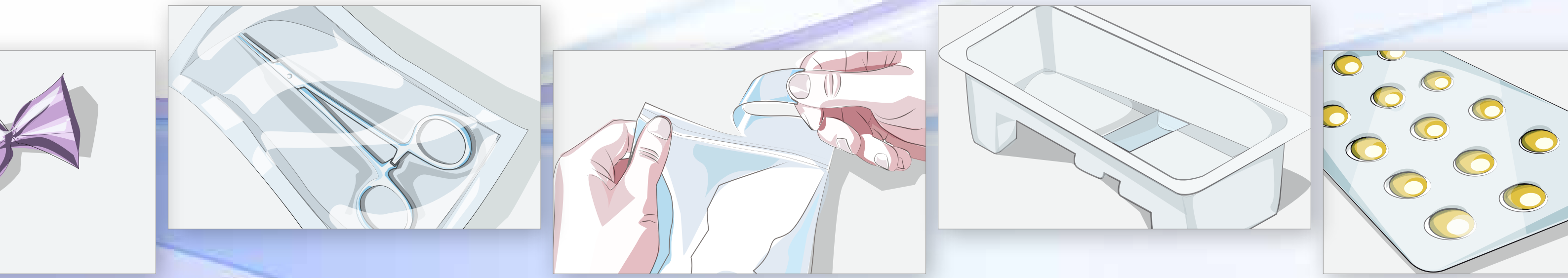
TOPAS
Advanced Polymers



PACKAGING WITH TOPAS® COC

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TOPAS Advanced Polymers

TOPAS Advanced Polymers is the world's leading maker of COC (cyclic olefin copolymer), a glass-clear plastic for healthcare, optics, packaging, and electronics applications. From insulin delivery, to food contact films, to tablet and smartphone displays, TOPAS is the high performance material of choice. The broad global regulatory compliance of TOPAS can make your next development a simpler task.

TOPAS Advanced Polymers also supplies the chemical raw material norbornene. A joint venture of Polyplastics Co., Ltd. and Daicel Corporation, the company is headquartered in Frankfurt, Germany. It operates the world's largest COC plant in Oberhausen, Germany. TOPAS® is a registered trademark of TOPAS Advanced Polymers for its family of cyclic olefin copolymer resins.

Important

The properties of articles can be affected by a variety of factors, including choice of material, additives, part design, processing conditions, and exposure to the environment. Customers should take responsibility as to the suitability of a particular material or part design for a specific application. In addition, before commercializing a product that incorporates TOPAS, customers should take the responsibility of carrying out performance evaluations. The products mentioned herein are not designed or promoted for use in medical or dental implants. Unless specified, the numerical values given in this literature are for reference purposes only and not for use in product design. Without exception, please follow the information and other procedures explained in this literature. This literature does not guarantee specific properties for our company's products. Please take the responsibility to verify intellectual property rights of third parties.

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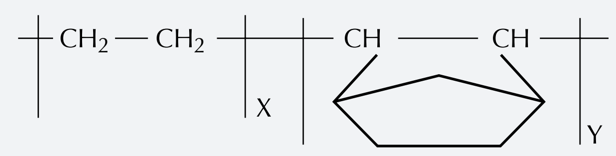
PACKAGING WITH TOPAS® COC

1. Introduction

TOPAS (cyclic olefin copolymer)

TOPAS is an amorphous, glass-clear copolymer based on the polymerization of ethylene and norbornene using metallocene catalysts. Its property profile can be varied over a wide range by adjusting the chemical structure during polymerization.



This range of copolymers exhibits a unique combination of properties whose performance benefits include:

- Glass transition temperature up to 180 °C
- Excellent moisture and aroma barrier
- High stiffness and strength
- Easy to extrude and thermoform
- Polyolefin property enhancement
- Resists hydrolysis, polar organics, acids and alkalis
- High transparency and gloss
- Broad global food and healthcare regulatory compliance

Broad use in packaging

These characteristics have made TOPAS® COC a widely accepted packaging material that enhances packaging performance over a broad range of applications. TOPAS opens new opportunities by adding a new broad use in packaging.

Table 1: TOPAS packaging applications

Blister packs	High moisture barrier, deep draw, halogen-free
Medical trays	High moisture barrier, deep draw, clarity
Forming films	Improved forming window and uniformity
Protective packaging	Enable downgauging by enhanced barrier property, toughness and low creep.
Shrink sleeves and labels	High shrinkage and stiffness with low shrink force
Soft shrink film	Tough, stiff, soft shrink, halogen-free, polyolefin
Twist wrap	High end clarity and gloss, excellent deadfold
Metalized films	TOPAL® barrier metalization on TOPAS substrates enables foil replacement where other solutions fail. Unique combination of moisture, gas and aroma barrier with excellent sealing and folding properties
Linear tear and easy open films	Customizable tear properties for ideal opening behavior, with added benefits for downgauging
Sealant films	Additional stiffness and barrier properties, improved seal strength and hot tack
Bags/pouches	Increased stiffness at room temperature and under hot-fill conditions, easy tear, retort performance
Lidding films	Functional layer for curl control and stiffness in advanced 7-13 layer films
Paperboard coating	Increased moisture barrier, reduced curl

2. Product portfolio

TOPAS is a high purity, colorless, transparent polymer usually processed by extrusion. TOPAS F-series grades (Table 2/3) give optimum performance in extruded sheet, cast film and blown film. TOPAS grades differ primarily in their glass transition (Tg) and the related heat deflection temperature (HDT/B), i.e., those with higher norbornene content have higher heat resistance. Flow characteristics may be adjusted independently of heat resistance with molecular weight. Most grades can be blended with polyethylene and other polyolefins in films.

Table 2: Standard TOPAS film grades

Grade	Description	Tg/°C
TOPAS 9506F-500	Low glass transition temperature (Tg) grade for applications including shrink films and labels, heat seals, and thermoforming applications requiring low temperature processing. May be used in blends or discrete layers. Suited for blown and cast processing.	65
TOPAS 8007F-600	Standard film extrusion grade with broadest extrusion processing window (equipment and conditions). Recommended for most cast and blown film applications, such as food packaging, either in blends or discrete layers. Suitable for grooved feed extruders.	78
TOPAS 7010F-600	Higher temperature resistant grade with broad extrusion processing window (equipment and conditions) for applications such as hot fill packaging, and metallizing. Recommended in blends or discrete layers, cast or blown films.	110
TOPAS 6013F-04	High clarity, temperature resistant extrusion grade for food and healthcare packaging. Provides excellent stiffness and moisture barrier. Can be used in coextruded films as a discrete layer or in blends with PE.	138

Table 3: Special TOPAS film grades

Grade	Description	Tg/°C
TOPAS 9903D-10	Lowest glass transition temperature (Tg) grade for applications including shrink films. May be used in blends or discrete layers. Requires climate controlled storage.	33
TOPAS 8007F-04	High clarity version for clear food and healthcare packaging. Most often used in cast film applications, e.g. blister film. Offers excellent stiffness, water vapor barrier and thermoformability. Broadest healthcare regulatory compliances within our packaging portfolio.	78
TOPAS 5013F-04	Temperature resistant blending grade for healthcare and food films. Used in blends with PE. Higher melt flow than TOPAS 6013F-04.	136
TOPAS E-140	Flexible thermoplastic elastomer grade with Tg of 6°C and melting temperature of 84°C. Offers a very good balance of gas and water vapor barrier, transparency, modulus and cleanliness.	6

3. Product performance

3.1 Physical properties

TOPAS is an amorphous thermoplastic having a glossy, crystal clear appearance with high modulus and low shrinkage. It is available with glass transition temperatures (Tg) ranging up to 180 °C. Film grades of TOPAS have Tg's ranging from 33 to 138°C. For all TOPAS grades, rigidity is maintained until about 10°C below Tg. Other properties associated with the various grades of TOPAS are given in Table 4.

Table 4: Physical properties of TOPAS standard film grades

Property	Unit	Test method	9506F-500	8007F-600	7010F-600	6013F-04
Density	kg/m³	ISO 1183	1010	1010	1010	1020
Melt Volume Rate (MVR)	cm³/10 min	ISO 1133				
· at 230°C, 2.16 kg load			6.0	12.0	11.0	1.0
· at 190°C, 2.16 kg load			1.0	2.0	0.8	< 0.1
Melt Flow Rate	g/10 min	ISO 1133*				
· at 230°C, 2.16 kg load			5.5	11.0	9.2	0.9
· at 190°C, 2.16 kg load			0.9	1.9	1.7	< 0.1
Water absorption (23°C - sat)	%	ISO 62	0.01	0.01	0.01	0.01
Thermal properties						
Glass transition temperature (10°C/min)	°C	ISO 11357 -1, -2, -3	65	78	110	138
Mechanical properties (tensile bars)						
Tensile modulus	MPa	ISO 527-1, -2	2300	2400	2700	2900
Mechanical properties (cast film 70 µm)						
Tensile modulus	MPa	ISO 527-3				
· machine direction			1800	2100	2200	2400
· transverse direction			1700	1700	2100	2250
Tensile strength at break	MPa	ISO 527-3				
· machine direction			55	57	60	55
· transverse direction			55	50	57	45
Elongation at break	%	ISO 527-3				
· machine direction			2.9	3.4	3.6	2.4
· transverse direction			3.6	3.4	3.5	2.2
Mechanical properties (cast film 50 µm)						
Elmendorf tear strength	N	ISO 6383-2	2.1	1.3	0.3	<0.1
Instrumented dart impact		ISO 7765-2				
· peak force	N		25	24	27	13
· deformation	mm		4	5	4	3
Optical properties (cast film 50 µm**)						
Gloss 60°	%	ISO 2813	> 120	> 120	> 120	> 120
Haze	%	ISO 14782	< 2	< 2	< 4	< 1
Barrier properties (film)						
Water vapor permeability (38°C, 90% RH)	g-100 µm/(m²-day)	ISO 15106-3	0.8	0.8	1.0	1.3
Oxygen permeability (23°C, 50% RH)	cm³-100 µm/(m²-day-bar)	ASTM D3985	170	200	260	280

* Calculated from ISO 1133 MVR using a melt density of 0.92., ** optical properties will depend on processing conditions.
The above values are representative values and not guaranteed values for quality or design purposes.

