Cyclic Olefin Copolymer (COC)

TOPAS®
Molding Technology

POLYPLASTICS CO., LTD.
TOPAS® COC
Cyclic olefin copolymer
Molding Technology

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TOPAS® is a registered trademark of TOPAS Advanced Polymers GmbH in Germany, the United States, and other countries.
1. Introduction

TOPAS® COC is the trade name of a cyclic olefin copolymer (COC) manufactured by TOPAS ADVANCED POLYMERS GmbH. It is an amorphous transparent resin having a cyclic olefin structure.

TOPAS is highly regarded in the market as a resin having heat resistance higher than PC (polycarbonate), dimensional stability superior to PMMA and PC, which originates from low water absorbability, etc. In addition, TOPAS has gained attention in the packaging material field as a material suitable for modification of conventionally used materials, such as improvements in water vapor barrier property and rigidity, and additions of heat resistance and easy-to-cut performance.

As TOPAS molding methods, injection molding, extrusion molding and blow molding are widely used. Here, we introduce the technologies of injection molding to realize its advantages.
2. Cautions in molding

2.1 Recommended material change method

For changeover from any other material to TOPAS® COC, it is recommended to directly clean the screw, cylinder and nozzle by disassembling the plasticizing unit. Rub off contamination, etc., with a brass brush or the like. Resin adherents, if any, can be easily removed by heating up to the resin's glass transition temperature (Tg) or more. Note that the initial portion of plasticization of the screw, the inside of the backflow prevention valve, and the inner wall of the nozzle tip, to which resins easily adhere, are dirty in many cases.

2.2 Simple material change methods

There are cases where the plasticizing unit is difficult to disassemble and clean for low-volume prototyping or due to a schedule conflict. In this case, materials are changed by purging. Changeover to a transparent resin by purging is difficult, and due caution is required for low-viscosity TOPAS in particular. Example methods of changeover from various resins are shown below. If material replacement fails by these methods, the plasticizing unit will need to be disassembled and cleaned. Consult with us for efficient purging methods, which vary with the types of molding machines and with plasticizing units.

(1) Changeover to the TOPAS 5013 family

Since the TOPAS 5013 family is extremely low in viscosity, a direct change from any other material cannot be made by purging. Therefore, the other resin should be replaced first by purging with the TOPAS 6013 family that is slightly high in viscosity, and then purged with the TOPAS 5013 family to complete replacement. For changeover to the TOPAS 5013 family by purging, preparation of a resin in the TOPAS 6013 family is requested. Points to be noted before changeover to such a resin in the TOPAS 6013 family are in accordance with (2).

(2) Changeover to any other resin than the TOPAS 5013 family

As the effects of purging differ according to the type and viscosity of the previous resin, example methods are shown below.

(a) When the previous material is a high-viscosity resin
First replace the common material with a purging material of the lowest possible viscosity, such as PP or PE. If replacement with a low-viscosity purging material, such as PP or PE, is impossible, first use a high-viscosity one, and then replace with a low-viscosity one. Note that if this replacement is inadequate, non-defective products cannot be finally obtained. After this, increase to the molding temperature of the TOPAS to be molded and purge it.

(b) When the previous material is a low-viscosity resin
First, replace the common material with a low-viscosity purging material, such as PP or PE. After this, increase to the molding temperature of the TOPAS to be molded and purge it.

(c) When the previous material is COC or COP
Increase to the molding temperature of the TOPAS to be molded and purge it. However, since COC or COP gets oxidized by oxygen in air to form carbides, keep the cylinder filled with resin. Specifically, when the previous material disappears from the hopper opening, immediately stop the screw to keep the cylinder filled with the previous resin. Next, clean the hopper, etc., input TOPAS and proceed with purging. Where nitrogen is injected into the hopper, perform purging while it is injected. To perform purging while keeping the cylinder filled with the resin is the point
2.3 Temporary halt methods

In order to prevent oxidation, temporarily halt molding by the following methods. For lowering cylinder temperature, stop the screw after the metering process where possible. Since screw movements are to start from the injection process after reheating, even if part of the resin is not melted due to some trouble, abnormality can be detected by the fact that the screw does not go forward. If movements start from the rotation process after reheating, the twist-sensitive screw may break when some trouble occurs.

(1) Halt of several tens of minutes to about one hour
Halt as the screw and hopper are filled with resin together with nitrogen if it is to be injected in the hopper. Start molding after purging the residual resin.

(2) Halt of several hours to about half a day
Decrease cylinder temperature down to near \( T_{g}+10^\circ C \) as screw and hopper are filled with resin together with nitrogen if it is to be injected in the hopper. Increase cylinder temperature to molding temperature, purge residual resin, and then start molding.

