EVAC ethylene-vinyl acetate copolymer

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	ethylene-vinyl acetate copolymer	
ACS name	-	acetic acid ethenyl ester, polymer with ethene	
Acronym	-	EVAC	
CAS number	-	9003-20-7; 24937-78-8	
EC number	-	203-545-4	
RTECS number	-	AK0920000	
SYNTHESIS			
Monomer(s) structure	-	$CH_3COOCH=CH_2$; $CH_2=CH_2$	
Monomer(s) CAS number(s)	-	108-05-4; 74-85-1	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	86.09; 28.05	
Vinyl acetate content	wt%	3-32 (packaging resins); 9-40 (industrial resins)	
Method of synthesis	-	both monomers are polymerized in the presence of initiator (details in ref.)	Lee, H-Y; Yang, T-H; Chien, I-L; Huang, H-P, Computers Chem. Eng., 33, 1371-78, 2009.
Temperature of polymerization	^oC	164-187	
Catalyst	-	Ziegler-Natta, metallocene	
Number average molecular weight, M_n	dalton, g/mol, amu	16,000-42,000	McAlduff, M; Reven, L, Macromolecules, 38, 3745-53, 2005; Martin-Alfonso, J E; Franco, J M, Polym. Testing, 37, 78-85, 2014.
Mass average molecular weight, M_w	dalton, g/mol, amu	35,200-210,000	Martin-Alfonso, J E; Franco, J M, Polym. Testing, 37, 78-85, 2014.
Polydispersity, M_w/M_n	-	2.03-6	McAlduff, M; Reven, L, Macromolecules, 38, 3745-53, 2005.
STRUCTURE			
Crystallinity	%	5.9-60	Shi, X M; Zhang, J; Jin, J; Chen, S J, eXPRESS Polym. Lett., 2, 89, 623-29, 2008; Jin, J; Chen, S; Zhang, J, Polym. Deg. Stab., 95, 725-32, 2010; Martin-Alfonso, J E; Franco, J M, Polym. Testing, 37, 78-85, 2014.
Crystallite size	nm	9.1 (L_{110}); 4.8 (L_{200})	Chen, Y; Zou, H; Liang, M; Cao, Y, Thermochim Acta, 586, 1-8, 2014.
Crystallization rate coefficent	min^{-1}	1.957	Chen, Y; Zou, H; Liang, M; Cao, Y, Thermochim Acta, 586, 1-8, 2014.
Rapid crystallization temperature	^oC	52-76	
COMMERCIAL POLYMERS			
Some manufacturers	-	DuPont; Exxon; LyondellBasel	
Trade names	-	Elvax; Escorene; Ultrathene	
PHYSICAL PROPERTIES			
Density at 20^{o}C	g cm^{-3}	0.92-0.98	
Color	-	colorless to white	
Refractive index, 20^{o}C	-	1.467-1.498	
Haze	%	0.7-20	
Gloss, 60^o, Gardner (ASTM D523)	%	34-100	

EVAC ethylene-vinyl acetate copolymer

PARAMETER	UNIT	VALUE	REFERENCES
Odor	-	mild, ester-like	
Melting temperature, DSC	^oC	58-112	
Decomposition temperature	^oC	221-240	
Fusion enthalpy	J g^{-1}	16.9-78.4	Martin-Alfonso, J E; Franco, J M, Polym. Testing, 37, 78-85, 2014.
Thermal expansion coefficient, 23-80^oC	$^oC^{-1}$	1.6-2.5E-4	
Thermal conductivity, melt	W m^{-1} K^{-1}	0.311-0.324; 0.26 (tubes)	Ghose, S; Watson, K A; Working, D C; Smith, J G; Lin, Y; Sun, Y-P, Polymers in Defence and Aerospace 2007, Rapra, 2007, paper 5.
Glass transition temperature	^oC	-38 to -42	
Maximum service temperature	^oC	<230	
Long term service temperature	^oC	<204	
Vicat temperature VST/A/50	^oC	36-86	
Hildebrand solubility parameter	$MPa^{0.5}$	17.0-19.2	
Volume resistivity	ohm-m	9.3E13	
Speed of sound	m s^{-1}	28-30	
Acoustic impedance		1.60-1.69	
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile strength	MPa	2-41	Ghose, S; Watson, K A; Working, D C; Smith, J G; Lin, Y; Sun, Y-P, Polymers in Defence and Aerospace 2007, Rapra, 2007, paper 5.
Tensile modulus	MPa	10	Ghose, S; Watson, K A; Working, D C; Smith, J G; Lin, Y; Sun, Y-P, Polymers in Defence and Aerospace 2007, Rapra, 2007, paper 5.
Tensile stress at yield	MPa	4.6-7.4	
Elongation	%	300-860	Ghose, S; Watson, K A; Working, D C; Smith, J G; Lin, Y; Sun, Y-P, Polymers in Defence and Aerospace 2007, Rapra, 2007, paper 5.
Tensile yield strain	%	9-150	
Flexural modulus	MPa	28-121	
Elastic modulus	MPa	164-188	
Charpy impact strength, unnotched, 23^oC	kJ m^{-2}	NB	
Izod impact strength, notched, 23^oC	J m^{-1}	NB	
Elmendorf tear strength	g/10 min	80-260 (MD); 60-330 (TD)	
Dart drop impact	g/10 min	100-660	
Adhesive bond strength	MPa	1.5 (Al)	
Compression set	%	23 (23^oC/24 h); 66 (50^oC/6 h)	
Shore A hardness	-	65-96	
Shore D hardness	-	15-43	
Brittleness temperature (ASTM D746)	^oC	-70 to -85	
Melt viscosity, shear rate=92.5 s^{-1}	Pa s	1,000-2,800	Ghose, S; Watson, K A; Working, D C; Smith, J G; Lin, Y; Sun, Y-P, Polymers in Defence and Aerospace 2007, Rapra, 2007, paper 5.