3. Product performance

Table 5: Physical properties of TOPAS special film grades

Property	Unit	Test method	9903D-10	8007F-04	5013F-04	E-140
Density	kg/m³	ISO 1183	980	1010	1020	940
Melt Volume Rate (MVR)	cm³/10 min	ISO 1133				
· at 230°C, 2.16 kg load			4.0	12.0	9.0	3.0
· at 190°C, 2.16 kg load			1.0	2.0	<0.1	1.0
Melt Flow Rate	g/10 min	ISO 1133*				
· at 230°C, 2.16 kg load			3.7	11.0	8.0	2.7
· at 190°C, 2.16 kg load			0.9	1.9	< 0.1	0.9
Water absorption (23°C - sat)	%	ISO 62		0.01	0.01	
Thermal properties						
Glass transition temperature (10°C/min)	°C	ISO 11357 -1, -2, -3	33	78	136	6
Melting Temperature	°C	ISO 11357	n/a	n/a	n/a	84
Mechanical properties (tensile bars)						
Tensile modulus	MPa	ISO 527-1, -2	1260	2600	3600	50
Mechanical properties (cast film 70 µm)						
Tensile modulus	MPa	ISO 527-3				
· machine direction				2200	2600	50***
· transverse direction				1800	2500	
Tensile strength at break	MPa	ISO 527-3				
· machine direction			25	57	35	26***
· transverse direction			22	50	25	
Elongation at break	%	ISO 527-3				
· machine direction			> 150	2.9	1.4	>500***
· transverse direction			> 100	3.0	1.1	
Mechanical properties (cast film 50 µm)						
Elmendorf tear strength	N	ISO 6383-2	1.1	1.5	<0.1	11.5
Instrumented dart impact		ISO 7765-2				
· peak force	N		17	19	7	117
· deformation	mm		33	3	3	60
Optical properties (cast film 50 µm**)						
Gloss 60°	%	ISO 2813	> 120	> 120	> 120	> 120
Haze	%	ISO 14782	< 1	< 1	< 1	< 1
Barrier properties (film)						
Water vapor permeability (38°C, 90% RH)	g-100 µm/(m²-day)	ISO 15106-3	0.8	0.8	1.0	4.6
Oxygen permeability (23°C, 50% RH)	cm³-100 µm/(m²-day-bar)	ASTM D3985	400	200	250	1200

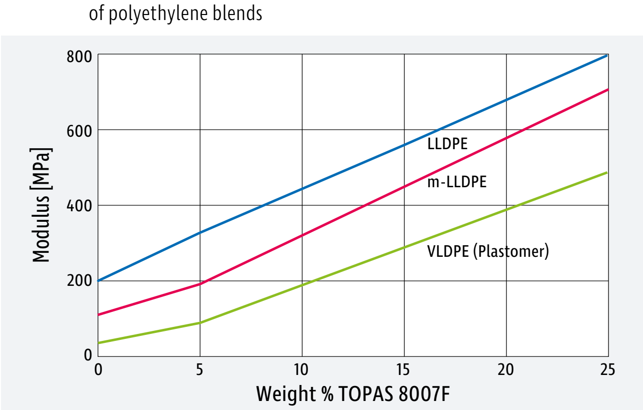
* Calculated from ISO 1133 MVR using a melt density of 0.92., ** optical properties will depend on processing conditions,*** measured on tensile bars.
The above values are representative values and not guaranteed values for quality or design purposes.

3.1.1 Mechanical properties of blends

TOPAS is a stiff (high modulus) amorphous polymer. It is available in a wide range of glass transition temperatures and molecular weights. Like other glassy amorphous polymers, it has low elongation at break. For this reason, it is rarely used as a pure monolayer structure unless exceptional optics are needed.

TOPAS grades have an average tensile modulus of above 2000 MPa. They significantly enhance the stiffness of polyolefin film when used as a blend component, which greatly improves the performance of PE bags, pouches and other packaging. This occurs even at low addition levels as illustrated in Figure 1. For example, a 10% blend of TOPAS with polyethylene raises film stiffness more than 100% while preserving a low haze level.

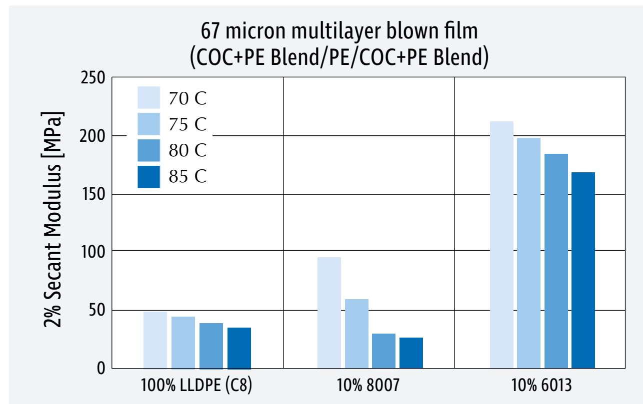
Figure 1: Effect of TOPAS content on room temperature modulus of polyethylene blends



The added stiffness allows downgauging to thinner and less costly film structures. When high-Tg grades are utilized, these modulus improvements are maintained up to temperatures approaching the Tg of the TOPAS, improving hot-fill performance and elevated temperature capability as shown in Figure 2.

Adding TOPAS to PE films also boosts thermal resistance and significantly decreases Elmendorf tear values, especially in the machine direction, enabling the design of "Easy Tear" and "Linear Tear" products, and improving film cutting behavior. Adjusting the TOPAS level in PE films can yield a desired tear resistance while increasing puncture resistance in monolayer PE films. For instance, the force needed to puncture monolayer LLDPE film containing a LL/COC blend increases almost linearly as TOPAS increases from 0 to 30%.

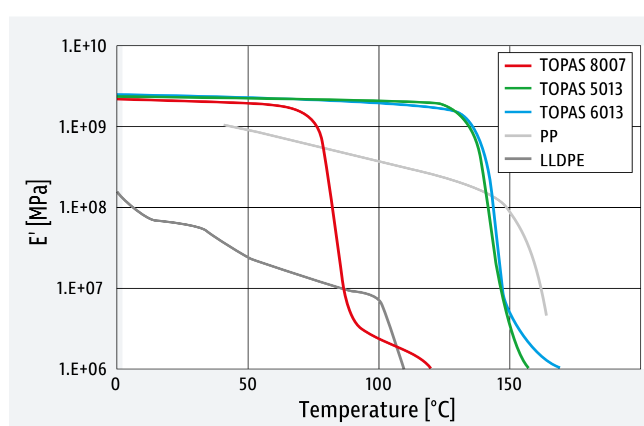
Figure 2: Effect of TOPAS content on elevated temperature modulus of blends



3.1.2 Thermal properties

All amorphous TOPAS grades are polymers with high modulus at room temperature. Unlike commodity plastics such as PE and PP, mechanical properties of TOPAS COC are maintained at temperatures up to nearly the glass transition of each grade. Compared to semicrystalline resins, the rigidity (E') of TOPAS at higher temperature can remain more than an order of magnitude higher, as shown in Figure 3. An application of this property is shown in Figure 2 where small amounts of TOPAS 8007 and 6013 added to LLDPE effectively boost modulus at elevated temperature. This is very helpful in packaging of hot materials, such as foods, and in helping packaging materials to resist thermal challenges including metallization, printing, sterilization and more.

Figure 3: Rigidity (E') of TOPAS grades and commodity resins at elevated temperature



PACKAGING WITH TOPAS® COC

3. Product performance

3.1.3 Barrier properties

TOPAS is used as a barrier material in food and healthcare packaging. Packaging must preserve the taste, flavor and composition of packaged foods and the composition of non-food items such as medicines and fragrances. It must prevent excessive amounts of oxygen, water, solvents, flavors, aromas and other gases or liquids from leaving or entering a package. This has become more important as packaging has moved away from heavy, inflexible glass and metal containers to those made of plastic. Such packaging often involves sophisticated, multilayer structures containing high-barrier polymers like EVOH and PVdC. These structures can be costly, require adhesive polymers, use advanced and expensive processing equipment, and reduce the potential for recycling.

TOPAS has one of the highest moisture barriers of any polymeric material. While not considered a high barrier to oxygen or other gases, it is a significantly better barrier than PE and can be used in blends to modify oxygen, carbon dioxide and other gas transmission rates to target specific values such as those required by fresh produce.