(3) Halt of half a day to several days
Decrease cylinder temperature down to near \( T_{g}+10^\circ C \) as the screw is filled with resin together with nitrogen if it is to be injected in the hopper. Redo drying of the resin in the hopper before resumption of molding. Increase cylinder temperature to molding temperature, purge residual resin, and then start molding.

(4) Halt of several days or more
Turn off heater and decrease cylinder temperature as the screw is filled with resin together with nitrogen if it is to be injected in the hopper. Stop nitrogen when cylinder is sufficiently cooled down. Redo drying of the resin in the hopper before resumption of molding. For resumption of molding, inject nitrogen in the hopper three hours or more before start of molding, and increase cylinder temperature up to near \( T_{g}+10^\circ C \). After three hours or more have passed in this condition, increase cylinder temperature to molding temperature, purge residual resin, and then start molding.

![Illustrated example of changeover from COP or COC](image-url)
3. Molding machine

3.1 Machine selection

For molding TOPAS® COC, commercially-available molding machines are generally used, so special molding machines are not needed. When a molding machine is selected, the size of the molding machine should be determined from the one-shot injection volume and projected area of molded products. In other words, make a selection using the following two points as a guide.

Selection of a plasticizing unit:

- One-shot injection volume = injection capacity • 20 to 80% (30 - 50% if possible)

Selection of mold clamping force:

- low-pressure molded products like lenses:
  - Mold clamping force > Projected area of molded products • 49 to 69 MPa
- high-pressure molded products like light guide plates:
  - Mold clamping force > Projected area of molded products • 343 MPa

3.2 Plasticizing mechanism

For molding TOPAS, a general-purpose screw can be used, but an optical screw is recommended in consideration of mixing of carbides and stability. If some molten resin comes in close contact with the screw, it will be oxidized and mixed in molded products in carbide form. Therefore, what is important in designing the screw is how to decrease close contact with resin.

Since TOPAS is generally low in viscosity, the functioning of the backflow prevention valve is important. This is to prevent molten resin from flowing back to the hopper side and to apply sufficient pressure to the cavity during the pressure-keeping process. It should be noted that inadequate backflow prevention will cause sink marks, bubbles (voids), dimensional variation, strength deterioration, etc. Select a securely functioning valve that mechanically closes the passage by rotating reversely to metering, or that closes the passage by using resin pressure.

As for the compression ratio of the screw, select approximately 2.0 to 2.5. If the selected compression ratio is relatively high, shear stress goes up during plasticization with the result that the resin may be discolored or resin carbides may be mixed.

Since appropriate design of the screw varies depending on the heater position, etc., contact your molding machine manufacturer.

3.3 Nozzle construction

Either an open type or a shutoff type can be used; however, an open type with less residence of molten resin is recommended.

Since TOPAS is low in viscosity, an open-type nozzle sometimes causes drooling and stringing, but these can be reduced by using a nozzle having a small diameter or a long-type nozzle. Also, since the occurrence of problems is greatly reduced by heater position and nozzle tip design, careful consideration of the advice above regarding nozzle selection is recommended when selecting a molding machine.
4. Molding conditions

4.1 Standard conditions

Table 4-1 shows standard molding conditions of TOPAS® COC.

<table>
<thead>
<tr>
<th>Grade</th>
<th>5013-xx</th>
<th>6013-xx</th>
<th>6015-xx</th>
<th>6017-xx</th>
<th>8007-xx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder temperature (°C)</td>
<td>Nozzle</td>
<td>250~320</td>
<td>250~320</td>
<td>270~300</td>
<td>290~300</td>
</tr>
<tr>
<td></td>
<td>Metering</td>
<td>250~320</td>
<td>250~320</td>
<td>270~300</td>
<td>290~320</td>
</tr>
<tr>
<td></td>
<td>Compression</td>
<td>240~320</td>
<td>240~320</td>
<td>250~300</td>
<td>270~320</td>
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<tr>
<td></td>
<td>Feed</td>
<td>220~320</td>
<td>220~320</td>
<td>240~300</td>
<td>260~320</td>
</tr>
<tr>
<td>Mold temperature (°C)</td>
<td>80~120</td>
<td>110~120</td>
<td>125~135</td>
<td>125~136</td>
<td>50~60</td>
</tr>
<tr>
<td>Injection pressure (MPa)</td>
<td>40~120</td>
<td>40~120</td>
<td>40~120</td>
<td>40~120</td>
<td>40~120</td>
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<tr>
<td>Injection speed (mm/sec)</td>
<td>30~300</td>
<td>20~100</td>
<td>20~100</td>
<td>20~100</td>
<td>20~100</td>
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<tr>
<td>Screw rotation rate (rpm)</td>
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<td>80~200</td>
<td>80~200</td>
<td>80~200</td>
<td>80~200</td>
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<tr>
<td>Back pressure (MPa)</td>
<td>5~15</td>
<td>5~15</td>
<td>5~15</td>
<td>5~15</td>
<td>5~15</td>
</tr>
<tr>
<td>Drying</td>
<td>Temperature (°C)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Time (hr)</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

4.2 Pre-drying

Although TOPAS® COC does not absorb moisture, pre-drying is required to deoxidize the pellets. General hot-air drying is acceptable. For the 5013 family, 6013 family, 6015 family, and 6017 family, perform pre-drying at 100°C for 6 hours. For 8007, which does not usually need drying, perform pre-drying at 60°C for 24 hours if stringent optical characteristics are required.

