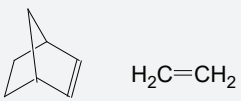


# COC cyclic olefin copolymer

PARAMETER	UNIT	VALUE	REFERENCES
<b>GENERAL</b>			
Common name	-	cyclic olefin copolymer	
CAS name	-	bicyclo[2.2.1]hept-2-ene, polymer with ethene	
Acronym	-	COC	
CAS number	-	26007-43-2	
RTECS number	-	RC0190000	
<b>SYNTHESIS</b>			
Monomer(s) structure	-		
Monomer(s) CAS number(s)	-	498-66-8; 74-85-1	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	94.17; 28.05	
Monomer(s) expected purity(ies)	%	99; 99.95	
Norbornene contents	%	20.2-82	
Temperature of polymerization	°C	80-120	
Time of polymerization	h	60	
Pressure of polymerization	kPa	120-240	Young, M-J; Chang, W-S; Ma, C-C M, Eur. Polym. J., 39, 165-71, 2003.
Catalyst	-	ethylenebis-(indenyl)zirconium dichloride; metallocene	
Initiation rate constant	mol s <sup>-1</sup>	1.94E5	Young, M-J; Chang, W-S; Ma, C-C M, Eur. Polym. J., 39, 165-71, 2003.
Propagation rate constant	mol s <sup>-1</sup>	2.804E5, 2.782E5	Young, M-J; Chang, W-S; Ma, C-C M, Eur. Polym. J., 39, 165-71, 2003.
Termination rate constant	mol s <sup>-1</sup>	2.4E8	Young, M-J; Chang, W-S; Ma, C-C M, Eur. Polym. J., 39, 165-71, 2003.
Chain transfer rate constant	mol s <sup>-1</sup>	4.159E3, 3.471E1	Young, M-J; Chang, W-S; Ma, C-C M, Eur. Polym. J., 39, 165-71, 2003.
Number average molecular weight, M <sub>n</sub>	dalton, g/mol, amu	51,000-173,000	
Mass average molecular weight, M <sub>w</sub>	dalton, g/mol, amu	41,000-188,000	
Polydispersity, M <sub>w</sub> /M <sub>n</sub>	-	1.5-4.1	
Molar volume at 298K	cm <sup>3</sup> mol <sup>-1</sup>	51.1-67.5	Poulsen, L; Zebger, I; Klinger, M; Eldrup, M, Sommer-Larse, P; Ogilby, P R, Macromolecules, 36, 7189-98, 2003.
Van der Waals volume	cm <sup>3</sup> mol <sup>-1</sup>	32.5-46.1	Poulsen, L; Zebger, I; Klinger, M; Eldrup, M, Sommer-Larse, P; Ogilby, P R, Macromolecules, 36, 7189-98, 2003.
<b>STRUCTURE</b>			
Crystallinity	%	amorphous	
Entanglement molecular weight	dalton, g/mol, amu	31,000	Blochowiak, M; Pakula, T; Butt, H-J; Bruch, M; Fluodas, G, J. Chem. Phys., 124, 134903, 1-8, 2006.

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PARAMETER	UNIT	VALUE	REFERENCES
<b>COMMERCIAL POLYMERS</b>			
Some manufacturers	-	Mitsui Chemical; Topas	
Trade names	-	Apel; Topas COC	
<b>PHYSICAL PROPERTIES</b>			
Density at 20°C	g cm <sup>-3</sup>	1.00-1.08	
Bulk density at 20°C	g cm <sup>-3</sup>	0.55-0.60	
Refractive index, 20°C	-	1.51-1.54, 1.53 (Topas)	
Birefringence	-	0.02	Oh, G K; Inoue, T, Rheol. Acta, 45, 116-23, 2005.
Transmittance	%	90-92, 91.4 (Topas)	
Haze	%	0.5-4	
Gloss, 60°, Gardner (ASTM D523)	%	>100	
Softening point	°C	60	
Decomposition temperature	°C	407-440	Liu, C; Yu, J; Sun, X; Zhang, J; He, J, Polym. Deg. Stab., 81, 197-205, 2003.
Thermal expansion coefficient, 23-80°C	°C <sup>-1</sup>	0.6-0.7E-4	
Glass transition temperature	°C	62-177; 114-122 (metallocene catalyst); 96-125 (depending on annealing temperature)	Benavente, R; Scrivani, T; Cerrada, M L; Zamfirova, G; Perez, E; Perena, J M, J. Appl. Polym. Sci., 89, 3666-71, 2003; Tritto, I; Marestin, C; Boggioni, L; Sacchi, M C; Brintzinger, H-H; Ferro, D R, Macromolecules, 34, 5770-77, 2001.
Heat deflection temperature at 0.45 MPa	°C	75-150; 75-170 (Topas)	
Heat deflection temperature at 1.8 MPa	°C	60-125; 68-151 (Topas)	
Vicat temperature VST/B/50	°C	80-137	
Hansen solubility parameters, $\delta_D$ , $\delta_P$ , $\delta_H$	MPa <sup>0.5</sup>	18.0, 3.0, 2.0	Hansen, C M; Just, L, Ind. Eng. Chem. Res., 40, 21-25, 2001.
Molar volume	kmol m <sup>-3</sup>	5.0	Hansen, C M; Just, L, Ind. Eng. Chem. Res., 40, 21-25, 2001.
Dielectric constant at 100 Hz/1 MHz	-	2.2 (Topas)	
Relative permittivity at 1-10 Hz	-	2.35	
Relative permittivity at 1 GHz	-	2.3	
Dissipation factor at 1 GHz	-	7E-5	
Volume resistivity	ohm-m	1E14	
Comparative tracking index, CTI, test liquid A	-	>600	
Permeability to oxygen, 25°C	cm <sup>3</sup> cm m <sup>-2</sup> day <sup>-1</sup> bar <sup>-1</sup>	1.7-4	
Permeability to water vapor, 25°C	g mm m <sup>-2</sup> day <sup>-1</sup>	0.200; 57% reduction with addition of 0.06 wt% graphene; 0.023-0.045 (Topas)	Lai, C-L; Fu, Y-J; Chen, J-T; Wang, D-M; Sun, Y-M; Huang, S-H; Hung, W-S; Hu, C-C; Lee, K-R, Carbon, 90, 85-93, 2015.
Diffusion coefficient of oxygen	cm <sup>2</sup> s <sup>-1</sup> x10 <sup>8</sup>	2.2-5.8	Poulsen, L; Zebger, I; Klinger, M; Eldrup, M, Sommer-Larse, P; Ogilby, P R, Macromolecules, 36, 7189-98, 2003.