Over a broad range of permeants TOPAS has better barrier properties than LLDPE, typically five times or more. It does not require an adhesive in combination with polyethylenes. Polyethylene/TOPAS blends having more than 70% TOPAS typically provide over 90% of the barrier of pure COC. This can dramatically improve the performance of a packaging film in preserving the original characteristics of a package's contents or moderating the transfer or loss of aromas and odors as illustrated in

Figure 4: TOPAS is one of the best polymeric water vapor barriers

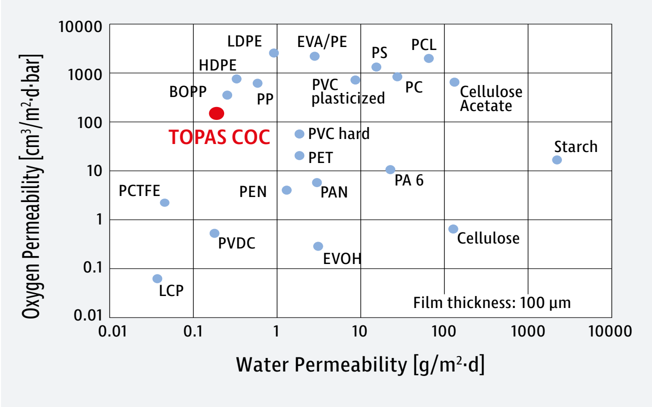
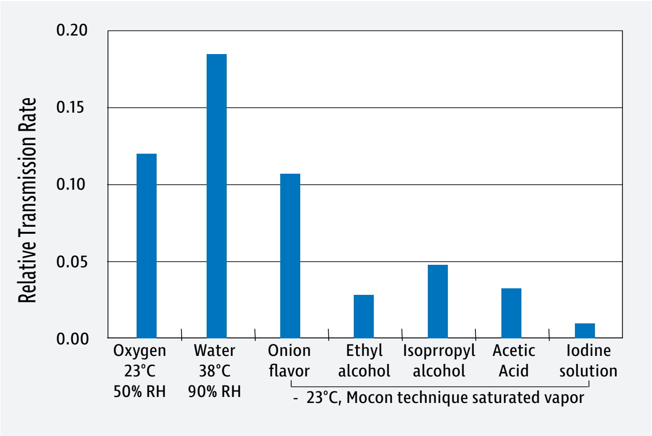


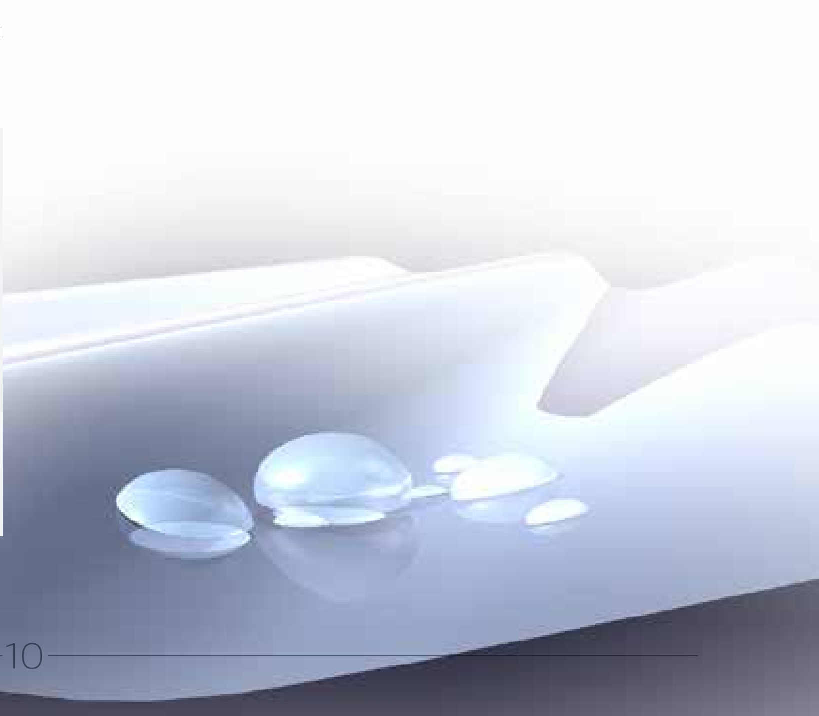
Figure 5. TOPAS barrier layers can compensate for the poor water vapor transmission performance of commonly used oxygen barrier materials such as nylon and EVOH.

Figure 5: Relative transmisson rate of TOPAS 8007 compared to LLDPE



3.1.4 Deadfold

TOPAS has the excellent deadfold characteristics required by twist-wrapped candy. These applications often require an expensive cellophane film. A coextruded film with thin outer TOPAS layers and a PE or PP core delivers excellent deadfold, clarity and a high-gloss surface with good metallizability. Best of all, unlike other substitutes, these TOPAS-based twist films have the easy cutting properties needed for commercial high-speed wrapping lines designed for cellophane.



3.2 Chemical resistance

TOPAS is very pure because the metallocene catalyst used in its production is filtered out after polymerization. It also is extremely low in extractables, e.g. hexane extractables are 0.3% or less and ash is nearly zero. It easily passes the European Pharmacopoeia Section 3.1.3 extractable test for polyolefins. It has excellent organoleptic properties. Tests with various food components have yielded lower extractables and similar scalping levels to those of standard PE resins.

As a non-polar material, TOPAS is highly resistant to polar compounds such as water, alcohol and acetone. Like most polyolefins, it is less resistant to nonpolar materials. TOPAS should be tested against specific compounds when chemical resistance is critical in an application.

Table 6: Chemical resistance of TOPAS

pH < 7 (acidic/aqueous)	hydrochloric acid 36%	⊕
	sulfuric acid 40%	⊕
	nitric acid 65%	⊕
	acetic acid > 94%	⊕
pH = 7 (neutral/aqueous)	water	⊕
	aqueous solution of soap	⊕
	saline solution	⊕
pH > 7 (basic/aqueous)	sodium hydroxide 50%	⊕
	ammonia (aq. sol.) 35%	⊕
Polar organic solvents	ethanol, methanol, butanol, isopropanol (short chain alcohols)	⊕
	acetone, butanone (short chain ketones)	⊕
Aromatic solvents	benzaldehyde	⊙
	toluene	⊖
	benzene	⊖
	chlorinated solvents	⊖
Non-polar organic solvents	pentane, hexane, heptane etc. (alkanes)	⊖
	gasoline (petrol ether)	⊖
	norbornene	⊖
Other	oleic acid	⊖

⊕ resistant
increase of weight < 3%
or loss of weight < 0.5%
elongation at break not substantially altered

⊙ limited resistance
increase of weight 3 to 8%
or loss of weight 0.5 to 5%
elongation at break reduced by < 50%

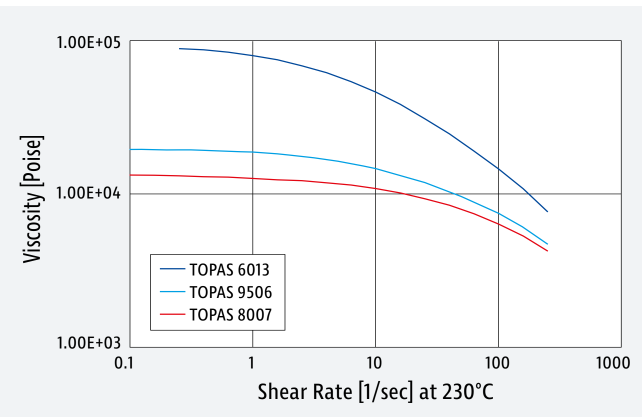
⊖ not resistant
increase of weight > 8%
or loss of weight > 5%
elongation at break reduced by > 50%

3. Product performance

3.3 Rheology

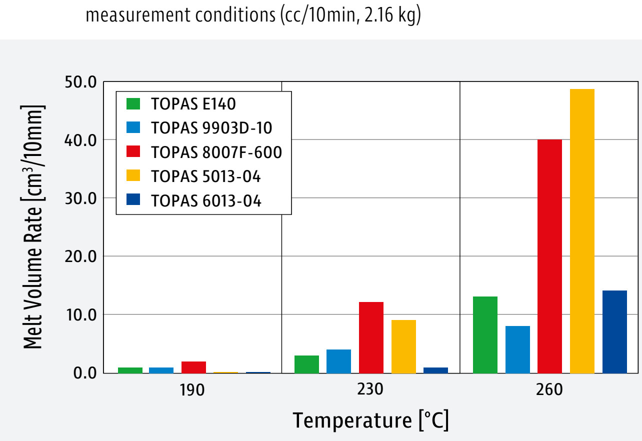
The melt viscosity of TOPAS is a function of molecular weight and Tg at a given measurement temperature. The relationship between viscosity and shear rate is illustrated in Figure 6.

Figure 6: Viscosity as a function of shear rate for various TOPAS grades



TOPAS is often utilized as a blend component or coextruded with conventional polyolefins. Similar melt volume rate (MVR) is commonly utilized to match flow characteristics. Several grades of TOPAS have MI values similar to those of common extrusion grades of polyethylene as illustrated in Figure 7.