Fig. 4-1 shows drying conditions and YI changes of TOPAS 6013S-04. In drying at 120°C, oxidization of pellets proceeds due to extra drying of several hours and YI goes up. In drying at the recommended 100°C, YI never goes up over an extended period of time. With a hopper dryer or the like that will have problems in pellet replacement, 100°C drying should be performed in a range of 6 hours to 24 hours.

Although dehumidification drying is not needed, vacuum drying or drying by nitrogen replacement is recommended for products with stringent color tone and yield requirements. Fig. 4-2 shows the relationship between YI, Haze and drying conditions of TOPAS 5013L-10. It can be seen that vacuum drying and drying by nitrogen replacement show lower YI and better optical characteristics.
4.3 Cylinder temperature

Optimum setting of cylinder temperature varies according to screw shape and heater position, but on a 25 mm diameter or less molding machine in particular, better-appearance samples can be obtained by setting upper side temperature and nozzle side temperature identically. If cylinder temperature is too high, resin will deteriorate, causing discoloration, variations in cushion, fill ration, etc. On the contrary, if temperature is too low, instability of metering, mixing of some unmelted resin, etc., will occur.

4.4 Mold temperature

Standard mold temperatures for molding TOPAS® COC are as shown in Table 4-1, and it is necessary to search for an appropriate mold temperature in this setting temperature range according to the mold surface nature, mold release condition by shape, and required accuracy. For example, if the mold surface is coarse, temperature can be on the low side, while if the mold surface is very smooth, like an optical surface, temperature should be set on the high side for beautiful transfer of the molded product surface.

4.5 Injection pressure

Since flowability of TOPAS is good compared with general transparent materials, such as PMMA, PC, and COP, injection pressure needs to be set lower than them. If injection pressure is inappropriate, the following problems may occur.

- If injection pressure is too high: burrs, etc. will occur.
- If injection pressure is too low: short shots, sink marks, flow marks, voids, etc. will occur.
4.6 Injection speed
Injection speed should be determined in consideration of molded product shape, wall thickness, required quality, runner thickness, gate size, etc.

- High speed is advisable for:
  - thin-walled molded products and multiple-cavity products of stringent dimensional accuracy.
- Low speed is advisable for: thick-walled molded products on which voids or flow marks will become a problem; e.g., lenses, etc., whose optical characteristics are important.

If injection speed is inappropriate, the following problems may occur.

- If injection speed is too high:
  - jetting, flow marks, burrs, burn marks, etc., will occur.
- If injection speed is too low:
  - sprue marks, poor appearance, short shots, flow marks, etc., will occur.

4.7 Screw rotation rate and back pressure
In order to obtain good-appearance molded products with TOPAS, it is necessary to raise screw rotation rate and lower back pressure. As a guide, set so that the following metering time results.

\[ \text{Injection stroke (mm)} \times (0.1 \text{ to } 0.2) > \text{Metering time (sec)} \]

Make this setting by comprehensive judgment because it also has effects on stringiness, drooling, mixing of bubbles, etc.

4.8 Nitrogen purge of hopper
Nitrogen purge or evacuation of the hopper is strongly recommended. Removal of oxygen from the place where the resin starts melting can restrain carbide formation on the screw and cylinder, and also can restrain discoloration especially when cylinder temperature is relatively high.

For nitrogen introduction into the hopper, you should, in principle, connect parts including a nitrogen input port, which should be purchased from your molding machine manufacturer, but as far as testing is concerned, you may input nitrogen by inserting a tube into the cylinder inlet as shown in Fig. 4-3. Seal up the gap between the tube and hopper lid with tape, etc., to some extent.

As for nitrogen to be input, residual oxygen concentration should be approximately 0.1% or less, and flow rate, which cannot be determined categorically because airflow in the hopper loader, hopper dryer, etc., should be taken into consideration, can be several nano-liters per minute if airflow in the hopper is low and molding is stable.

Fig. 4-4 shows an example of the effects of whether the hopper is nitrogen-purged or not. In normal molding, there is little difference between nitrogen-purging and not nitrogen-purging, but when subjected to residence, the degree of discoloration is clearly restrained low by nitrogen introduction.

Connect to a nitrogen generator, cylinder, etc.