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PARAMETER	UNIT	VALUE	REFERENCES
<b>MECHANICAL &amp; RHEOLOGICAL PROPERTIES</b>			
Tensile strength	MPa	22-72, 46-63 (Topas)	
Tensile modulus	MPa	1260-3200	
Tensile stress at yield	MPa	37-60	
Elongation	%	1.1-100	
Tensile yield strain	%	6.5	
Flexural strength	MPa	90-110	
Flexural modulus	MPa	2,400-3,200	
Charpy impact strength, 23°C	kJ m <sup>-2</sup>	13-20, 13-20 (Topas)	
Charpy impact strength, notched, 23°C	kJ m <sup>-2</sup>	1.6-2.6; 1.8-2.6 (Topas)	
Izod impact strength, notched, 23°C	J m <sup>-1</sup>	25-45	
Ball indentation hardness at 358 N/30 S (ISO 2039-1)	MPa	130-184	
Shrinkage	%	0.1-0.7	
Melt viscosity, shear rate=1000 s <sup>-1</sup>	Pa s	100-650	
Melt volume flow rate (ISO 1133, procedure B), 230°C/2.16 kg	cm <sup>3</sup> /10 min	1-9 (extrusion grades); 14-48 (injection molding grades)	
Melt index, 260°C/2.16 kg	g/10 min	2-36; 48	Akin, D; Kosgoz, A; Durmus, A, Composites: Part A, 60, 44-51, 2014.
Water absorption, equilibrium in water at 23°C	%	<0.01	
<b>CHEMICAL RESISTANCE</b>			
Acid dilute/concentrated	-	resistant	
Alcohols	-	resistant	
Alkalis	-	resistant	
Aliphatic hydrocarbons	-	non-resistant	
Aromatic hydrocarbons	-	non-resistant	
Esters	-	resistant	
Greases & oils	-	non-resistant	
Halogenated hydrocarbons	-	non-resistant	
Ketones	-	resistant (short chain)	
<b>FLAMMABILITY</b>			
Autoignition temperature	°C	445	
UL 94 rating	-	HB	
<b>WEATHER STABILITY</b>			
Spectral sensitivity	nm	280-380	
Activation wavelengths	nm	267	
Activation energy of aging	kJ mol <sup>-1</sup>	1,522	Huang, W-J; Chang, F-C, J. Polym. Res., 10, 195-200, 2003.
Products of degradation	-	chromophores, hydroperoxides, COOH	Pu, Q; Oyesanya, O; Thompson, B; Liu, S; Alvarez, J C, Langmuir, 23, 1577-83, 2007.
Stabilizers	-	antioxidants (e.g. Irganox 1010)	

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PARAMETER	UNIT	VALUE	REFERENCES
<b>TOXICITY</b>			
<b>NFPA: Health, Flammability, Reactivity rating</b>	-	1/1/0	
<b>TLV, ACGIH</b>	mg m <sup>-3</sup>	10; 3 (respirable fraction)	
<b>OSHA</b>	mg m <sup>-3</sup>	5 (respirable dust); 15 (total dust)	
<b>Oral rat, LD<sub>50</sub></b>	mg kg <sup>-1</sup>	3250	
<b>PROCESSING</b>			
<b>Typical processing methods</b>	-	injection molding, extrusion, thermoforming	
<b>Processing temperature</b>	°C	190-240	
<b>Processing pressure</b>	MPa	14 (extrusion); 50-110 (injection pressure)	
<b>Process time</b>	min	15 (injection molding)	
<b>Additives used in final products</b>	-	rheological additives, graphene, montmorillonite, carbon fillers, silica	Lai, C-L; Fu, Y-J; Chen, J-T; Wang, D-M; Sun, Y-M; Huang, S-H; Hung, W-S; Hu, C-C; Lee, K-R, Carbon, 90, 85-93, 2015.
<b>Applications</b>	-	bottles, contact lenses, cosmetics, electronics, film, health-care, industrial parts, optical parts, pharmaceuticals, packaging, printer toner, sheet	
<b>Outstanding properties</b>	-	high clarity, outstanding moisture barrier, high heat distortion temperature	
<b>BLENDS</b>			
<b>Suitable polymers</b>	-	LLDPE, PC, POE, PP	
<b>ANALYSIS</b>			
<b>FTIR (wavenumber-assignment)</b>	cm <sup>-1</sup> /-	C=O – 1850-1680; C=C – 1680-1590; C-O-C – 1400-1100	Nakade, K; Nagai, Y; Ohishi, F, Polym. Deg. Stab., 95, 2654-58, 2010.