Figure 7: Melt volumen rate (MVR) of TOPAS at standard polyolefin measurement conditions (cc/10min, 2.16 kg)



Due to its amorphous structure, the temperature dependence of MVR is higher for TOPAS resins than for typical semicrystalline polyolefins, a fact which needs to be considered when choosing materials and process temperatures.

3.4 Regulatory

Many TOPAS grades comply with industry certifications and national and international regulations for food, drug, and medical devices. For details on individual grades please contact your technical representative.

TOPAS uses no ingredients (heavy metals) regulated by CONEG and uses no ingredients listed on California Proposition 65. It also uses no ingredients listed on the following EU Directives: WEEE – EU-Directive 2002/96/EC; RoHS – EU-Directive 2002/95/EC and EU-Directive 2003/11/EC.

TOPAS is formulated without controversial ingredients such as phthalates, BPA, PFOA, halogens, vinyl chloride, ozone-depleting materials, or conflict minerals.

3.4.1 Food packaging

Most TOPAS grades comply with all major regulatory food contact requirements. In the US, it complies with FDA FCN #405 for direct food contact, which covers all applications, including films, sheets and bottles, for all types of food and all conditions of use. These notifications allow TOPAS to be used in single-use and repeat-use applications. Its conditions of use span categories A to H in Table 2 of 21 CFR 176.170(c). The low Tg of some TOPAS grades produces a practical use temperature limitation.

TOPAS is also suitable for food-contact applications in Europe, and complies with the requirements of Regulation 10/2011/EU, Framework Regulation 1935/2004/EC and Regulation 2023/2006/EC. Manufacturers who use TOPAS should check any restrictions and migration rate limits on the finished article.

3.4.2 Pharmaceutical and medical packaging

TOPAS has undergone testing for use in medical and pharmaceutical applications. A U.S. FDA Drug Master File (DMF #12132) and a FDA Device Master File (MAF #1043) have been established for most grades. In addition, several TOPAS grades have passed United States Pharmacopoeia (USP) Class VI biocompatibility protocols, including acute systemic, intracutaneous and implantation tests. Some grades have passed other biocompatibility tests as defined in ISO 10993, including those for physicochemical effects, cytotoxicity and hemolysis. Certain grades have passed similar tests in accord with EU and Japanese protocols.

In the pharmaceutical sector, structures containing TOPAS 8007F-04 have been used in and been in contact with CDER-approved solid oral doses. TOPAS is widely used in medical devices and in medical device packaging.

3.5 Recycling

Most TOPAS packaging applications involve mixed structures with other polymers. Processors can blend COC-containing scrap into their products at various rates. In general, this approach is most practical when TOPAS is blended with olefin-based polymers.

Post-consumer recycling depends on the polymers with which TOPAS is combined. Although some blends and multilayered structures should be coded "7" under the SPI system, certain PE/COC combinations may use the code of the majority PE component if commercial use will be compatible with post-consumer recycling processes. For instance, a LDPE structure having a minor amount of COC may retain a SPI recycle code of "4".

If it is not practical to recycle a COC-containing product, TOPAS may safely be utilized in municipal waste-to-energy systems. It contains only carbon and hydrogen; no chlorine or other halogens are present. When combusted completely, it yields carbon dioxide and water and releases over 23,000 kJ/kg (10,000 BTU/lb).

4. Processing

4.1 Cast film extrusion

4.1.1 Cast film extrusion of discrete TOPAS layers

As an amorphous thermoplastic, TOPAS lacks crystallinity and a defined melting point. It softens as temperature rises over a range determined by Tg. For discrete TOPAS layers or TOPAS-rich blends, process temperatures depend primarily on the Tg of the TOPAS grade. The minimum temperature for extrusion processing TOPAS is generally 120°C or more above the Tg of the grade used. Best solids conveying occurs at relatively high rear zone temperatures. Higher casting roll temperatures generally give the best clarity.

Several TOPAS packaging grades are suitable for extruding as discrete layers in multilayer films. Choose the grade having a viscosity curve most comparable to the other polymers in a structure to minimize instabilities between film layers. TOPAS grades with suffix F-500/F-600 like 8007F-600 are specially formulated grades for easy processing in discrete layers over a broader range of extruder types and conditions. Process aids can be used. Equipment recommendations are the same as for TOPAS/PE blends. Recommended start-up conditions for discrete TOPAS layers or high-COC blends (> 65% TOPAS) as cast film for film thicknesses of 25 to 250 microns are given in Table 7.

Table 7: Cast film temperature profiles for discrete TOPAS layers

TOPAS Grade	Tg [°C]	Melt Flow Rate [g/10 min] at		Rear Temp. [°C]	Center Temp. [°C]	Front Temp. [°C]	Adapter Temp. [°C]	Die Temp. [°C]
		190°C	230°C					
9506F-500	65	0.9	5.5	210-220	230-240	230-240	230-240	230-240
8007F-04 / F-600	78	1.9	11.0	210-220	230-240	230-240	230-240	230-240
7010F-600	110	1.7	9.2	210-220	230-240	230-240	230-240	230-240
6013F-04	138	0.1	0.9	210-220	260-270	260-270	260-270	260-270

4.1.2 Cast film extrusion of TOPAS/PE blends

Each of the TOPAS grades suitable for cast film blends has its own process requirements. It is best to choose a grade based on process viscosity and the end-use properties needed. Most polyethylenes have excellent compatibility with TOPAS in blends. Linear PE is especially compatible. Good results have been demonstrated using PE with melt index of 1 to 6 g/10 min at 190°C.

When extruding PE-TOPAS blends, it is important that the extruder temperatures in the first few zones of the extruded are kept high enough, close to the values recommended in table 7 for discrate layers. This will ensure thorough melting of the TOPAS pellets. Higher temperatures may be used if desired for overall processing, as TOPAS is quite thermally stable and has been processed at up to 320°C on extrusion coating lines. Higher melt and casting roll temperatures are recommended for best clarity with higher-Tg TOPAS grades.

4.1.3 Cast film extrusion equipment

Screws with long preheat section, shear and mixing elements have proven effective. In most cases standard or multipurpose screws can also be used with good results.

Use a screw L/D (screw length to diameter) ratio of 24:1 or above and a low compression ratio for optimum melt homogeneity.

Use typical coathanger dies and a draw down ratio of 2:1 to 20:1, depending on final thickness.

Casting roll temperatures about 10 to 20°C below Tg of the chosen TOPAS grade are working well. Sticking on the roll will be the limitation. Keep in mind that TOPAS is amorphous and high cast roll temperatures will not result in haze.

4.2 Blown film extrusion

TOPAS performs well in blown film extrusion systems. Typical grades and starting conditions are listed in table 8. Extrusion recommendations given for cast film basically can also be used for blown film. The key new variables are bubble stability and bubble collapsing. TOPAS has lower melt strength than LDPE and the melt strength of other polymers in the film structure will strongly influence bubble stability.

Extrusion starting temperatures indicated in table 8 may be increased for optimum melt homogeneity if bubble stability allows.

Structures containing high levels of TOPAS or thick discrete layers of COC will be stiff and can cause challenges in achieving wrinkle-free lay-flat. In general, keeping the bubble and rollers in the collapsing area warmer helps the collapsing process. Collapsing equipment designed to handle stiff films such as nylons and HDPE will generally produce better results with stiff TOPAS.

Table 8: Blown film temperature profiles for discrete TOPAS layers

TOPAS Grade	Tg [°C]	Melt Flow Rate [g/10 min] at		Rear Temp. [°C]	Center Temp. [°C]	Front Temp. [°C]	Adapter Temp. [°C]	Die Temp. [°C]
		190°C	230°C					
9506F-500	65	0.9	5.5	190-200	200-210	200-210	200-210	200-210
8007F-600	78	1.9	11.0	200-210	220-230	220-230	220-230	220-230
7010F-600	110	1.7	9.2	200-210	220-230	220-230	220-230	220-230

4.2.1 Blown film extrusion equipment

Multipurpose barrier screws with shear and mixing elements work best, where the advancing melt pool is separated from the unmolten pellets. Maddock mixing sections have proven effective.

A preferred screw has an L/D ratio (screw length to diameter) of 24:1 or above and a low compression ratio for optimum melt homogeneity. A standard blown film tower can be used.

Extruders with smooth bore are preferred. Common extruder designs with mild grooved barrel sections are also being used with good result. Heating for feed and grooved barrel zones may be necessary for optimum melt quality.

Use typical spiral dies and die gaps of 1.5 to 2.25mm (60 to 90 mils). Recommended blow-up ratio (BUR) is 2:1, but good results have been achieved at 1.5:1 to 3.5:1 as well.

4.3 Extrusion coating

TOPAS grades can be also processed in extrusion coating. They are compatible with typical process conditions for extrusion coating. Best process stability is achieved when processed as discrete layer or blend in co-extrusion with polyethylene. Additional details are available on request.

4.4 Drying

TOPAS requires no drying. It should not be stored in an extremely high temperature environment, as pellet sticking may result. Extrusion of discrete layers of high Tg grades (TOPAS 6013F-04) may call for degassing to improve processability by removing residual gas that can result in die lines and deposits. This is best done by heating the polymer in a vacuum dryer or a nitrogen-purged dryer for 4 hours at 20 to 30°C below the HDT of the TOPAS grade. Alternately, use the same drying conditions with a desiccant dryer.