Fig. 4-3 Effects of whether hopper is nitrogen-purged or not (example)
4.9 Measures against stringiness

The viscosity of TOPAS® COC is controlled low in order to improve its moldability. As a result, problems such as stringiness and drooling may occur. In such cases, first take the following measures.

- Take a suck-back. Note that taking it too much will result in entry of bubbles. Basically, set to approximately 1/10 of the screw diameter.
- Perform sucking back immediately before the mold opens. Set by metering delay or suck-back delay.
- Decrease nozzle temperature. As a guide, decrease in steps of 5 degrees. Note that decreasing it too much will result in solidification at nozzle tip and unstable injection.
- There are cases where stringiness is difficult to stop depending on the shape or type of the nozzle of the molding machine; e.g., nozzle diameter is large or nozzle tip design is not suitable for low-viscosity resins. Contact us if stringiness cannot be stopped by taking the above measures because measures to be taken differ with situations.

Fig. 4-5 shows nozzle tip temperatures and stringing conditions. (Molding machine = Sumitomo SE75D, Mold temperature = 110°C) From this, it can be seen that stringiness can be corrected by decreasing the nozzle tip temperature.
5. Molding characteristics

5.1 Flowability

![Fig. 5-1 0.3 mmt flow length]

![Fig. 5-2 Wall thickness dependence of flow length]

5.2 Mold shrinkage

![Fig. 5-3 Mold shrinkage of 5013L-10 (80 mm square plate, 2 mm thickness)]

![Fig. 5-4 Mold shrinkage of 6013S-04 (80 mm square plate, 1 mm thickness)]

![Fig. 5-5 Mold shrinkage of 6013S-04 (80 mm square plate, 2 mm thickness)]

![Fig. 5-6 Mold shrinkage of 6015S-04 (80 mm square plate, 1 mm thickness)]
Fig. 5-7 Mold shrinkage of 6015S-04 (80 mm square plate, 2 mm thickness)

Fig. 5-8 Mold shrinkage of 8007S-04 (80 mm square plate, 2 mm thickness)

Fig. 5-9 Mold shrinkage of 6013EC-01 (120 mm square plate, 3 mm thickness)
5.3 After-shrinkage

Fig. 5-10, Fig. 5-11, Fig. 5-12 and Fig. 5-13 show after-shrinkage by annealing of 8007S-04, 5013L-10, 6013S-04, and 6015S-04, respectively. Resins shrink due to annealing, by which molding distortion is relieved. Basically, we recommend that the annealing temperature be lower than mold temperature and 20°C lower than DTUL.

Fig. 5-10  After-shrinkage of 8007S-04 (50°C annealing, 2 mm thickness)

Fig. 5-11  After-shrinkage of 5013L-10 (100°C annealing, 2 mm thickness)

Fig. 5-12  After-shrinkage of 6013S-04 (100°C annealing, 2 mm thickness)

Fig. 5-13  After-shrinkage of 6015S-04 (120°C annealing, 2 mm thickness)
5.4 Thermal stability

(1) Characteristic changes by residence in cylinder
TOPAS® COC mold pieces usually turn yellow after residence in cylinder. On the other hand, there is no great change in mechanical properties as shown in Fig. 5-14.

(2) Characteristic changes by long-time high-temperature treatment
Fig. 5-15 - 18 shows changes in YI and Haze in the case where TOPAS molded products are high-temperature-treated. There seem to be tendencies of yellowing and hazing due to long-time high-temperature treatment.
(3) Characteristic changes by cylinder temperature

Figs. 5-19 to 5-22 show changes of 5013L-10 in some properties according to cylinder temperature. YI, Haze and bending elastic modulus change at 330°C or more. Basically, molding in the recommended condition range is advisable.

Fig. 5-19  Cylinder temperature and YI, Haze of 5013L-10

Fig. 5-20  Physical properties of 5013L-10 by cylinder temperature
(tensile test)

Fig. 5-21  Physical properties of 5013L-10 by cylinder temperature
(Charpy impact strength)
6. Product design

6.1 Melt viscosity

Figs. 6-1 to 6-6 show representative melt viscosity data.
6.2 PVT data

Figs. 6-7 to 6-10 show PVT data of TOPAS® COC.
6.3 Linear expansion coefficient

Fig. 6-11 shows linear expansion coefficient of each grade.

