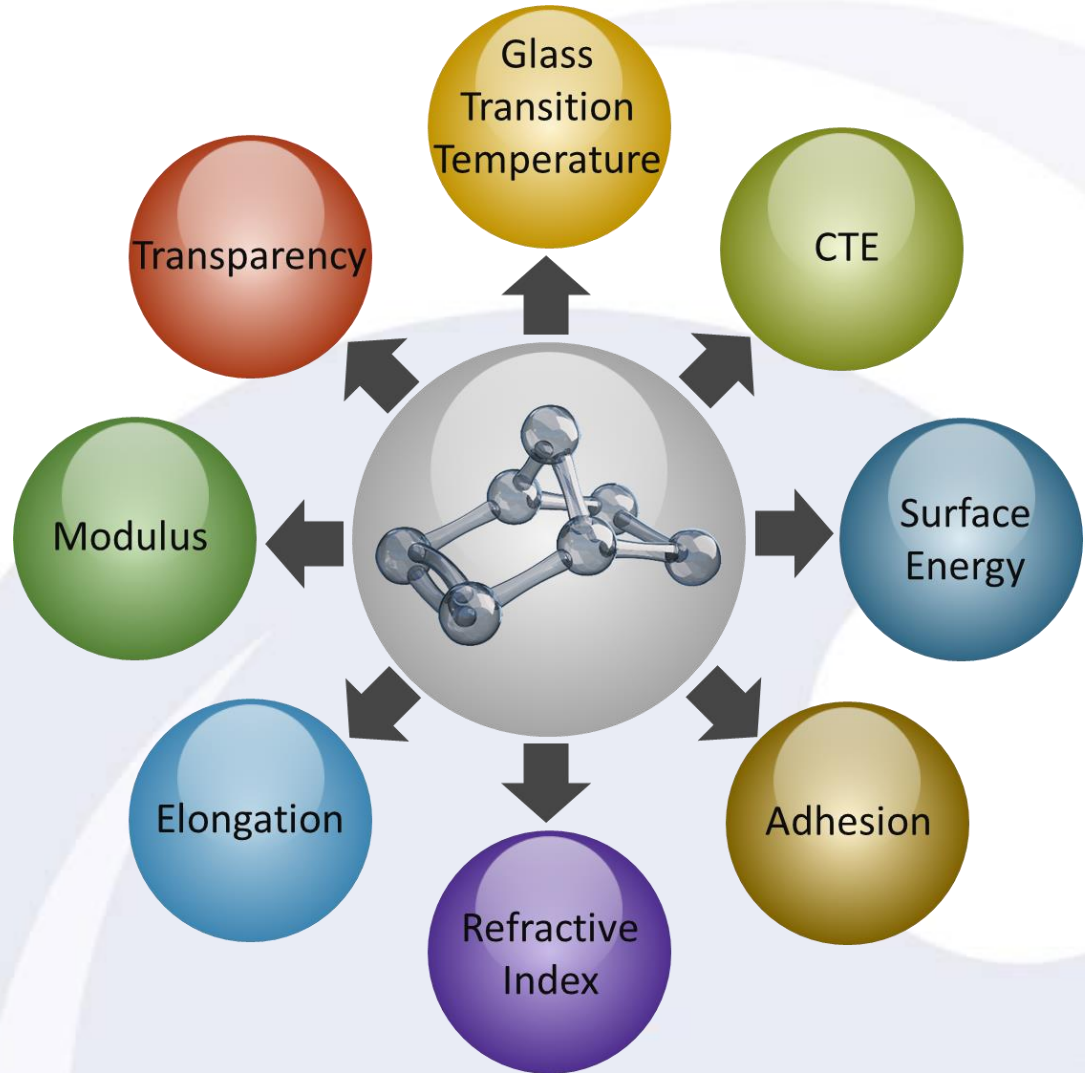
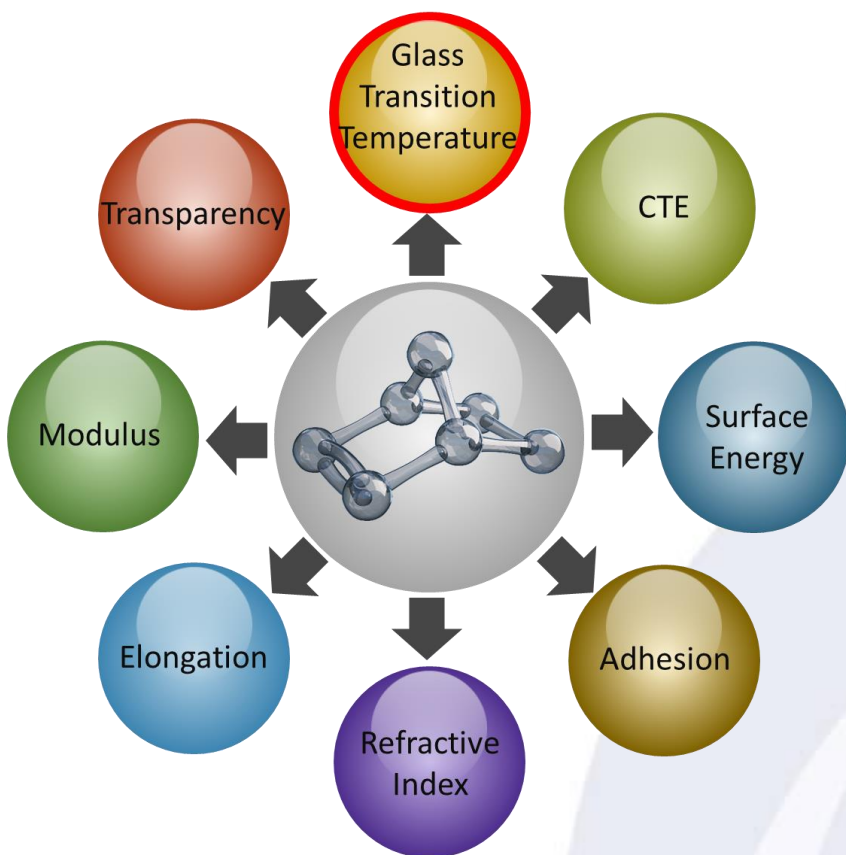