4. Processing

4.5 Multilayer films

Monolayer TOPAS films and sheeting create clear and stiff packaging having exceptional moisture, alcohol and aroma barrier. These benefits can be captured in multilayer structures having one or more TOPAS layers. TOPAS resins can be coextruded without tie adhesive layers and adhere to LLDPE, LDPE, EVA, HDPE and SBC. Adhesion issues with these materials can usually be corrected by adjusting processing conditions and flow properties. If this does not resolve the issue, any adhesive commonly used with PE will work with TOPAS. Tie layers may be needed when it is coextruded with polypropylene homopolymer (it adheres well to polypropylene random copolymer) and when draw depth and area draw ratio is aggressive.

TOPAS and PET (including PETG and APET) can be bonded with ethylene-methyl acrylate (EMA) polymers having 25% or more methyl acrylate and a melt volume rate of 5 or above. Tie resins recommended for PE-PETG interfaces have also proven successful. For adhesion to other polymers, consult suppliers of tie layer materials and ask for tie recommendations between the polymer of interest and HDPE.

With polypropylene homopolymer, LLDPE with a MVR of 4 or above is an effective tie layer, although commercial anhydride-grafted tie resins are also used.

Many multilayer structures can be made with TOPAS, which enhances formability and reduces gauge variation. Discrete TOPAS layers often improve appearance by lowering haze and increasing gloss. Such layers may enhance the stiffness of the overall structure, depending on the location of the COC layer(s), allowing downgauging and significant cost savings.

4.6 Monolayer blends

TOPAS is compatible with most polyolefins, so lower cost polymers not often found in thermoforming applications may be used. TOPAS can be melt blended in any ratio with LLDPE, EVA, LDPE, PP and HDPE. COC-rich monolayer blend films and sheeting are usually tougher than COC alone, yet retain much of the COC barrier, stiffness and forming properties. PE-rich monolayer films and sheeting have excellent forming properties. Thermoformed parts from monolayer LLDPE-COC films having as little as 15% COC have low gauge variation, added stiffness, and high dimensional stability with little or no snap back. Such improved performance can be expected with most grades of LLDPE, regardless of comonomer or catalyst.

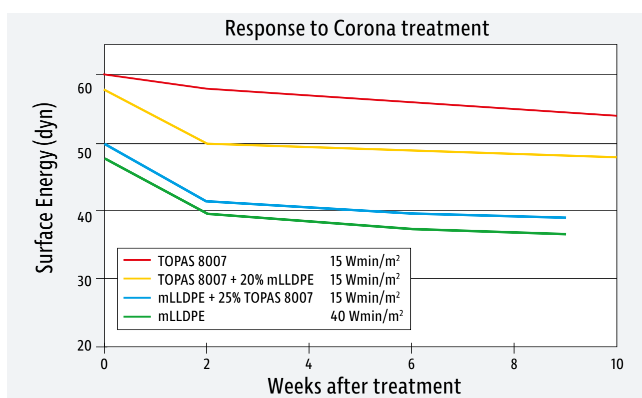
4.7 Additives

TOPAS can be modified with additives to fit specific requirements. Its coefficient of friction and blocking properties can be modified with many of the same slips and antiblocks used in polyethylene. Specialty additives such as processing aids, antioxidants, antistats, and impact modifiers have been utilized with TOPAS and should be considered on an application dependent basis. In general, additives compounded in a PE base are often suitable for use with TOPAS.

4.8 Corona treatment

TOPAS grades respond well to corona treatment. Compared to PE film high surface energy can be obtained on most TOPAS grades with lower corona power and surface tension level remains more stable over time.

Figure 8. Corona surface treatment of TOPAS and mLLDPE



4.9 Purge and shutdown

TOPAS is a very stable resin, and is highly resistant to formation of "gels" as often seen in extrusion of PE and certain other resins. However, it may be desirable to purge TOPAS from extrusion equipment for transitions or shutdown. To purge equipment after running TOPAS, one may use a purge blend comprising 50% 1 MI LLDPE and 50% of a typical PE purge compound. For a shutdown blend, one may use 0.25 MI LDPE and 50% of a standard PE antioxidant masterbatch.

Follow these procedures for purge shutdown:

1. Reduce rear zone temperature to 205°C and introduce the purge blend. Retain existing temperatures on the rest of the extruder and die. Purge for about 20 to 30 minutes.
2. Reduce all temperatures to 180°C and introduce the shutdown blend. Continue to run until the extrudate is clear and machine temperature is below 190°C.
3. Shut down. Do not run the equipment dry.
4. For equipment start-up, heat the extruder and other equipment to 180°C and heat soak for the required time. Start the extruder with the shutdown blend and raise it to the desired temperature. Follow the shutdown blend with an LDPE (preferably one with a melt volume rate between 2 and 3), run for about 15 to 20 min and then introduce TOPAS.

4.10 Troubleshooting

TOPAS is an easy-to-run material. If problems arise during processing, take the steps described below to resolve them. If problems persist, please contact a TOPAS technical representative.

Table 9: Film and sheet: troubleshooting guide

Issue	Potential solution	Explanation
Particles (unmelt, or 'gels') in extrudate	Raise extruder temperatures Adjust MI of PE in PE-rich blends [Needs detail]	Temperatures in the early zones (1, 2, 3) are critical in softening the resin. Unmelts flush out readily once proper conditions are found.
	Raise extrusion pressure ("back pressure")	For lines without a melt pump, a change to finer screens at the screen pack can increase pressure. Increase screw speed.
	Preheat TOPAS pellets	AA resin dryer can be used to give the resin a boost toward its Tg. Be sure not to overheat TOPAS and fuse pellets in dryer.
Haze/Optics	Lower extrusion temperatures, decrease cooling roll temperature	Can be effective at low TOPAS percentages (< 20%) in blends with PE and discrete layers of 8007F-600.
	Dry resin	Rare issue that can occur with high-Tg grades. TOPAS is non-hygroscopic and in this case drying is actually de-oxygenation.
	Increase extrusion temperatures	Higher melt temperatures typically give the lowest haze with grades other than 8007F-600.
Purging TOPAS after run	Most PE and PP resins work well	LDPE with antioxidant concentrate can be used for shutdowns.
Degradation/Gels	Rarely encountered due to stability	"Gels" are usually unmelts (see above for solutions).
Moisture in resin	TOPAS is very moisture-resistant	If pellets themselves are wet, drying is suggested.
Surging of extruder/Pressure variation	Raise extruder temperatures	Temperatures in the early zones (1, 2, 3) are critical in softening the TOPAS resin to stabilize melting behavior. A high quality, uniform temperature melt will produce a more uniform output.
	Lower extruder temperatures (early zones)	If using a resin blend, the non-TOPAS material may start to bridge in the feed throat or plug the screw flights in the feed zone. This can often be diagnosed through visual observation.
	Raise extrusion pressure ("back pressure")	For lines without a melt pump, a change to finer screens at the screen pack can increase pressure. Usually, 10 MPa (1500 psi) is sufficient.
	Check filters for plugging	A coarser mesh screen may be needed in this case.
	Preheat TOPAS pellets	A resin dryer can be used to give melting a head start.
Brittleness	Use lower Tg TOPAS	Higher Tg resins are stiffer, and hence more brittle.
Curl	Use TOPAS on both sides of structure	The amorphous TOPAS resin reduces shrinkage of the structure.
Low interlayer adhesion in coex structures	Change PE type or use a tie layer	Adhesion of TOPAS to LLDPE is higher than to LDPE and HDPE. Conventional PE tie layers can also be used.
Die deposits	Dry resin and extrude under nitrogen	Rare issue, seen with high-Tg grades. Drying works by removing absorbed oxygen from the polymer. Fluoropolymer process aids can produce improvement. Vacuum venting can also reduce deposits.

5. Secondary operations

5.1 Thermoforming film and sheet

TOPAS offers many thermoforming advantages. As an amorphous polymer, its broad softening range enables a wide thermal window prior to forming, unlike the narrow range typical of semicrystalline materials like PE and PP. Its wide processing window enables good formability and less gauge variation in the formed cavity.

Film properties can be adjusted for best forming behavior by selection of TOPAS grade with glass transistion temperature adapted to temperatures of the forming process.

