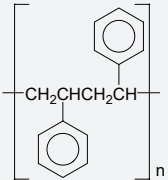
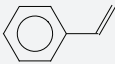


# PS, syndio syndiotactic-polystyrene

PARAMETER	UNIT	VALUE	REFERENCES
<b>GENERAL</b>			
Common name	-	syndiotactic polystyrene	
IUPAC name	-	poly(1-phenylethane-1,2-diyl)	
CAS name	-	benzene, ethenyl-, homopolymer, syndiotactic	
Acronym	-	s-PS	
CAS number	-	28325-75-9	
Formula			
<b>HISTORY</b>			
Person to discover	-	Ishihara, N; Kuramoto, M; Uoi, M (Idemitsu)	JP Patent, 62 187 708, 1985.
Date	-	1985	
Details	-	polymerization in the presence of titanium complex/methylaluminum catalyst	
<b>SYNTHESIS</b>			
Monomer(s) structure	-		
Monomer(s) CAS number(s)	-	100-42-5	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	104.15	
Monomer ratio	-	100%	
Method of synthesis	-	reactor is charged with toluene, triisobutylaluminum, methylaluminum, and styrene and then catalyst	Huang, C-L; Wang, C; Hsiao, T-J; Tsai, J-C, Polym. Mat. Sci. Eng., 101, 1618-20, 2009; Schellenberg, J; Leder, H-J, Adv. Polym. Technol., 25, 3, 141-51, 2006.
Temperature of polymerization	°C	25	
Time of polymerization	h	24	
Catalyst	-	CpTiCl <sub>3</sub> , methylalumoxane	Perrin, L; Kirillov, E; Carpentier, J-F; Maron, L, Macromolecules, 43, 6330-36, 2010.
Number average molecular weight, M <sub>n</sub>	dalton, g/mol, amu	69,000-139,000	
Mass average molecular weight, M <sub>w</sub>	dalton, g/mol, amu	13,000-560,000	
Polydispersity, M <sub>w</sub> /M <sub>n</sub>	-	1.8-6.2	
<b>STRUCTURE</b>			
Crystallinity	%	40-55; 20-35 (isotactic)	
Cell type (lattice)	-	monoclinic (δ), hexagonal (α), orthorhombic (β, ε)	
Cell dimensions	nm	a:b:c=1.75:1.18:0.78 (monoclinic); 0.263:0.263:0.51 (hexagonal); a:b:c=1.62:2.20:0.79 (orthorhombic)	Figuroa-Gerstenmaier, S; Daniel, C; Milano, G; Vitillo, J G; Zavorotynska, O; Spoto, G; Guerra, Macromolecules, 43, 8594-8601, 2010.
Unit cell angles	degree	γ=97 (monoclinic)	

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PARAMETER	UNIT	VALUE	REFERENCES
Number of chains per unit cell	-	4 (orthorhombic)	
Polymorphs	-	$\alpha$ , $\beta$ , $\gamma$ , $\delta$ , $\varepsilon$	Tarallo, O; Petraccone, V; Albonia, A R; Daniel, C; Guerra, G, <i>Macromolecules</i> , 43, 8549-58, 2010.
Tacticity	%	98-99 (syndiotactic; metallocene)	Saga, S; Matsumoto, H; Saito, K; Minagawa, M; Tanioka, A, <i>J. Power Source</i> , 176, 16-22, 2008.
Chain conformation	-	<i>trans</i> -planar ( $\alpha$ and $\beta$ ); helical $s(2/1)_2$ ( $\gamma$ , $\delta$ , $\varepsilon$ ); helical (TTGG) in solution and all <i>trans</i> (TTTT) in melt	Tarallo, O; Petraccone, V; Albonia, A R; Daniel, C; Guerra, G, <i>Macromolecules</i> , 43, 8549-58, 2010.
Rapid crystallization temperature	°C	210-260	Sorrentino, A; Pantani, R; Titomanlio, G, <i>J. Polym. Sci. B</i> , 48, 1757-66, 2010.
Avrami constants, k/n	-	n=3.03-3.49; 1.3-1.7 (commercial sPS)	Benson, S D; Moore, R B, <i>Polymer</i> , 51, 5462-72, 2010; Chen, C-M; Hsieh, T-E; Ju, M-Y, <i>J. Alloys compounds</i> , 480, 658-61, 2009.
<b>COMMERCIAL POLYMERS</b>			
Some manufacturers	-	Dow; Idemitsu	
Trade names	-	Questra; Xarec	
<b>PHYSICAL PROPERTIES</b>			
Density at 20°C	g cm <sup>-3</sup>	1.01-1.05	
Melting temperature, DSC	°C	265-284	
Thermal expansion coefficient, 23-80°C	°C <sup>-1</sup>	9.2E-5	
Glass transition temperature	°C	86-102	Chen, C-M; Hsieh, T-E; Ju, M-Y, <i>J. Alloys Compounds</i> , 480, 658-61, 2009.
Heat of fusion	kJ mol <sup>-1</sup>	5.8	
Long term service temperature	°C	127	
Heat deflection temperature at 0.45 MPa	°C	110	
Heat deflection temperature at 1.8 MPa	°C	95	
Enthalpy of crystallization	J g <sup>-1</sup>	29	Sorrentino, A; Pantani, R; Titomanlio, G, <i>J. Polym. Sci. B</i> , 48, 1757-66, 2010.
Dielectric constant at 100 Hz/1 MHz	-	-2.6	
Dielectric loss factor at 1 kHz	-	0.001	
Dissipation factor at 1 MHz	E-4	10	
Volume resistivity	ohm-m	>E14	
Electric strength K20/P50, d=0.60.8 mm	kV mm <sup>-1</sup>	66	
Comparative tracking index, CTI, test liquid A	V	600	
Arc resistance	s	91	