PNB Polymer Properties are Controlled by Changing the Functional Group (FG)

- ▶ Promerus' core technology provides ability to incorporate Functional Groups into PNB backbone
- ▶ Other Poly Cyclic Olefins do not offer the same degree of Functional Group tailorability



Glass Transition Temperature Can Be >300°C

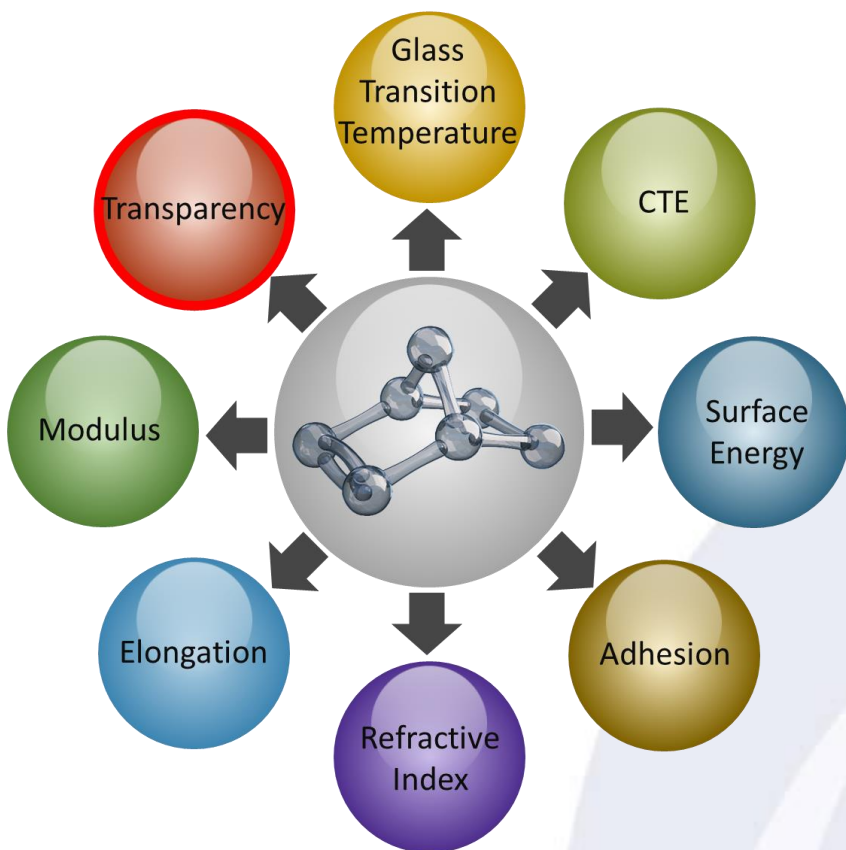


Polymer	T _g
Polynorbornene	100-330°C
Polystyrene	90-110°C
PMMA	85-105°C
Zeonex®	69-163°C
Topas®	70-180°C