Figure 9: TOPAS improves stiffness, appearance and part uniformity at lower gauge

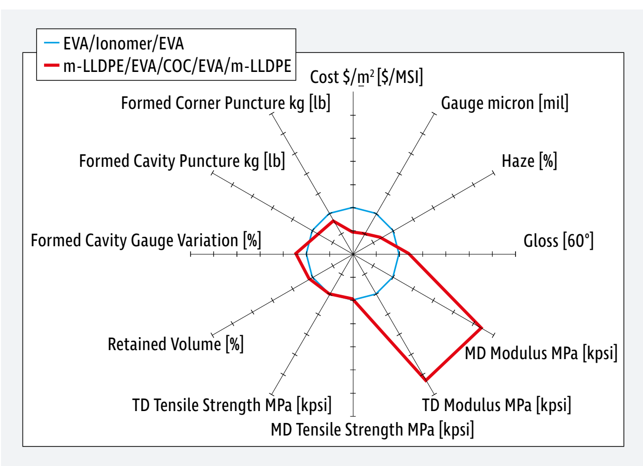
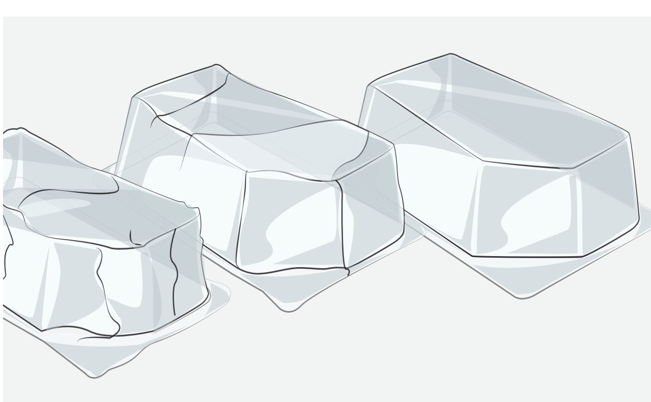


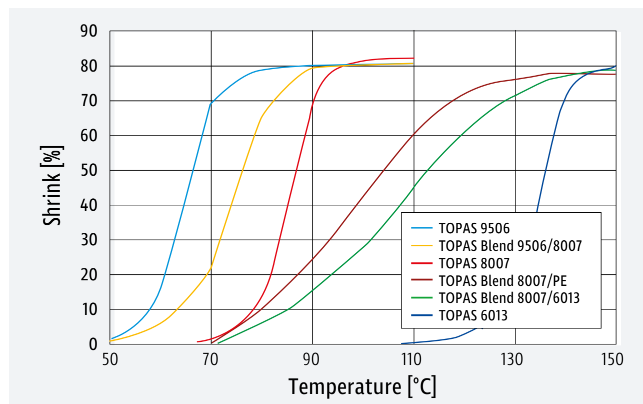
Figure 10: TOPAS addition to PE forming film enhances appearance and properties.



5.2 Orientation and shrinkage

TOPAS orients readily at appropriate temperatures above its Tg. Its broad grade range (Tg from 33 to 138°C) allows orientation and shrink temperatures to be tailored to a process and a product. Shrink temperature curve steepness can be controlled precisely by blending TOPAS grades, as illustrated in Figure 11. Shrinkage rates can also be influenced by blending TOPAS with other polymers.

Figure 11: Shrinkage performance of oriented film can be adjusted with blends of TOPAS grades



TOPAS 8007 and 9506 have been monoaxially and biaxially oriented in flat (tenter, and machine direction stretcher) and tubular (double bubble) processes. Orientation greatly increases TOPAS ductility, while adding some stiffness. As a monolayer in biaxial processing, TOPAS orients best at about a 4x4 ratio. Higher orientation ratios are attainable when TOPAS is a layer or component of a multicomponent structure, e.g., skin layers of TOPAS can be oriented at a 5x10 ratio in OPP tentering and other processes.

TOPAS has high shrink recovery. In monoaxially oriented labels, shrinkage of over 75% is possible. Its shrink stress can be less than half that of competing materials, provided it is not oriented at too low temperatures. Inherent high dimensional stability is useful in shrink applications by reducing film shrinkage below its Tg, e.g., in warm storage conditions.

5.3 Sealing

Heat-sealing capability is usually specified by seal strength, hot tack strength and seal initiation temperature. As it cools, TOPAS rapidly transitions from a rubbery to a glassy state to create a high-modulus material at 65°C (TOPAS 9506) to 78°C (TOPAS 8007). This adds significant seal strength at temperatures where PE has low strength and modulus.
When blended with PE, TOPAS broadens the seal temperature range of many polyethylenes. Figure 12 shows a typical case where the seal range for pure LLDPE is extended and the seal strength is also noticeably higher. TOPAS often improves hot tack performance (strength of the hot seal after cooling for 0.1 sec.) as much as 100%. Hot tack strength is important in vertical form, fill and seal equipment where contents are dropped into bags while the seal is still hot. The more robust sealing performance with TOPAS is valuable in a wide range of "real-world" packaging situations.

When an all-COC surface layer is used in a packaging film, the film can be sealed to itself much like a PE film. For example, TOPAS 9506 seals to itself at a seal initiation temperature of 105°C (defined as seal temperature where 8.8 N seal strength is achieved). The seal strength of the COC-COC seal is similar to that of LDPE and LLDPE. It also has good hot-tack strength. The high modulus of COC means the seal may not be as tough as that of other materials, although the seal will be hermetic.

Figure 1 2: Addition of TOPAS improves seal properties

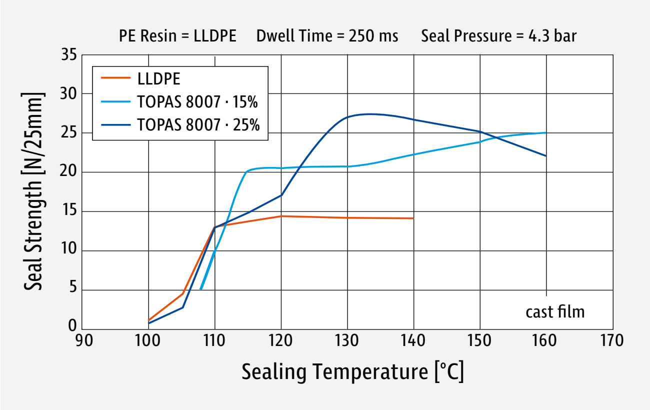
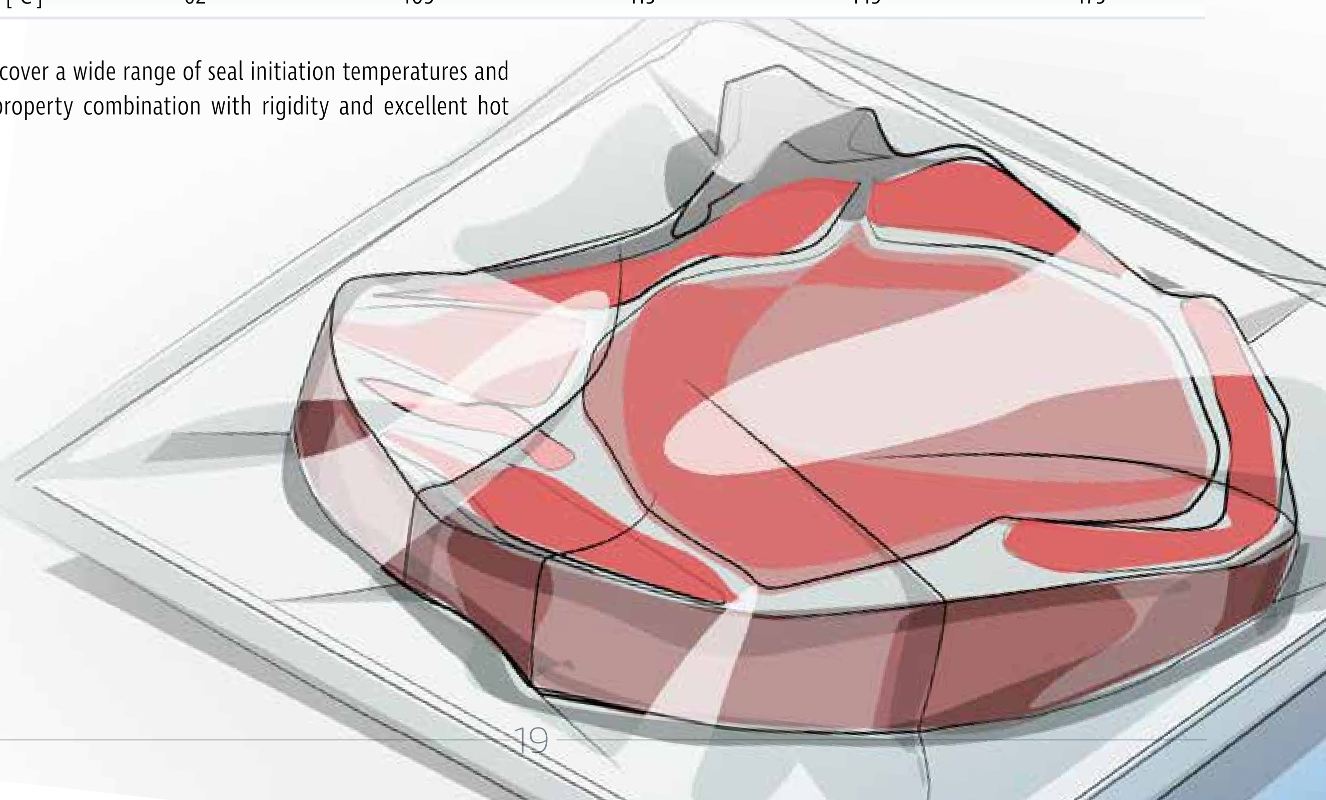


Table 10: Seal initiation temperatures

TOPAS Grades	9903D-10	9506F-500	8007F-600	7010F-600	6013F-04
Tg [°C]	33	65	78	110	138
Seal initiation [°C]	62	105	115	145	175

TOPAS grades cover a wide range of seal initiation temperatures and offer unique property combination with rigidity and excellent hot tack.