Fig. 6-11  Linear expansion coefficient of TOPAS® COC
### 6.4 Representative values

**Table 6-1** Representative values of physical properties

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Test method</th>
<th>Standard 8007S-04</th>
<th>Standard 5013S-04</th>
<th>Standard 6013S-04</th>
<th>Standard 6015S-04</th>
<th>Standard 6017S-04</th>
<th>High flow 5013L-10</th>
<th>Special 6013EC-01</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ISO (JIS) material designation</strong></td>
<td></td>
<td></td>
<td>&gt;COC&lt;</td>
<td>&gt;COC&lt;</td>
<td>&gt;COC&lt;</td>
<td>&gt;COC&lt;</td>
<td>&gt;COC&lt;</td>
<td>&gt;COC&lt;</td>
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<tr>
<td>Density</td>
<td>Kg/m³</td>
<td>ISO 1183</td>
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<td>1.020</td>
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<td>1.020</td>
<td>1.020</td>
<td>1.020</td>
<td>1.000</td>
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<tr>
<td>Water absorption rate (23°C, saturated)</td>
<td>%</td>
<td>ISO 62</td>
<td>0.01</td>
<td>0.01</td>
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<td>0.01</td>
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<tr>
<td>Water vapor permeability (23°C, 85%RH)</td>
<td>g·mm²/m²·day</td>
<td>DIN 53122</td>
<td>0.025</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>MVR (260°C, 2.16kg)</td>
<td>cm³/10min</td>
<td>ISO 1133</td>
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<td>48</td>
<td>14</td>
<td>4</td>
<td>1.5</td>
<td>48</td>
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<td>Tensile elastic modulus (1mm/min)</td>
<td>MPa</td>
<td>ISO 527-2/1A</td>
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<td>2,900</td>
<td>3,000</td>
<td>3,000</td>
<td>3,200</td>
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<td>Tensile strength at break (5mm/min)</td>
<td>MPa</td>
<td>ISO 178</td>
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<td>97</td>
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<td>60</td>
<td>58</td>
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<td>Tensile elongation at break (5mm/min)</td>
<td>%</td>
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<td>4.5</td>
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<td>27</td>
<td>2.5</td>
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<td>1.7</td>
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<td>Bending strength</td>
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<td>-</td>
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<td>1,800</td>
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<td>Bending elastic modulus</td>
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<tr>
<td>Charpy impact strength (notched)</td>
<td>kJ/m²</td>
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<td>1.6</td>
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<td>Charpy impact strength (unnotched)</td>
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<td>Glass transition temperature (10°C/min)</td>
<td>°C</td>
<td>ISO 11357 -1.2.3</td>
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<td>134</td>
<td>138</td>
<td>158</td>
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<td>134</td>
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<tr>
<td>Deflection temperature under load (0.45 MPa)</td>
<td>°C</td>
<td>ISO 75-1.2</td>
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<td>130</td>
<td>150</td>
<td>170</td>
<td>127</td>
<td>130</td>
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<td>Vicat softening point (50°C, 0.5N)</td>
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<td>ISO 306</td>
<td>80</td>
<td>135</td>
<td>137</td>
<td>156</td>
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<td>-</td>
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<tr>
<td>Relative dielectric constant (1-10kHz)</td>
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<tr>
<td>Relative dielectric constant (1 GHz)</td>
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<td>-</td>
<td>2.3</td>
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<td>2.27</td>
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<td>Volume resistivity</td>
<td>Ω·cm</td>
<td>IEC 60093</td>
<td>1.0x10¹⁴&lt;</td>
<td>1.0x10¹⁴&lt;</td>
<td>1.0x10¹⁴&lt;</td>
<td>1.0x10¹⁴&lt;</td>
<td>1.0x10¹⁴&lt;</td>
<td>1.0x10¹⁴&lt;</td>
<td>-</td>
</tr>
<tr>
<td>Dissipation factor (1GHz)</td>
<td></td>
<td>IEC 60250</td>
<td>-</td>
<td>-</td>
<td>0.00007</td>
<td>0.00007</td>
<td>0.00007</td>
<td>-</td>
<td>0.0006</td>
</tr>
<tr>
<td>Tracking resistance</td>
<td>V</td>
<td>IEC 60112</td>
<td>600 &lt;</td>
<td>600 &lt;</td>
<td>600 &lt;</td>
<td>600 &lt;</td>
<td>600 &lt;</td>
<td>600 &lt;</td>
<td>-</td>
</tr>
<tr>
<td>Light transmittance (2mm)</td>
<td>%</td>
<td>ISO 13488-1</td>
<td>91</td>
<td>91</td>
<td>91</td>
<td>91</td>
<td>91</td>
<td>91.4</td>
<td>-</td>
</tr>
<tr>
<td>Refractive index</td>
<td></td>
<td>ISO 489</td>
<td>1.53</td>
<td>1.53</td>
<td>1.53</td>
<td>1.53</td>
<td>1.53</td>
<td>1.53</td>
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</tr>
<tr>
<td>Abbe number</td>
<td></td>
<td></td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Haze (2mm)</td>
<td>%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Flammability</td>
<td></td>
<td>UL94</td>
<td>HB</td>
<td>HB</td>
<td>HB</td>
<td>HB</td>
<td>HB</td>
<td>HB</td>
<td>-</td>
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<tr>
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<tr>
<td>Applicable article number of the Export Trade Control Order</td>
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<td>E177491</td>
<td>E177491</td>
<td>-</td>
</tr>
</tbody>
</table>
6.5 Other properties

Figs. 6-12 and 6-13 show weld strength. While strength is not greatly affected, elongation decreases due to the effect of notching. Table 6-2 shows pencil hardness. Fig. 6-14 shows fatigue characteristics. Fig. 6-15 shows dynamic solid viscoelasticity. In addition, values of Poisson ratio, etc., are shown.