Additional Information

- Rigid polycyclic backbone yields high T_g
- Other polycyclic olefins lose chain rigidity when flexible co-monomers or ring-opening is employed

Transparency is high across broad spectrum

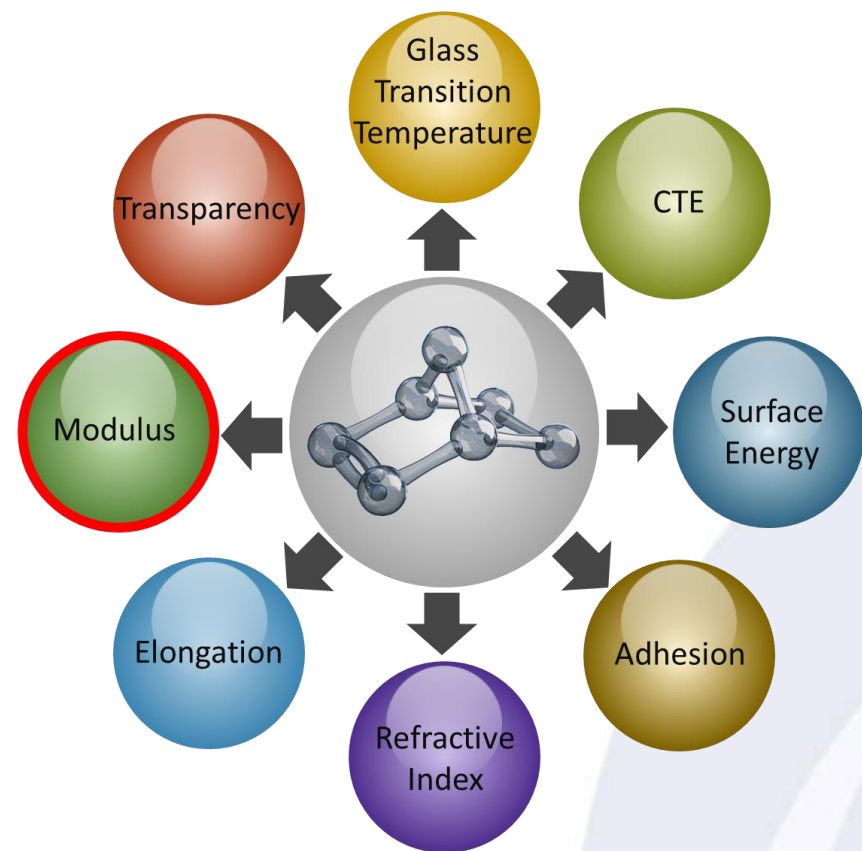


Polymer	Visible transparency
Polynorbornene	>92%
Polystyrene	90%
PMMA	>92%
Zeonex [®]	>92%
Topas [®]	>92%

Additional Information

- PNB can be transparent at 157, 193, 365, 405, 436, 1080 and 1550 nm

Modulus can be high (FG = H) or low (FG = Alkyl)