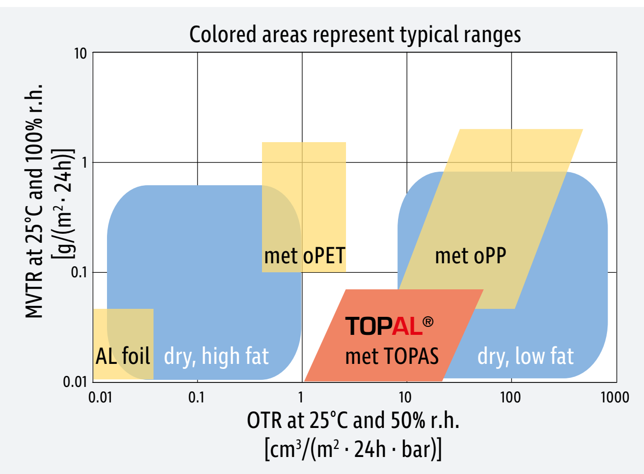
5. Secondary operations

5.4 Vacuum metallizing

TOPAS-based film usually outperforms other polyolefins in decorating, printing and other secondary operations. It delivers a clean, hard surface, high stiffness, and thermal stability.

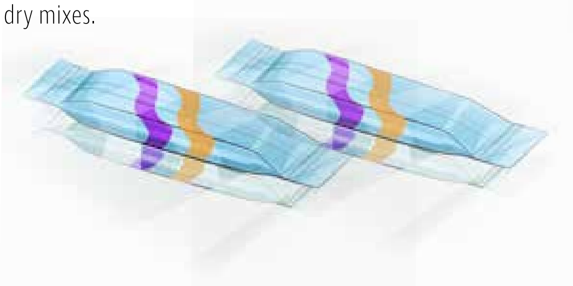
Attractive metallic coatings, usually aluminum, may be applied to TOPAS. Vacuum aluminum metallization of TOPAS has been performed without surface treatments such as flame or corona and when corona is used its effects last significantly longer than on polyethylene.

Figure 13: Gas and moisture barrier of metallized TOPAS



TOPAS film is ideal for aesthetic uses calling for high clarity, gloss and reflection. In twist-wrapped candies, for example, it produces a sleek, shiny, metallized surface and the excellent deadfold needed for clear twist closures.

When metallized, cast or blown films with TOPAS skins yield barriers equal or superior to metallized OPP applications for dry foods with low fat content, making TOPAS-containing film a cost-effective candidate for packaging dry foods such as crackers, rice, coffee, cereal, pet food, snacks and dry mixes.



5.5 Printing

Printing is usually difficult on traditional PE film because it lacks sufficient modulus, is not thermally stable, and must be carefully dried in an oven to drive off the ink solvent. In contrast, TOPAS provides a superior printing surface by improving flatness, increasing temperature resistance and providing a glossy, high quality surface.

TOPAS can also be blended with olefins to raise thermal resistance and modulus, which aids web handling and reduces film elongation under tension for better print registration since adding as little as 10% TOPAS to LLDPE doubles film modulus. Like other polyolefins, TOPAS films require pretreatment with corona or plasma before printing. Their low moisture absorption, high modulus and heat resistance can overcome film processibility problems and deliver more consistent yields. Standard polyolefin ink systems are effective for TOPAS and TOPAS/PE blends.

6. TOPAS® COC applications

Quality packaging delivers both environmental and physical protection of the product inside the package. Environmental protection takes the form of keeping desirable components inside the package, while keeping undesirable contaminants out. This often requires some level of barrier to substances such as moisture, oxygen, chemicals or aromas. Meanwhile, physical protection is achieved through use of a sufficiently rigid or protective package structure that can withstand physical and thermal demands and still deliver the surface properties needed for an appealing, easy-to-produce package. The unique properties of TOPAS allow it to enhance both the environmental and physical aspects of a broad variety of packages, and do so in a very cost-effective manner.

Polyethylene remains one of the major polymers utilized in food packaging but it has disadvantages in that it is a relatively poor barrier and often lacks desired mechanical properties. TOPAS is now being utilized in a large variety of packaging structures that overcome limitations of previously existing packaging materials over a broad area of applications. TOPAS compatibility with polyethylene can often produce a simpler, lower cost package with improved functionality while maintaining recyclability.

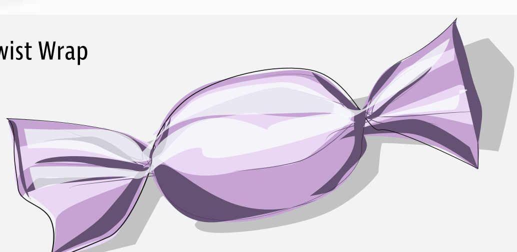
6.1 Food

TOPAS improves food packaging by adding barrier, stiffness, puncture resistance, and clarity, and by improving film processibility in package production operations such as forming, sealing, cutting and folding.

Pouch

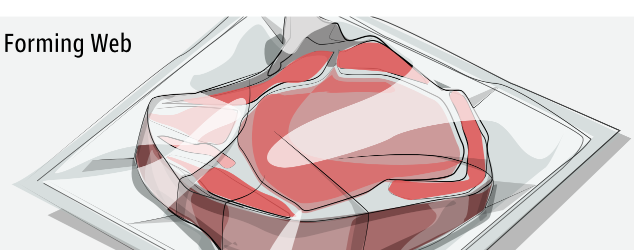
Description	Advantage
Multilayer pouches with TOPAS/PE sealant layer	Improved stiffness Potential for downgauging Excellent clarity and gloss Controlled easy tear properties
Material: TOPAS® 8007F-600	

Twist Wrap



Description	Advantage
Multilayer twist/fold wrap films for candy	Excellent deadfold for twist retention High transparency and gloss Superior value versus cellophane, HDPE and PVC
Material: TOPAS® 8007F-600	

Forming Web



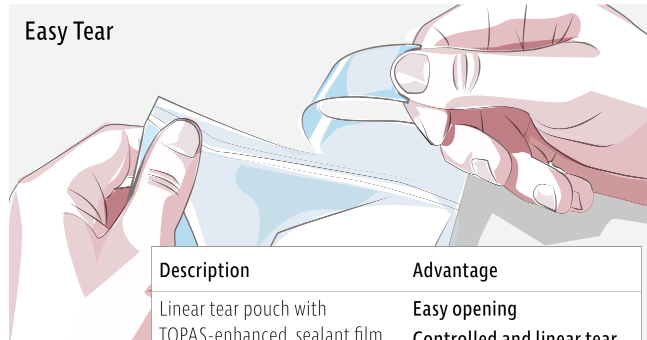
Description	Advantage
Enhanced properties for PE based forming webs. TOPAS used as blend component in PE-LLD	Excellent thermoformability Improved toughness Puncture resistance Potential for downgauging
Material: TOPAS® 9506F-500	

6. TOPAS® COC applications

6.2 Consumer

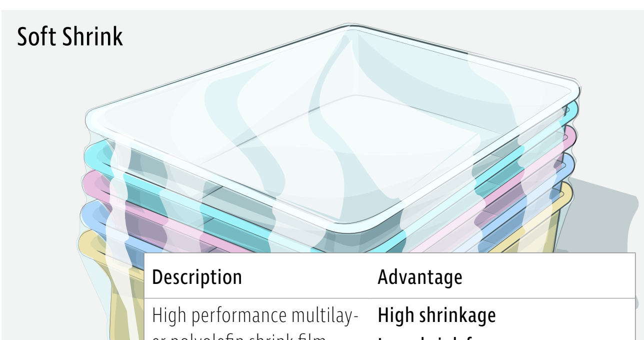
TOPAS delivers solutions over a wide range of packaging needs beyond food, healthcare and personal care. In the fast-growing area of shrink film and shrink labels, TOPAS allows the combination of excellent shrink characteristics and good aesthetics in a halogen-free, easily recyclable film. Stiffness and high temperature capability are being utilized in applications as disparate as foam containers suitable for high temperature (> 100°C) microwaving, to improved quality plastic zippers. TOPAS is a valuable new tool in the packaging engineer's toolbox, providing more versatility than ever in the design of functional, environmentally friendly packaging.

Easy Tear



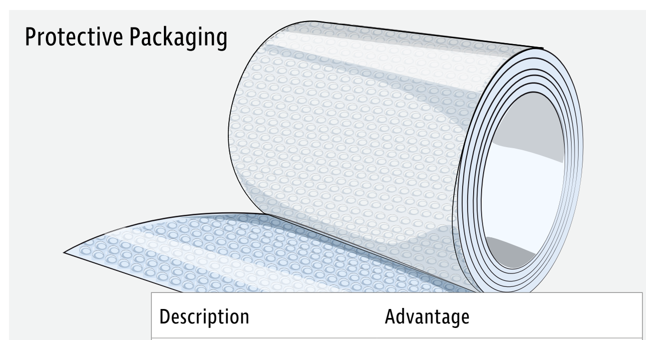
Description	Advantage
Linear tear pouch with TOPAS-enhanced sealant film	Easy opening Controlled and linear tear Improved stiffness
Material: TOPAS® 8007F-600 / 7010F-600	

