Among plastic-based materials, PTFE offers diverse benefits including heat resistance, chemical resistance, insulation, non-stick, and low friction. Its scope of application is broad: it is used in various fields including semiconductor devices, chemical plants, automobiles, office equipment, and home appliances. However, PTFE suffers from inadequate abrasion resistance and creep resistance, which are serious disadvantages leading to severe self-damage in the case where PTFE is used in sliding parts like shaft bearings and large deformation in the case where one is used in load-bearing parts. The addition of a different material, namely, filler, can alleviate these problems. This report described the types, features, and applications of typical fillers.

2. Features

2-1) Modifiable Features
The addition of filler can modify features including abrasion resistance, creep resistance, thermal conductivity, and coefficient of linear expansion. Modified PTFE has approximately 1000 times stronger abrasion resistance, twice the creep resistance, and up to twice the thermal conductivity of pure PTFE. The optimal filler should be selected depending on the desired modification.

2-2) Types of Filler
Typical fillers include inorganic fillers such as glass fiber, graphite, molybdenum disulfide, and bronze. Organic fillers are also used.

The features of each filler-added PTFE are described below.

- **Inorganic fillers**
  - **Glass fiber**
    Glass fiber has little effect on chemical and electrical properties. Glass fiber-added PTFE has approximately twice the compression creep resistance and approximately 1000 times better abrasion resistance than pure PTFE. These features make glass fiber-added PTFE ideal for improving abrasion resistance. The color is white, which makes it easy to use. However, it might break a counterpart shaft when used for shaft bearings.
  - **Graphite**
    Graphite improves creep resistance and reduces initial wear and starting resistance of PTFE. Graphite-added PTFE has excellent thermal conductivity and chemical resistance. It is less abrasive to the counterpart material, so it is economically efficient, although its abrasion resistance is not excellent.
  - **Carbon fiber**
    Carbon fiber-added PTFE has excellent compressive
strength, creep characteristics, and abrasion resistance. These features are significantly improved in the high-temperature region above 200°C. It also has excellent sliding characteristics and good chemical resistance in water. It offers excellent sliding characteristics in fluids of low lubricity including acid and alkaline fluids.

- **Molybdenum disulfide**
  Molybdenum disulfide-added PTFE has improved creep resistance and lubrication. It does not degrade electrical insulation, so it can be used for electrical usages. However, molybdenum disulfide is rarely added to PTFE as a single filler; it is added along with glass fiber and bronze.

- **Bronze**
  Bronze-added PTFE has significantly improved abrasion resistance, compressive strength, creep resistance, hardness, and dimensional stability. It tends to retain oil on sliding surfaces, and has excellent abrasion resistance under oil lubrication, so it can be used for oil lubrication usages. However, it is important to note that bronze-added PTFE is not suitable for electrical and chemical applications.

- **Organic fillers**
  - **Polyimide-based resin**
    Polyimide based resin-added PTFE is beneficial in the case where soft metal moving parts that are likely to be damaged by carbon-added or graphite-added PTFE are used as a counterpart material.
  - **Polyphenylene sulfide-based resin**
    Polyphenylene sulfide-added PTFE has creep resistance and dimensional stability.
  - **Aromatic polyester-based resin**
    Aromatic polyester based resin-added PTFE has improved mechanical characteristics including compression and bending, as well as stable sliding.

Like these examples, there are many types of filler. An appropriate filler should be selected depending on the usage conditions including load, sliding speed, lifespan, frictional conditions, counterpart material, linear expansion, corrosion resistance, and electrical properties.

Although pure PTFE is white, some fillers turn PTFE black or dark brown. These conditions should be

### Table 2 List of filler-added PTFE properties

<table>
<thead>
<tr>
<th>Filler content</th>
<th>Amount (%)</th>
<th>Unit</th>
<th>PTFE</th>
<th>M2</th>
<th>M2S</th>
<th>M2X</th>
<th>M2O</th>
<th>M2G</th>
<th>M2S</th>
<th>M20</th>
<th>M2A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molybdenum disulfide-added PTFE</td>
<td>5</td>
<td>MPa</td>
<td>20.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Bronze-added PTFE</td>
<td>10</td>
<td>MPa</td>
<td>50.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Organic fillers</td>
<td>20</td>
<td>MPa</td>
<td>70.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
</tr>
</tbody>
</table>

**Note:** The values are approximate and may vary depending on the specific applications and conditions.
considered depending on the position of use and the application.

3. Conclusion

PTFE has excellent chemical characteristics, sliding properties and non-stick, making it suitable for shaft bearings and sliding parts. In the case where filler is added to PTFE, the PTFE gains improved frictional and creep characteristics, making it suitable for mechanical purposes.

The type of filler determines the improvement in characteristics of PTFE. We hope the above explanation of various fillers will help our readers when selecting a material.

4. Reference

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