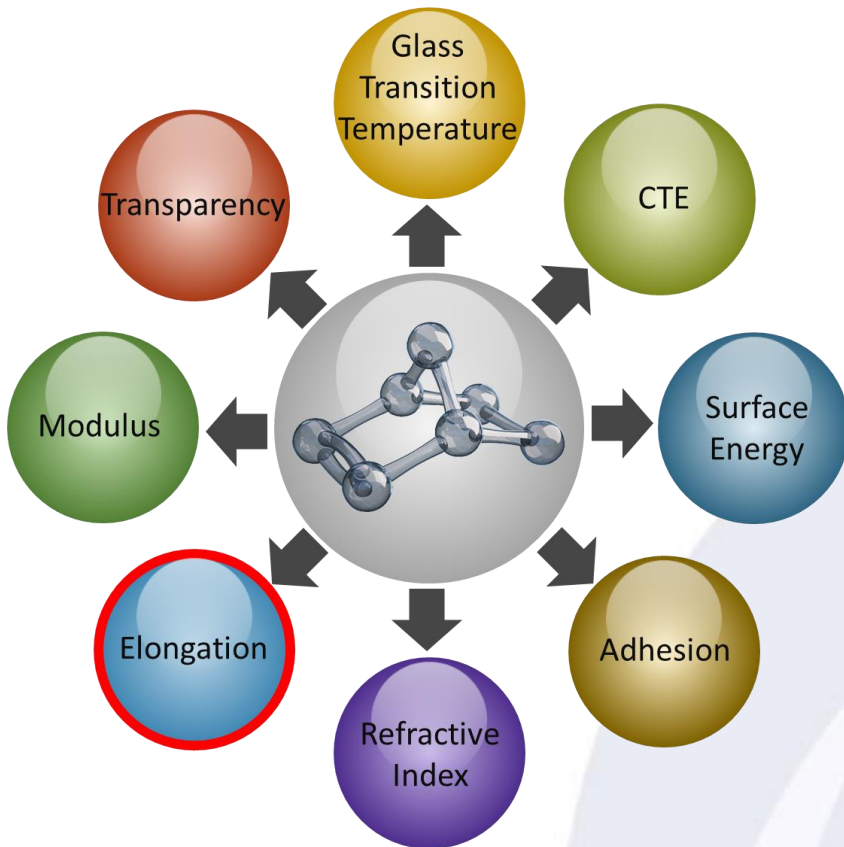


Polymer	Typical
Polynorbornene	0.5 to 3.5 GPa
Polystyrene	3 to 3.5 GPa
PMMA	2.2 to 3.8 GPa
Zeonex®	1.8 to 2.4 GPa
Topas®	2.6 to 3.2 GPa

Additional Information

- Lower modulus give lower wafer stress
- Lower modulus gives stress compliant layers

Elongation at break can be low (FG = H) or high (FG = Alkyl)

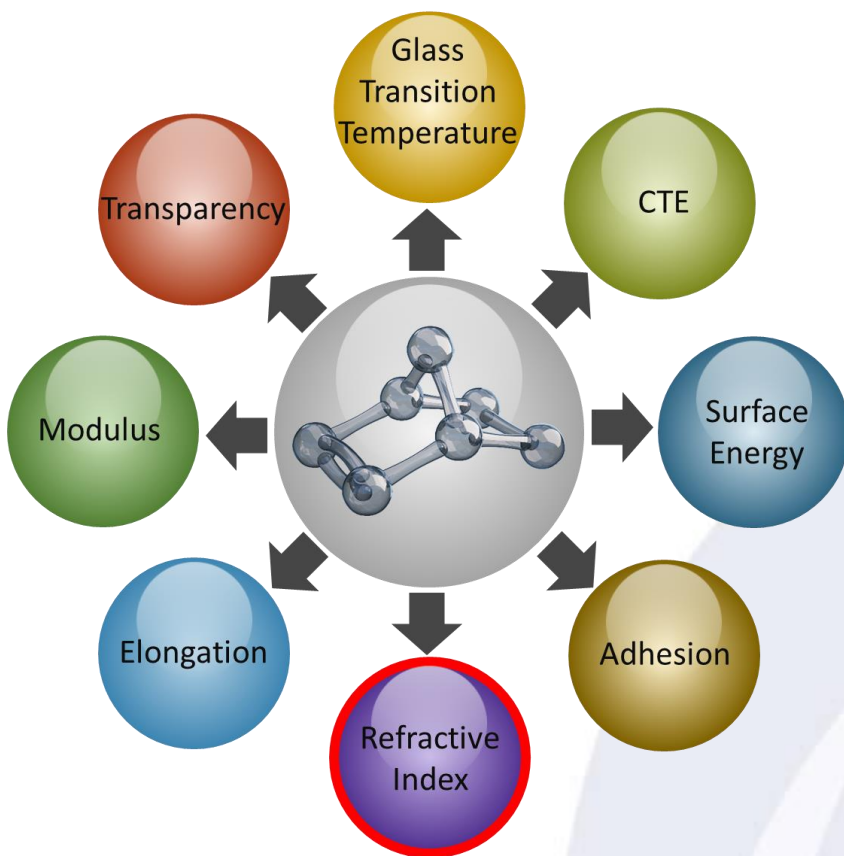


Polymer	Typical
Polynorbornene	5 to 100%
Polystyrene	7%
PMMA	~3%
Zeonex [®]	10-120% (inversely proportional with Tg)
Topas [®]	<10% (biaxially oriented films are higher)