Soft Shrink



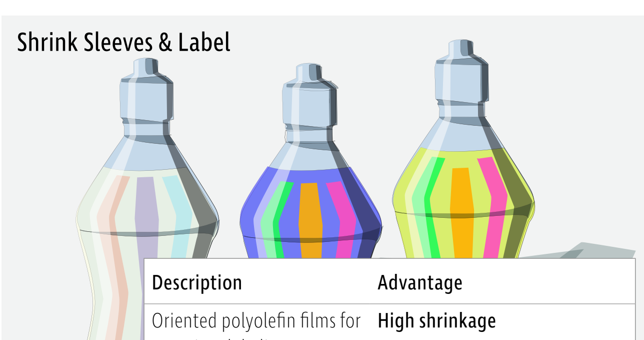
Description	Advantage
High performance multilayer polyolefin shrink film	High shrinkage Low shrink force Low shrink temperature Tough and stiff Clarity
Material: TOPAS® 9903D-10 / 9506F-500	

Protective Packaging



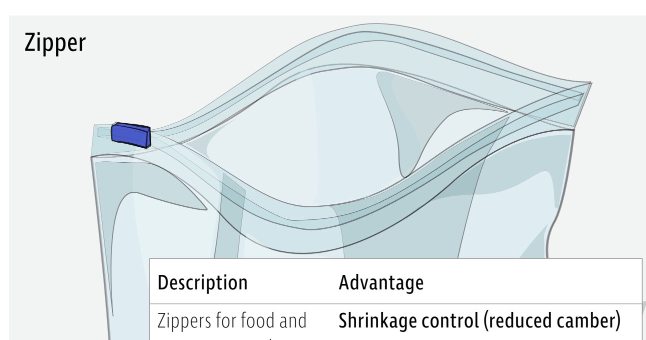
Description	Advantage
Bubble wrap films for protective packaging. TOPAS used as modifier for PE	Polyolefin solution with enhanced gas barrier and stiffness Downgauging potential
Material: TOPAS® 8007F-600	

Shrink Sleeves & Label



Description	Advantage
Oriented polyolefin films for container labeling	High shrinkage Low shrink force Low density for easy recycling Printability
Material: TOPAS® 9506F-500 / 8007F-600	

Zipper



Description	Advantage
Zippers for food and consumer goods	Shrinkage control (reduced camber) High strength for heavy bags Mechanical strength and stiffness
Material: TOPAS® 6013F-04	

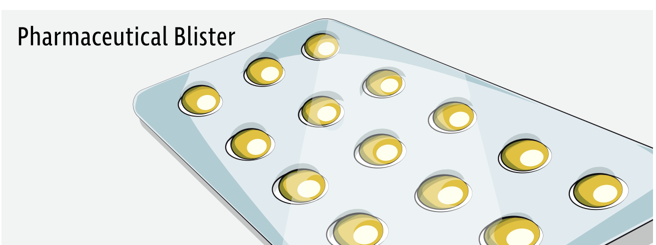
6.3 Healthcare

Packaging for medicines and devices must meet such demanding criteria as biocompatibility, protection against external influences, optimum shelf life, clear identification and easy handling and dispensing. For medicines in tablet form, blister packs have become increasingly desirable because they are easy and safe for patient use, and help patients comply with dosage recommendations. Modern medical devices often require protection from moisture, while clarity is desired for ease of identification and quality control.

TOPAS-based blister films provide high moisture barrier, are crystal clear, physiologically inert, and can be produced and disposed of in an environmentally friendly way. TOPAS films used in pharmaceutical blister packs usually have thin PP or HDPE outer layers and an interior layer of pure TOPAS or TOPAS blended with PE. For medical trays, TOPAS is combined with outer layers of PE, PP or PETG for clear deep draw packaging with outstanding moisture barrier.

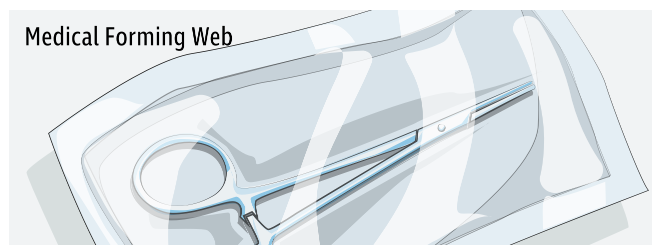
TOPAS significantly improves thermoforming uniformity and film stiffness when used in blends or discrete layers. This provides improved barrier performance due to decreased corner thinning and opportunities for downgauging while maintaining tactile stiffness in many formed packages. Clarity and high gloss enticingly display health, beauty, and medical products in many types of formed packages, including forming webs.

Pharmaceutical Blister



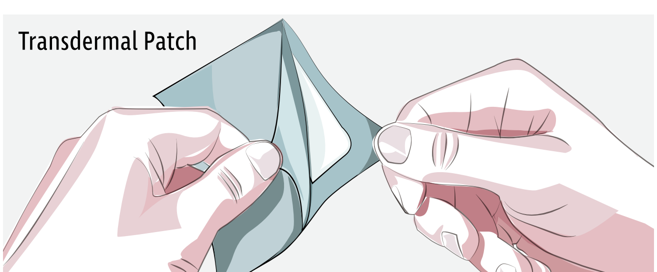
Description	Advantage
TOPAS as moisture barrier in multilayer coextruded or laminated films	Excellent moisture barrier Good thermoformability High purity Halogen free High clarity
Material: TOPAS® 8007F-04	

Medical Forming Web



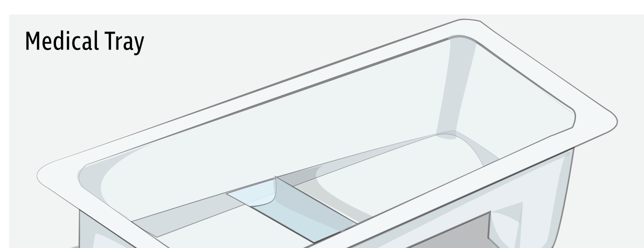
Description	Advantage
Forming webs for medical device packaging made from PE/TOPAS blends	Good forming properties Limited shrink back Excellent stiffness Downgauging Easy tear
Material: TOPAS® 8007F-600	

Transdermal Patch



Description	Advantage
Non-adsorption of active ingredient	Possible alternative to PAN for selected pharmaceuticals Polyolefin solution
Material: TOPAS® 6013F-04 / 8007F-04	

Medical Tray



Description	Advantage
Clear thermoformable barrier film with deep draw capability	Excellent clarity High moisture barrier Retains barrier and optics in deep draw Good formability
Material: TOPAS® 6013F-04 / 8007F-04	

7. Subject index

8. Conversion table

Unit conversion factors

		← Multiply by	Divide by →
Length	Meter (m)	0.0254	Inch (in)
		0.3048	Foot (ft)
Area	Square meter (m^2)	6.45×10^{-4}	Square inch (in^2)
		0.0929	Square feet (ft^2)
Volume	Cubic meter (m^3)	1.64×10^{-5}	Cubic inch (in^3)
		0.0283	Cubic feet (ft^3)
Mass	Kilogram (kg)	0.4535	Pound (lb)
Force	Newton (N)	4.448	Pound force (lb_f)
		9.807	Kilogram force (kg_f)
Pressure	Pascal (Pa)	1	Newton/meter² (N/m^2)
		9.81×10^4	kg_f/cm^2
		10^5	Bar
		$6{,}897 \times 10^3$	lb_f/in^2 (psi)
	Megapascal (MPa)	$6{,}897 \times 10^{-3}$	lb_f/in^2 (psi)
Viscosity	Pascal second (Pa s)	0.1	Poise
Energy	Joule (J)	4.187×10^3	Calorie (cal)
	Kilojoule/kilogram (kJ/kg)	4.187×10^3	Calories/gram (cal/g)
	Joule/kilogram (J/kg)	2.33×10^3	btu/lb

Tensile or flexual property conversion

Strength	MPa	75	100	125	150	175	200	225	250	275	300
	psi	10,900	14,500	18,100	21,800	25,400	29,000	32,600	36,300	39,900	43,500
Modulus	MPa	6,000	8,000	10,000	12,000	14,000	16,000	18,000	20,000	22,000	24,000
	psi x 106	0.87	1.16	1.45	1.74	2.03	2.32	2.61	2.90	3.19	3.48

Length conversion

inches	1 (1)	1/2 (0.5)	1/4 (0.25)	1/8 (0.125)	1/16 (0.0625)	1/32 (0.0313)	1/64 (0.0156)
mils	1000	500	250	125	62.5	31.3	15.6
cm	2.54	1.27	0.64	0.32	0.16	0.08	0.04
mm	25.4	12.7	6.4	3.2	1.6	0.8	0.4

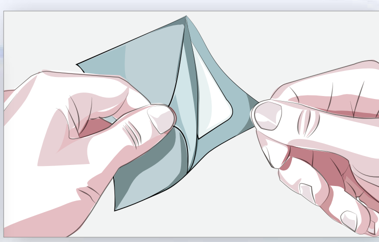
Temperature conversion (Conversion factor: °F = 1.8 (°C) + 32)

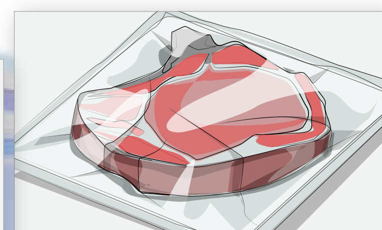
Degrees Centigrade (°C)	0	10	20	50	75	100	125	150	175	200
Degrees Fahrenheit (°F)	32	50	68	122	167	212	257	302	347	392

Your notes

Your notes

TOPAS Advanced Polymers
A member of Polyplastics Group

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