BMI polybismaleimide

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	polybismaleimide	
IUPAC name	-	poly[N,N'-(1,4-phenylene)dimaleimide]	
CAS name	-	[1,1'-bi-1H-pyrrole]-2,2',5,5'-tetrone, homopolymer	
Acronym	-	BMI	
CAS number	-	62238-79-3, 26140-67-0	
SYNTHESIS			
Monomer(s) structure	-	$C_2H_2(CO)_2O$; diamine	
Monomer(s) CAS number(s)	-	108-31-6; large number of amines used	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	98.06; from 100 to over 500	
Method of synthesis	-	maleic anhydride and diamines are reacted in the presence of catalyst such as triethylamine, these are further cured to form crosslinked polymers. Thermal curing is promoted by the presence of radical or ionic initiators. BMI can also be synthesized by Diels-Alder reaction (see ref.)	Jiang, B; Hao, J; Wang, W; Jiang, L; Cai, X, Eur. Polym. J., 37, 463-70, 2001.
Temperature of polymerization	^oC	225-290	
Time of polymerization	h	0.5	
Catalyst	-	triethylamine	
Yield	%	93-97 (Diels-Alder)	
Activation energy of polymerization	kJ mol^{-1}	87.8-111.9	
COMMERCIAL POLYMERS			
Some manufacturers	-	Hexcel, Huntsman; Neopreg	
Trade names	-	HexPly, Kerimid; Kinel	
PHYSICAL PROPERTIES			
Density at 20^{o}C	g cm^{-3}	1.25-1.27	
Melting temperature, DSC	^oC	90-360; 166-202 (naphthalene-containing)	
Storage temperature	^oC	<0	
Shelf life	month	12 (at -18^{o}C); 6 (at 4^{o}C)	
Decomposition temperature	^oC	400-430	
Thermal expansion coefficient, 23-80^{o}C	$^oC^{-1}$	4.9-5.2E-5	
Glass transition temperature	^oC	316-380; 225-232 (wet); 291-334 (naphthalene-containig)	Wang, C-S; Hwang, H-J, J. Appl. Polym. Sci., 60, 857-63, 1996.
Maximum service temperature	^oC	232 (short term); 316 (structural integrity)	
Long term service temperature	^oC	-75 to 204	
High temperature stability (special grades)		400-430	Kumar, D; Kaur, J, J. Macromol. Sci., Part A: Pure Appl. Chem., 29, 11, 267-275, 1992.
Dielectric constant at 100 Hz/1 MHz	-	3.09/3.4-3.7; 3.31 (47% glass fiber)	
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile strength	MPa	50-90; 418.5 (53% glass fiber); 744 (carbon fabric)	
Tensile modulus	MPa	3,500-4,500; 25,500 (53% glass fiber); 56,300 (carbon fabric)	

PARAMETER	UNIT	VALUE	REFERENCES
Elongation	%	3	
Flexural strength	MPa	637.8 (53% glass fiber); 917 (60% carbon fabric)	
Flexural modulus	MPa	31,100; 56,800 (carbon fabric)	
Compressive strength	MPa	480.6 (53% glass fiber); 889 (carbon fabric)	
Fracture toughness	MPa m(1/2)	0.46-0.97	
Strain energy release rate, G1C	kJ m-2	0.067	
Shear strength	MPa	96.5 (carbon fiber); 120 (carbon fabric)	
Shrinkage	%	0.007 (cure)	
Water absorption, equilibrium in water at 23°C	%	3.8-4.4	
Moisture absorption, equilibrium 23°C/50% RH	%	4.3	
CHEMICAL RESISTANCE			
Alcohols	-	poor	
Aromatic hydrocarbons	-	good	
Esters	-	poor	
Halogenated hydrocarbons	-	poor	
Ketones	-	poor	
Good solvent	-	methylethylketone, methylisobutylketone, dichloromethane, chloroform, tetrahydrofuran, acetone, methanol, ethanol, and hot toluene	
Non-solvent	-	DMAC, DMSO, chloroform	
FLAMMABILITY			
NBS smoke chamber	mg m^{-3}	0.025	
Burning rate (Flame spread index)		10	
Toxicity of smoke	HCN (ppm)	5-10	
Char at 500°C	%	7.6-18.5 (air); 43-71 (nitrogen); 43-44 (700°C)	Liu, Y-L; Chen, Y-J, Polymer, 45, 1797-1804, 2004; Surender, R; Mahendran, A; Than araichelvan, A; Alam, S; Vijayakumar, C T, Thermochim. Acta, 562, 11-21, 2013.
TOXICITY			
Oral rat, LD_{50}	mg kg^{-1}	>2,000	
Skin rabbit, LD_{50}	mg kg^{-1}	>5,400	
PROCESSING			
Typical processing methods	-	curing by free radical mechanism, prepreg preparation	
Processing temperature	°C	177-191; post cure at 232-246	
Processing pressure	kPa	586 (vacuum)	
Process time	h	6-4; post-cure time: 8	
Applications	-	prepreg systems used in civil and military aircrafts, electrical boards, adhesives	
Outstanding properties	-	dimensional stability at high temperatures, high service temperature, low thermal conductivity	

PARAMETER	UNIT	VALUE	REFERENCES
BLENDS			
Suitable polymers	-	PEI, PEEK, PES, silicone	
ANALYSIS			
FTIR (wavenumber-assignment)	cm^{-1}/-	C=O´1775-1780, 1710-1720; C-N-C´1390-1400; C=C 680-690	Wang, C-S; Hwang, H-J, J. Appl. Polym. Sci., 60, 857-63, 1996.