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 unlubricated condition is low compared with other materials, making adhesion difficult to occur.

- Stable in the wide range of temperature
  Since PERMA-FOIL® is produced only from natural graphite without using a binder, it is stable in the wide range of temperature (-200°C~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 3691936

- 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

It is extremely light when compared with other metals.

It has excellent heat resistance.
Manufacturing Process

Through heat treatment, acid treated graphite becomes expanded graphite.

Acid Treated Graphite
(Not treated graphite is natural graphite that has undergone acid treatment)

Expansion Treatment

Expanded Graphite

Preforming

Rolling

Winding

Bulk Roll

Inspection
Grade and Application

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>PERMA-FOIL® Standard products</td>
<td>Automotive gaskets</td>
<td>Roll products</td>
</tr>
<tr>
<td>PF-R2</td>
<td>Heat resistance improved version of standard products</td>
<td>General industrial packing</td>
<td>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 Heat resistance 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 ≥ 1.5mm)</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 expanded graphite products</td>
<td>General Industrial packing Battery parts</td>
<td></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>
</tr>
</thead>
<tbody>
<tr>
<td>Operation Temperature</td>
<td>°C</td>
<td>PF</td>
</tr>
<tr>
<td>Thickness</td>
<td>mm</td>
<td>0.2~1.0</td>
</tr>
<tr>
<td>Bulk Density</td>
<td>Mg/m³</td>
<td>0.5~1.1</td>
</tr>
<tr>
<td>Oxidation Loss</td>
<td>mass %</td>
<td>40</td>
</tr>
<tr>
<td>Initial Oxidation Temperature</td>
<td>°C</td>
<td>440</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>MPa</td>
<td>4.9</td>
</tr>
<tr>
<td>Sulfur Content</td>
<td>mass ppm</td>
<td>1000</td>
</tr>
<tr>
<td>Chlorine Content</td>
<td>mass ppm</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Compression Rate</td>
<td>%</td>
<td>47</td>
</tr>
<tr>
<td>Recovery Rate</td>
<td>%</td>
<td>15</td>
</tr>
<tr>
<td>Stress Release Rate</td>
<td>%</td>
<td>1.0</td>
</tr>
<tr>
<td>Ash Content</td>
<td>mass %</td>
<td>0.5</td>
</tr>
<tr>
<td>pH</td>
<td>—</td>
<td>5.1</td>
</tr>
<tr>
<td>Gas Permeability</td>
<td>m³/s</td>
<td>1.3×10⁻¹⁰</td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion</td>
<td>1/K</td>
<td>5×10⁻⁸</td>
</tr>
<tr>
<td>Thermal Conductivity (25°C)</td>
<td>W/(m K)</td>
<td>200</td>
</tr>
<tr>
<td>Electrical Resistivity (25°C)</td>
<td>μΩ·m</td>
<td>7</td>
</tr>
<tr>
<td>Flame Resistance</td>
<td>—</td>
<td>Equivalent to UL94 V-0</td>
</tr>
</tbody>
</table>

※The figures above are typical values and are not guaranteed.
※Property data with the density of 1.0Mg/m³.
※Oxidation loss is the result of the measurement for 1 hour at 670°C.
※Initial oxidation temperature represents the kick-off temperature of mass decrease by the result of the measurement using a thermo-balance 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 Chart]

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

### Relationship Between Density and Tensile Strength

![Tensile Strength Chart]

High density products have high strength.
Property Data

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.

Measurement Example

Excellent compressibility/recovery

The Relationship Between Density and Thermal Conductivity (25°C)

Thermal conductivity is independent from sheet thickness and grade.

Measurement Example

The thermal conductivity parallel to surface is excellent.

Thermal Conductivity [W/(m·K)]

0 10 20 30 40

Density [Mg/m³]

0 0.5 1.0 1.5

<Parallel to surface>

Thermal Conductivity [W/(m·K)]

0 50 100 150 200

Density [Mg/m³]

0 0.5 1.0 1.5

<Perpendicular to surface>

The insulating properties perpendicular to surface is excellent.

The Relationship Between Density and Electrical Resistivity (25°C)

Electrical resistivity is independent from sheet thickness and grade.

Measurement Example

The electrical resistivity parallel to surface is low.

Electrical Resistivity [Ω·m]

0 10 100 1000 10000

Density [Mg/m³]

0 0.5 1.0 1.5

<Parallel to surface>

Electrical Resistivity [Ω·m]

0 5 10 15 20

Density [Mg/m³]

0 0.5 1.0 1.5

<Perpendicular to surface>

The electrical resistivity perpendicular to surface is high.

PERMAFOIL® (-25°)
Copper
Aluminum
Iron
Lead
Stainless steel

High density products have an extremely high thermal conductivity.
Toyo Tanso has a wide range of carbon and graphite grades available to meet your requirements. Before actually using one of our products, please be sure to contact our sales department to consult on selecting the most appropriate grade.
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
- Automotive gaskets
- Heat transfer applications in electronic equipment
- Insulation material for furnace interiors
- Packing material for chemical plants
- High-purity components for use in furnace interiors