shapes made to customer specification.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Characteristics</th>
<th>Application</th>
<th>Forms of Supplies</th>
</tr>
</thead>
<tbody>
<tr>
<td>PF</td>
<td>Graphite Sheet Standard products</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PF-R2</td>
<td>Thermal stable property improved version of standard products</td>
<td>Automotive gaskets General industrial packing</td>
<td>Roll products Cut products</td>
</tr>
<tr>
<td>PF-HP</td>
<td>Low ash content products</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PF-G3</td>
<td>Corrosion resistance and thermal stable property improved version of R2 Products</td>
<td>Heat resistant gasket Packing</td>
<td></td>
</tr>
<tr>
<td>PF-UHP, UHPU, UHPL</td>
<td>High Purity products</td>
<td>Parts for high purity furnace for semiconductor and nuclear applications. Heat conducting material Heat spreader.</td>
<td></td>
</tr>
<tr>
<td>PF-A</td>
<td>Bonded products (Thickness ≥ 1.5 mm)</td>
<td>Heat insulation material General industrial packing</td>
<td></td>
</tr>
<tr>
<td>PF-SUS, AL</td>
<td>SUS, AL Foil Laminated products</td>
<td>Automotive gaskets General industrial packing</td>
<td></td>
</tr>
<tr>
<td>Gather Sheet S</td>
<td>Gather sheets with adhesive tape</td>
<td>Flange gasket</td>
<td></td>
</tr>
<tr>
<td>PF Powder 4, 8F</td>
<td>Pulverized graphite sheet</td>
<td>General industrial packing Battery parts</td>
<td>Powder</td>
</tr>
</tbody>
</table>

* For available dimensions, please contact our sales department.
## Property Data

### Typical properties

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Grade</th>
<th>PF</th>
<th>PF-R2</th>
<th>PF-HP</th>
<th>PF-UHPL</th>
<th>PF-UHPU, UHPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation Temperature</td>
<td>°C</td>
<td>0 to -200</td>
<td>0 to 3200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness</td>
<td>mm</td>
<td>0.2 to 1.0</td>
<td>0.2 to 1.5</td>
<td>0.05 to 1.0</td>
<td>0.2 to 1.0</td>
<td>0.38 to 1.0</td>
<td>0.1 to 1.5</td>
</tr>
<tr>
<td>Bulk Density</td>
<td>Mg/m³</td>
<td>0.5 to 1.1</td>
<td>0.5 to 1.1</td>
<td>0.5 to 2.0</td>
<td>0.5 to 1.1</td>
<td>1.0</td>
<td>1.0, 0.9</td>
</tr>
<tr>
<td>Oxidation Loss</td>
<td>mass %</td>
<td>40</td>
<td>25</td>
<td>40</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Initial Oxidation Temperature</td>
<td>°C</td>
<td>440</td>
<td>730</td>
<td>630</td>
<td>850</td>
<td>820</td>
<td>820</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>MPa</td>
<td>4.9</td>
<td>5.2</td>
<td>4.9</td>
<td>5.1</td>
<td>6.3</td>
<td>6.3</td>
</tr>
<tr>
<td>Sulfur Content</td>
<td>mass ppm</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Chlorine Content</td>
<td>mass ppm</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;3</td>
<td>&lt;3</td>
</tr>
<tr>
<td>Compression Rate</td>
<td>%</td>
<td>47</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery Rate</td>
<td>%</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress Release Rate</td>
<td>%</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ash Content</td>
<td>mass %</td>
<td>0.5</td>
<td>0.5</td>
<td>0.1</td>
<td>0.5</td>
<td>&lt;20 mass ppm</td>
<td>&lt;10 mass ppm</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>5.1</td>
<td>5.1</td>
<td>5.1</td>
<td>5.1</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Gas Permeability</td>
<td>m²/s</td>
<td>1.3 x 10⁻¹⁰</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion</td>
<td>1/K</td>
<td>5 x 10⁻⁴</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>W/(m·K)</td>
<td>2 x 10⁻⁴</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical Resistivity</td>
<td>μΩ·m</td>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flammability</td>
<td></td>
<td>Equivalent to UL94 V-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The figures above are typical values, and are not guaranteed.
* Property data with the density of 1.0 Mg/m³.
* Oxidation loss is the result of the measurement for 1 hour at 670°C.
* Initial oxidation temperature represents the starting temperature of mass decrease by the result of the measurement using a thermobalance in the air atmosphere.
* The measurement temperature range for the coefficient of thermal expansion is 300 to 400°C.
* There are standard size for each grade, thickness or bulk density.
* There are constraints of size depending on the size, thickness and bulk density.

Before actually using one of our products, please be sure to contact our sales department to consult on selecting the most appropriate grade.

### Initial Oxidation Temperature

![Initial Oxidation Temperature Graph](image)

We have several grades that may suit customers' heat resistance requirements.

### Relationship Between Density and Tensile Strength

![Relationship Between Density and Tensile Strength Graph](image)

High density products have high strength.
Property Data

■ Excellent Compressibility Recovery Properties
The relationship between density and compression stress during Compression and release (PF-50)

Determine the compression/recovery density by the thickness that has been altered by stress.
* By the JIS R3453 measuring method.

During Compression
During Release

■ ■

■ High Sealing Properties
The relationship between clamp pressure and amount of leakage (PF-50)

Sample dimensions: ø65 x ø50 (mm) ring

Measurement Example

■ ■

■ Effect of Compression Stress to Each Properties
Thermal conductivity

The thermal conductivity parallel to surface is excellent.

Measurement Example

High density products have an extremely high thermal conductivity.

PERMA-FOIL™ (D=2.0)
Copper
Aluminum
PERMA-FOIL™ (D=1.0)

0 100 200 300 400
Thermal Conductivity [W/(m·K)]

0 0.5 1.0 1.5
Density [Mg/m³]

Electrical Resistivity

The electrical resistivity parallel to surface is low.

Measurement Example

* Thermal conductivity is independent from sheet thickness and grade.

■ ■

■ ■

Thermal Conductivity [W/(m·K)]

0 0.5 1.0 1.5
Density [Mg/m³]

Electrical Resistivity [μΩ·m]

0 0.5 1.0 1.5
Density [Mg/m³]

<Parallel to surface>

<Perpendicular to surface>

The insulating properties perpendicular to surface is excellent.
No information in this catalog may be used or reproduced without the prior consent of Toyo Tanso.
Excellent heat conduction and pressure equalization effects of PERMA-FOIL™

- **Heat conduction effects**
  PERMA-FOIL™ possesses high thermal conductivity in the surface direction parallel to the surface, and has flexibility that allows it to adhere closely to other materials, which improves heat transmission from heat source to the heat sink.

- **Pressure equalization effects**
  PERMA-FOIL™ has high cushioning properties that allow the even application of pressure to the substrate in hot press and thermal bonding applications.

- **Example applications**
  - Components for semiconductor fabrication equipment
  - Heat transfer applications in electronic equipment
  - Automotive gaskets
  - Packing material for chemical plants
  - Insulation material for furnace interiors
  - High-purity components for use in furnace interiors