Additional Information

- Crosslinked PNB can retain high elongation at break

Refractive index range is broad for PNB

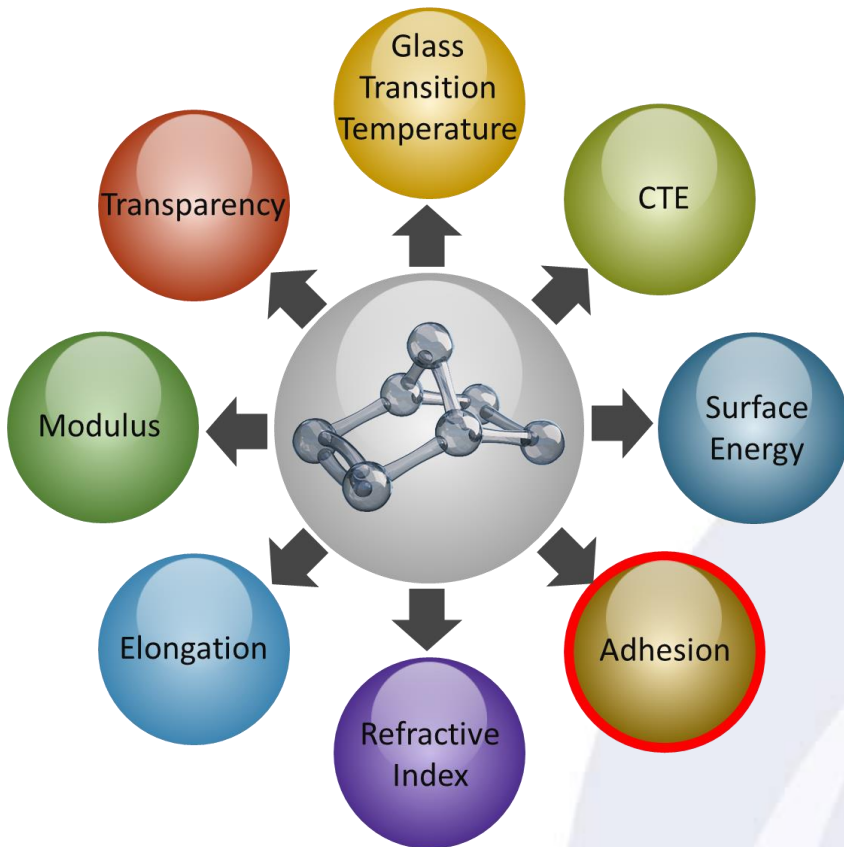


Polymer	Typical (589 nm)
Polynorbornene	1.49 to 1.64+
Polystyrene	1.59
PMMA	1.49
Zeonex [®]	1.51 to 1.53
Topas [®]	1.53

Additional Information

- Refractive index can be high for all C,H polymer (no hetero-atoms)
- Refractive index can be raised by addition of fillers