Fig. 6-12 Characteristic changes by welding

Fig. 6-13 Characteristic changes by welding

Fig. 6-14 Tensile fatigue fracture characteristics at 1 Hz of TOPAS® COC 6013S-04

Table 6-2 Pencil hardness

<table>
<thead>
<tr>
<th>Material name</th>
<th>Grade</th>
<th>L/N</th>
<th>Pencil hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOPAS® COC</td>
<td>8007S-04</td>
<td>600361</td>
<td>HB</td>
</tr>
<tr>
<td></td>
<td>6013S-04</td>
<td>600315</td>
<td>HB</td>
</tr>
<tr>
<td></td>
<td>6015S-04</td>
<td>600174</td>
<td>HB</td>
</tr>
<tr>
<td></td>
<td>6017S-04</td>
<td>600205A</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>5013S-04</td>
<td>600333A</td>
<td>F</td>
</tr>
</tbody>
</table>
Other data

Poisson ratio:

- 5013-**, 6013S-04, 6015-xx, 6017-xx : 0.37
- 6013EC-01 : 0.41

SP value: 7.8 \((\text{cal/cm}^3)^{1/2} = 16(\text{MPa})^{1/2}\)

6.6 Stress crack

(1) Stress crack
When a molded product is made of an amorphous resin and is non-uniform in wall thickness or when molding distortion remains, or when great external stress is exerted on the molded product, it may be crack. This is called stress crack.

Stress crack occurs in places where force is exerted in the tensile direction and stress is concentrated. In order to prevent it, wall thickness should be made as uniform as possible to reduce differential shrinkage on large molded products. On thick-walled parts, walls should be thinned to make thickness uniform. Also, in order to prevent stress concentration, sharp corners should be avoided, and corners should be rounded or chamfered. However, there are cases where stress concentration is unavoidable due to some product shapes. In such cases, reinforcing ribs should be provided. Rib thickness should be 1/3 to 1/2 with respect to product base.

Cracks do not occur immediately after molding but several days later. In such shapes as mentioned above, make observations over several weeks. Also, contact us at design time or when cracks occur because measures to be taken differ with cracking situations, shapes, etc.

(2) Insert shapes
Extra care is needed in performing so-called insert molding, in which some part is placed in a mold and molded integrally. For example, if the insert is notched to be a whirl-stop or retainer, round off corners as much as possible to prevent stress concentration.
7. Mold design

7.1 Sprues, Runners

(a) Runners
In consideration of pressure loss, we generally recommend runners that are circular in cross section, and secondly, trapezoidal runners. However, since TOPAS® COC has good mold transferability, the irregularities on the surfaces right-angled to the parting surfaces of a circular runner may become undercuts, and poor mold release or chipping may occur as a result. Fig. 7-1 shows an example of a circular runner for TOPAS, in which such trouble can be prevented by deforming a true circle so that the surfaces right-angled to the parting surfaces are minimized as can be seen.

(b) Runner size
From the aspects of suppression of cooling of molten resin and reduction of pressure loss, it is better if runners are thicker, but it is also necessary to make decisions regarding runner size taking into consideration economic aspects such as reducing runner ratio.

(c) Sprue and runner arrangement
Basically, a multiple-cavity mold should be designed so that respective cavities are filled with resin simultaneously as the runner lengths and thicknesses are identical and are also arranged symmetrically. What is especially important is a cold slug well, which should always be provided at the intersection of each runner. Fig. 7-2 shows an example of sprue and runner design, and Fig. 7-3 shows examples of runner arrangement and design.

\[ A = \text{Nozzle diameter } + \alpha (0.5 \text{ mm}) \]
\[ B > C \]

Fig. 7-2  Example of sprue and runner design for TOPAS® COC

Fig. 7-1  Examples of runner design
(2) Hot runners
Hot runners can also be used for transparent materials, but it should be kept in mind that resin damage by in-hot-runner heating is greater than that by in-cylinder heating. Therefore, it is not recommended for optically rigorous items because trouble resulting from mixing of carbides, discoloration, etc., is probable. In order to prevent such trouble, it is necessary to select hot runners designed to be suitable for optical materials and follow appropriate directions for use.

Hot runners suitable for transparent resins are to be designed with no dead space (resin residence) in consideration of internal polish, material, etc. For details, contact us.

