


# PN polynorbornene

PARAMETER	UNIT	VALUE	REFERENCES
<b>GENERAL</b>			
Common name	-	polynorbornene, poly(1,3-cyclopentylenevinylene)	
CAS name	-	bicyclo[2.2.1]hept-2-ene, homopolymer	
Acronym	-	PN	
CAS number	-	25038-76-0	
<b>HISTORY</b>			
Person to discover	-	Rinehart, R E	Rinehart, R E, US Patent 3,367,924, Uniroyal, Feb. 6, 1968.
Date	-	1968	
Details	-	emulsion polymerization of norbornenes in the presence of ruthenium or iridium catalysts	
<b>SYNTHESIS</b>			
Monomer(s) structure	-		
Monomer(s) CAS number(s)	-	498-66-8	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	94.15	
Monomer ratio	-	100%	
Formulation example	g	DI water – 95; norbornene – 5; acetone – 0.5; Na dodecyl sulfate – 0.25; catalyst – 0.0032; activator – 0.0056; THF – 1	Crosbie, D; Stubbs, J; Sundberg, D, <i>Macromolecules</i> , 40, 5743-49, 2007.
Method of synthesis	-	ring opening polymerization of norbornene	
Temperature of polymerization	°C	60	
Catalyst	-	$\beta$ -diketonate titanium, methylaluminumoxane, ruthenium chloride, palladium compound	Casares, J A; Espinet, P; Salas, G, <i>Organometallics</i> , 27, 3761-69, 2008.
Heat of polymerization	J g <sup>-1</sup>	652-690	Lebedev, B V; Smirnova, N; Kiparisova, Y, <i>Makromol. Chem.</i> , 193, 1399, 1992.
Mass average molecular weight, M <sub>w</sub>	dalton, g/mol, amu	2,000,000-3,000,000	
Van der Waals volume	cm <sup>3</sup> mol <sup>-1</sup>	calc.=108; exp.=150	
<b>STRUCTURE</b>			
Crystallinity	%	amorphous; only crystallizes when <i>cis</i> is predominant	
Cell type (lattice)	-	monoclinic	
Cell dimensions	nm	a:b:c=4.64-5.13:4.22-4.78:9.84:11.56	
Unit cell angles	degree	$\gamma$ =68.1-73.5	
Tacticity	%	75-81 ( <i>trans</i> )	
Chain conformation	-	helix	Karafilidis, C; angermund, K; Gabor, B; Rufinska, A; Mynott, R J; Breitenbruch, G; Thiel, W; Fink, G, <i>Angew. Chem. Int. Ed.</i> , 46, 3745-49, 2007.
Entanglement molecular weight	dalton, g/mol, amu	41,000	

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<b>COMMERCIAL POLYMERS</b>			
Some manufacturers	-	Astrotech	
Trade names	-	Norsorex	
<b>PHYSICAL PROPERTIES</b>			
Density at 20°C	g cm <sup>-3</sup>	0.94-0.96	
Color	-	white	
Refractive index, 20°C	-	1.534	
Odor	-	characteristic	
Decomposition temperature	°C	456 ( <i>trans</i> ), 466 ( <i>cis</i> )	
Thermal expansion coefficient, 23-80°C	10 <sup>-4</sup> °C <sup>-1</sup>	0.6	
Glass transition temperature	°C	35-45; 37 ( <i>trans</i> )	
Long term service temperature	°C	-40 to 80	
Dielectric constant at 100 Hz/1 MHz	-	2.6	
Dielectric loss factor at 1 kHz	-	0.0007	
<b>MECHANICAL &amp; RHEOLOGICAL PROPERTIES</b>			
Tensile strength	MPa	50-60	
Tensile modulus	MPa	1,400	
Elongation	%	10-20	
Shore A hardness	-	18-80	
Intrinsic viscosity, 30°C	dl g <sup>-1</sup>	3.4-5.0	
Water absorption, equilibrium in water at 23°C	%	0.1	
<b>CHEMICAL RESISTANCE</b>			
Acid dilute/concentrated	-	poor	
Alcohols	-	poor	
Alkalis	-	poor	
Aliphatic hydrocarbons	-	poor	
Aromatic hydrocarbons	-	poor	
Esters	-	poor	
Greases & oils	-	poor	
<b>FLAMMABILITY</b>			
Heat release	kW m <sup>-2</sup>	3,300	Mizuno, K; Ueno, T; Hirata, A; Ishikawa, T; Takeda, K; Polym. Deg. Stab., 92, 2257-63, 2007.
Char at 500°C	%	6	
Heat of combustion	J g <sup>-1</sup>	35,400	Mizuno, K; Ueno, T; Hirata, A; Ishikawa, T; Takeda, K; Polym. Deg. Stab., 92, 2257-63, 2007.
Volatile products of combustion	-	CO, CO <sub>2</sub> , more in ref.	Mizuno, K; Ueno, T; Hirata, A; Ishikawa, T; Takeda, K; Polym. Deg. Stab., 92, 2257-63, 2007.

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<b>WEATHER STABILITY</b>			
<b>Important initiators and accelerators</b>	-	singlet oxygen	Wu, S K; Lucki, J; Rabek, J F; Ranby, B, Polym. Photochem., 2, 125-32, 1982.
<b>Products of degradation</b>	-	alkoxy and hydroxy radicals, hydrogen abstraction, formation of carbonyls, and hydroxyl groups	
<b>TOXICITY</b>			
<b>Carcinogenic effect</b>	-	not listed by ACGIH, NIOSH, NTP	
<b>PROCESSING</b>			
<b>Additives used in final products</b>	-	Activators (zinc oxide, stearic acid), Crosslinkers (sulfur); Plasticizers (DOP, DIDP, DIDA, DOZ, DOA, DOS, DTDA); Process aids (stearic acid)	
<b>Applications</b>	-	bumpers, door sealing, electronic equipment, grip improvement, oil cleaning, rail, shoe parts, ski parts, tires, transmission belts, transport rolls	
<b>Outstanding properties</b>	-	high friction, high glass transition temperature, optical clarity, vibration dumping	
<b>BLENDS</b>			
<b>Suitable polymers</b>	-	NBR, PO, PVC	
<b>ANALYSIS</b>			
<b>FTIR (wavenumber-assignment)</b>	cm <sup>-1</sup> /-	OOH – 3450	Wu, S K; Lucki, J; Rabek, J F; Ranby, B, Polym. Photochem., 2, 125-32, 1982.