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PARAMETER	UNIT	VALUE	REFERENCES
<b>MECHANICAL &amp; RHEOLOGICAL PROPERTIES</b>			
Tensile strength	MPa	68	
Tensile modulus	MPa	2,400	D'Aniello, C; Rizzo, P; Guerra, G, Polymer, 46, 11435-41, 2005.
Tensile stress at yield	MPa	35	
Tensile yield strain	%	20	
Flexural strength	MPa	65	
Flexural modulus	MPa	2,500	
Rockwell hardness	-	L60	
Shrinkage	%	1.7	
Melt index, 230°C/3.8 kg	g/10 min	2.5-11.1	
Water absorption, 24h at 23°C	%	0.04	
<b>CHEMICAL RESISTANCE</b>			
Acid dilute/concentrated	-	very good/poor	
Alcohols	-	good	
Alkalis	-	good	
Aliphatic hydrocarbons	-	poor	
Aromatic hydrocarbons	-	poor	
Esters	-	poor	
Greases & oils	-	poor	
Halogenated hydrocarbons	-	poor	
Ketones	-	poor	
Other	-	toluene, perchloroethylene, carbon tetrachloride, carbon disulfide, MEK, dioxane, cyclohexanone, ethyl acetate	
⊖ solvents	-	benzene, i-butyl acetate, cyclohexane, methyl acetate	
Good solvent	-	n-tetradecane/decahydronaphthalene=2/1, trichlorobenzene	
Non-solvent	-	methyl ethyl ketone and methanol at boiling temperatures	
<b>FLAMMABILITY</b>			
Flammability according to UL-94 standard; thickness 1.6/0.8 mm	class	HB	
Ignition temperature	°C	296	
Autoignition temperature	°C	490	
Limiting oxygen index	% O <sub>2</sub>	17.8-18.1	
Minimum ignition energy	J	0.04	
Heat release	kW m <sup>-2</sup>	734 (HIPS without flame retardant); 283-378 (HIPS with flame retardants)	
NBS smoke chamber	-	470	
Char at 500°C	%	0	Lyon, R E; Walters, R N, J. Anal. Appl. Pyrolysis, 71, 27-46, 2004.
Heat of combustion	J g <sup>-1</sup>	43,650	
Volatile products of combustion	-	styrene, oligomers, organic acids, Alcohols, aldehydes, ketones, CO, CO <sub>2</sub>	
CO yield	%	8-13 (HIPS with flame retardants)	

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PARAMETER	UNIT	VALUE	REFERENCES
<b>WEATHER STABILITY</b>			
Spectral sensitivity	nm	290	
<b>PROCESSING</b>			
Typical processing methods	-	extrusion, injection molding, reaction injection molding, thermoforming	
Preprocess drying: temperature/time/residual moisture	°C/h/%	80/2-5/	
Processing temperature	°C	315-335 (extrusion, melt temperature)	
Outstanding properties	-	high melt temperature, high crystallinity, rapid crystallization rate	
<b>BLENDS</b>			
Suitable polymers	-	epoxy, EPR, HDPE, PA6, PC, POM, PPO, PPS, aPS, iPS, SEBS	
<b>ANALYSIS</b>			
FTIR (wavenumber-assignment)	cm <sup>-1</sup> /-	amorphous phase – 841; $\alpha$ crystal – 851; $\beta$ crystal – 858	Wu, S-C; Chang, F-C, Polymer, 45, 733-38, 2004.
Raman (wavenumber-assignment)	cm <sup>-1</sup> /-	<i>trans</i> -planar chains – 2917, 2845; TTGG conformation – 2850	Zheng, K; Liu, R; Kang, H; Gao, X; Shen, D; Huang, Y, Polymer, in press, 2011.
x-ray diffraction peaks	degree	6.7, 11.7, 12.3, 21.0	Wang, C; Lin, C-C; Chu, C-P, Polymer, 12595-606, 2005.