7.2 Gates

(1) Gate size
More stable products can be molded by positioning the gate at a thick portion of the products. The gate should be sized according to the product shape so as to avoid stress concentration at the gate area. Gate type can be a generally-used side gate, fan gate, and so on. Set sprues and runners on the large side to improve pressure transmission to products.

- Gate thickness should be 60 to 70% of the molded product thickness (in the case of side gates).
- Gate width should be taken by 1 to 1.5 times the gate thickness (in the case of side gates).
- Gate land should be as short as possible (in the case of side gates)
- Gate diameter should be wall thickness or less (in the case of pin gates).

If there are no quality problems, attach a smaller gate to improve molding cycle, gate finish, etc. Also, if molded products are thin-walled (0.3 mm or less), make thickness equal to molded products to prevent pressure loss of resin.
(2) Gate position

- Gates should be positioned at the thickest portion of molded products.
- Gates should be positioned at a part that does not influence appearance of molded products.
- No gate should be positioned where a force is exerted on molded products.
- Weld lines, if becoming a problem, should also be considered.

(3) Gate shape

Commonly-used gates can be used for TOPAS® COC, which does not have any special trouble with gate shape. However, in the case of a submarine gates, gates may break depending on the shape. Fig. 7-4 shows points to be noted.

7.3 Draft angle

Since TOPAS is small in mold shrinkage and excellent in transferability, small irregularities, which do not become a problem for other resins, will be transferred, due to which mold release problems may occur. From the point of mold releasability, as large a draft angle as possible in the allowable range should be provided.

1/2° to 1° at least; 2° if possible

For improving mold release, due care should be exercised regarding knockout systems, positions of ejector pins, their quantity, etc.

7.4 Undercut

With TOPAS, undercutting is basically impossible. When the surface is embossed, for instance, whether the embosses do not become an undercut should be considered.
7.5 Gas vents
If gas vents are poorly designed, filling may be impeded or gas burn may occur; therefore, sufficient attention should be paid to gas vents. Basically, it is effective to vent the gas from all over the circumference of molded products to the flow end.

Also, if the cold slug well of the sprue and runner is gas-vented, air in the sprue and runner will be discharged from there, so that the resin flow to cavity becomes efficient.

Sprues, runners and flow end of molded products should be vented 2/100 m and 1/100 to 2/100 mm, respectively, approximately 3 mm in width, and then grooved approximately 1 mm in depth for guiding out of mold. It should be approximately 1/100 mm for places in the middle of the flow of molded products and for molded products that should not be severely burred.

7.6 Temperature control
Since mold temperature greatly affects the molding cycle, molded product quality, etc., the temperature control method should carefully be considered in advance as in the case of mold structures including runners, gates, ejector systems, etc.

In designing mold temperature control, the following points should be considered.

- Circulation system not by heater but by heating medium
- Points of heating medium circulation system
  (a) Heat-transfer area of temperature control holes should be sufficient. (Cooling holes should be large enough in size and number).
  (b) Temperature control holes should be as close to cavity as possible. (If cooling holes are far from cavity, surface temperature distribution of mold becomes large.)
  (c) Amount of medium circulated should be sufficient. (A temperature controller, having discharge pressure that can overcome pressure loss at the cooling holes, the discharge rate of which is high, should be used.)
  (d) Connections should be made in series without split flows wherever possible.
7.7 Mold material

Since TOPAS® COC does not easily cause mold corrosion or wear, etc., there are no specific points to be noted for mold material. However, in the case of surfaces having difficulties in mold release, such as optical surfaces, some surface treatment to inhibit the adhesion of TOPAS may be required. Fig. 7-5 shows surface treatments and adhesion strength of TOPAS. It is obvious that the adhesion is reduced and mold release is facilitated by treatments of TiC, CrN, etc.

![Fig. 7-5  Surface treatments and results of adhesion evaluation of resins](image)
8. Countermeasures for detects

Typical defects and countermeasures against defects are shown below. Contact us if you cannot solve problems for undescribed causes, in case of equipment problems, or if you do not know what measures to take for unknown causes.