Adhesion is obtained by formulation

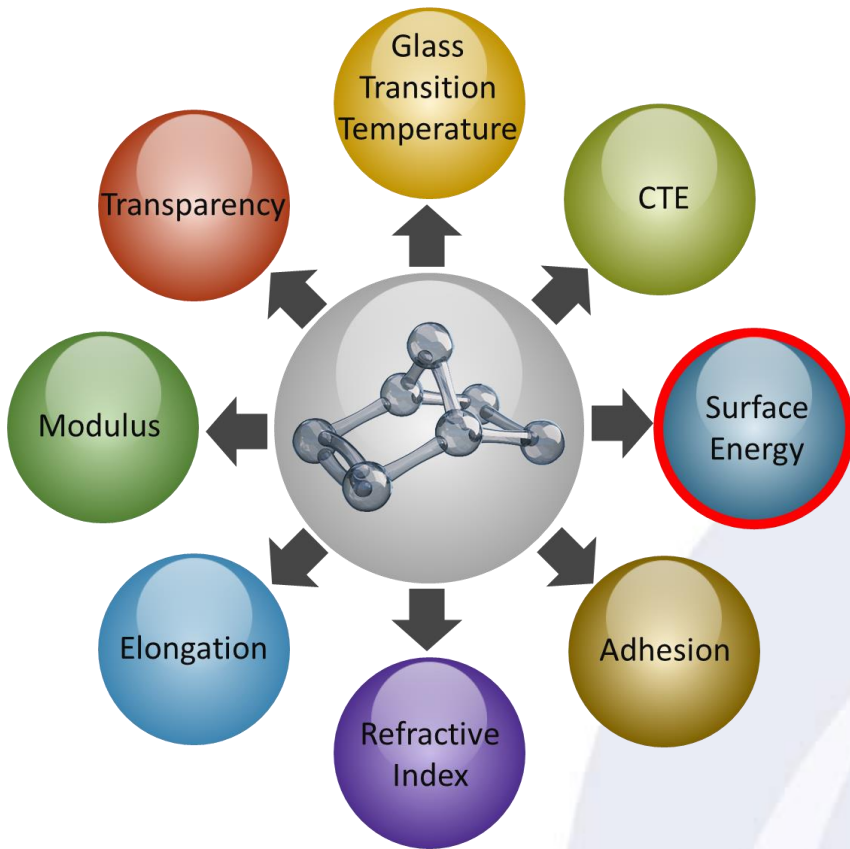


Polymer	Typical
Polynorbornene	SiO ₂ , Si ₃ N ₄ , Cu, Au, Ti, Al, etc
Polystyrene	Unlikely to adhere to substrates above
PMMA	
Zeonex [®]	
Topas [®]	

Additional Information

- Die shear >5 MPa after thermal compression
- Solvent-less polymerization system >10 MPa to silicon

Surface energy can be tailored

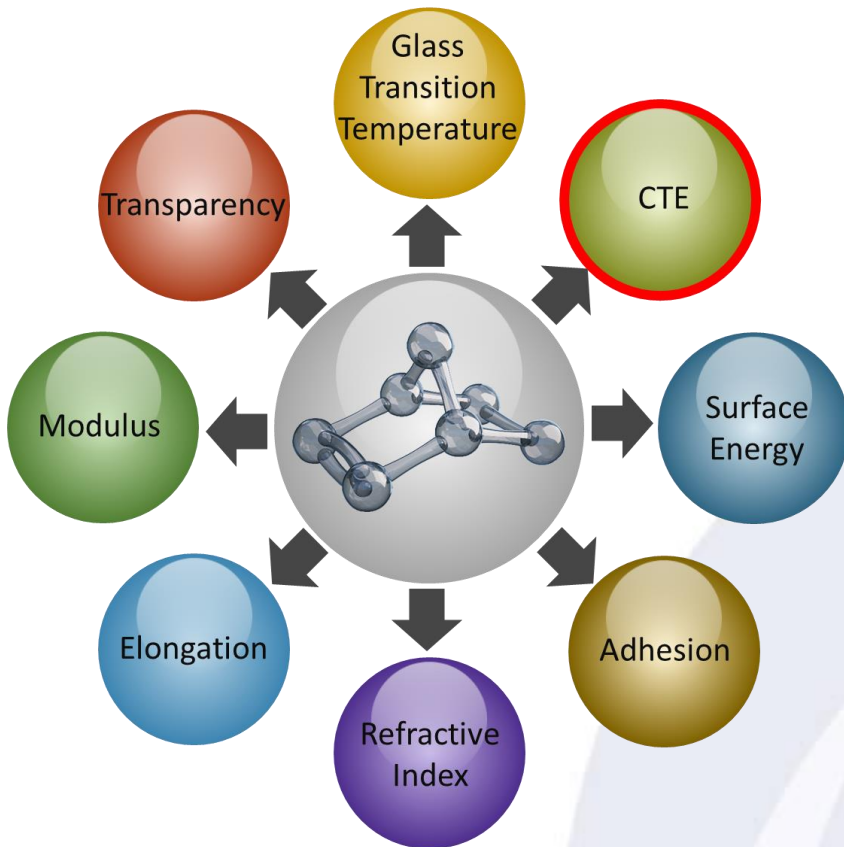


Polymer	Typical (H ₂ O contact angle)
Polynorbornene	40° to 109°
Polystyrene	87°
PMMA	71°
Zeonex [®]	>100°
Topas [®]	>100°

Additional Information

- Surface energy can be tailored to produce hydrophobic films that are soluble in aqueous base.

Coefficient of Thermal Expansion (CTE) can be low (FG = H) or high (FG = Alkyl)



Polymer	Typical
Polynorbornene	~50 to >200 ppm/°C
Polystyrene	70 ppm/°C
PMMA	70-77 ppm/°C
Zeonex [®]	60-70 ppm/°C
Topas [®]	60-70 ppm/°C

Additional Information

- CTE depends on crosslink density

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