Table 8-1  Causes of molding defects and countermeasures

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| 1. Streaky patterns (flow marks) appear along the flow direction of resin. | 1. Inappropriate molding conditions (sprue marks) | 1. Set metering conditions appropriately.  
a. Raise screw rotation rate to recommended value.  
b. Lower back pressure to recommended value.  
2. Set injection conditions appropriately.  
a. Raise temperature of rear of cylinder.  
b. Raise mold temperature to recommended value.  
c. Raise injection speed. |
| 2. Jetting patterns produced when resin passes through gate remain on surface. | Primary measures: Prevent jetting.  
1. Slow down early-stage gate passing speed.  
2. Scale up gate.  
Secondary measures: Make patterns difficult to remain even if jetting occurs.  
1. Change grade for better flowability.  
2. Raise resin temperature.  
4. Change gate position (Shorten straight-ahead distance after passing through gate.)  
a. Change gate to position where flow butts core, etc., in direction that butts the side.  
b. Use a tab gate. |
| 3. Flow patterns produced by change in flow speed when resin passes through corners and uneven-thickness parts (thin-walled parts ↔ thick-walled parts) remain on surface. | 1. Round corners.  
2. Gradually slope or round parts where wall thickness is changed. |
| 4. Mixing of different resins | 1. Investigate location of mixing and take measures. |
| 2. Flow marks | 1. Resin is in poor contact with cavity because pressure in cavity is insufficient. | 1. Raise dwelling force. Extend dwelling time.  
2. Scale up runner and gate.  
4. Raise injection speed. |
| 2. Gas venting is inadequate. | 1. Enhance gas venting.  
2. Do not raise resin temperature excessively.  
3. Dry material sufficiently. |
2. Set cylinder temperature in recommended range.  
3. Nitrogen-purge or evacuate hopper.  
4. Change design of places of oxidation degradation of resin (hot runners, etc.) appropriately. |
2. Set cylinder temperature in recommended range.  
3. Nitrogen-purge or evacuate hopper.  
4. Clean places of oxidation degradation of resin (screw, hot runner, etc.).  
5. Change the design of the places of oxidation degradation of resin (screws, hot runners, etc.) appropriately. |
<p>| 2. Mixing of foreign matter (dust) | 1. Investigate location of mixing and take measures. |</p>
<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Causes</th>
<th>Countermeasures</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Surface delamination</td>
<td>1. Mixing of different materials, such as PE and PP</td>
<td>1. Investigate location of mixing and take measures.</td>
</tr>
<tr>
<td></td>
<td>2. Adhesion to mold</td>
<td>1. Lower mold temperature.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Lower injection speed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Lower resin temperature.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Lower peak pressure for filling.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Scale up gate.</td>
</tr>
<tr>
<td>6. Stringiness, drooling</td>
<td>1. The viscosity of molten resin at nozzle tip is too low.</td>
<td>1. Take a suck-back.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Set metering delay or suck-back delay so that sucking back</td>
</tr>
<tr>
<td></td>
<td></td>
<td>is performed immediately before mold opens.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Lower nozzle tip temperature.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Replace nozzle with one having a smaller nozzle tip diameter.</td>
</tr>
<tr>
<td></td>
<td>products, central resin is drawn into surface in association with</td>
<td>2. Scale up gate, runner, sprue and nozzle adequately to molded product</td>
</tr>
<tr>
<td></td>
<td>cooling and shrinkage. As a result, central part is</td>
<td>thickness.</td>
</tr>
<tr>
<td></td>
<td>insufficiently filled.</td>
<td>3. Raise dwelling force. Extend dwelling time. Leave a cushion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>until gate sealing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Secure functioning of backflow prevention valve to prevent back-flow during</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dwelling.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Lower injection speed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. Change to higher-viscosity grade.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Raise back pressure.</td>
</tr>
<tr>
<td>8. Sink marks</td>
<td>1. Surface is drawn in and dented by internal shrinking because</td>
<td>1. Lower mold temperature.</td>
</tr>
<tr>
<td></td>
<td>thick-walled parts and ribs are insufficiently cooled or</td>
<td>2. Scale up sprue, runner and gate.</td>
</tr>
<tr>
<td></td>
<td>pressure in cavity is insufficient.</td>
<td>3. Raise the dwelling force. Extend dwelling time.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Leave a cushion until gate sealing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Make rib thickness approximately 1/3 of base thickness.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. Thin walls.</td>
</tr>
<tr>
<td>9. Cracks</td>
<td>1. Stress during mold release (occurring immediately after molding)</td>
<td>1. Improve parts having mold release problems (undercuts and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>parts on which a stress is exerted during mold release).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Review ejector system.</td>
</tr>
<tr>
<td></td>
<td>2. Adherence of oil, etc. (occurring immediately after molding or in</td>
<td>1. Clean mold (rust inhibitor, slide grease, etc.).</td>
</tr>
<tr>
<td></td>
<td>several days)</td>
<td>2. Use clean gloves (against adherence of sebum).</td>
</tr>
<tr>
<td></td>
<td>3. Internal distortion : stress crack (occurring several days after</td>
<td>1. Change shape so as not to leave internal distortion.</td>
</tr>
<tr>
<td></td>
<td>molding)</td>
<td>2. Perform annealing.</td>
</tr>
<tr>
<td></td>
<td>4. Stress distortion (occurring after assembly or during use)</td>
<td>1. Reduce stress exerted on molded products.</td>
</tr>
<tr>
<td></td>
<td>with substances or in several days)</td>
<td>1. Stop use of substances and chemicals that cause cracking.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Coat molded products.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Reduce internal and external distortion.</td>
</tr>
</tbody>
</table>
NOTES TO USERS

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