EVAC ethylene-vinyl acetate copolymer

PARAMETER	UNIT	VALUE	REFERENCES
Melt index, 190°C/2.16 kg	g/10 min	0.35-800	Dhamdhere, M; Deshpande, B; Patil, P; Hansen, M G, Antec, 2000.
Water absorption, equilibrium in water at 23°C	%	0.005-0.13	
CHEMICAL RESISTANCE			
Acid dilute/concentrated	-	poor	
Alcohols	-	good	
Alkalis	-	poor	
Aliphatic hydrocarbons	-	poor	
Aromatic hydrocarbons	-	poor	
Halogenated hydrocarbons	-	poor	
Ketones	-	poor	
Good solvent	-	toluene, THF, MEK	
FLAMMABILITY			
Ignition temperature	°C	260	
Autoignition temperature	°C	343-426	
Limiting oxygen index	% O_2	23	Chang, M-K; Hwang, S-S; Liu, S-P, J. Ind. Eng. Chem., 20, 1596-1601, 2014.
Heat release	kW m^{-2}	1680; 810	Nyambo, C; Kandare, E; Wilkie, C A, Polym. Deg. Stab., 94, 513-20, 2009; Cavodeau, F; Sonnier, R; Otazaghine, B; Lopez-Cuesta, J-M; Delaite, C, Polym. Deg. Stab., 120, 23-31, 2015.
Total heat release	kJ g^{-1}	23.62	Cavodeau, F; Sonnier, R; Otazaghine, B; Lopez-Cuesta, J-M; Delaite, C, Polym. Deg. Stab., 120, 23-31, 2015.
Volatile products of combustion	-	CO_2, H_2O, acetic acid, vinyl acetate, CO, aldehydes, acrolein, alcohols, oxides of nitrogen	Hull, T R; Quinn, R E; Areri, I G; Purser, D A, Polym. Deg. Stab., 77, 235-42, 2002.
WEATHER STABILITY			
Spectral sensitivity	nm	285, 335	Pern, F J, Solar Energy Mater. Solar Cells, 41/42, 587-615, 1996.
Excitation wavelengths	nm	350	Pern, F J, Solar Energy Mater. Solar Cells, 41/42, 587-615, 1996.
Emission wavelengths	nm	420	
Important initiators and accelerators	-	thermal processing	
Products of degradation	-	hydroperoxides, hydroxyl groups, polyene sequences, aldehyde, acetic acid	

EVAC ethylene-vinyl acetate copolymer

PARAMETER	UNIT	VALUE	REFERENCES
Stabilizers	-	UVA: 2-hydroxy-4-octyloxybenzophenone; 2-(2H-benzotriazol-2-yl)-6-dodecyl-4-methylphenol, branched & linear; propanedioic acid, [(4-methoxyphenyl)-methylene]-dimethyl ester; HAS: 1,3,5-triazine-2,4,6-triamine, N,N'''[1,2-ethanediyl-bis[[[4,6-bis[butyl(1,2,6,6-pentamethyl-4-piperidinyl)amino]-1,3,5-triazine-2-yl]imino]-3,1-propanediyl]bis[N',N''-dibutyl-N',N''-bis(1,2,2,6,6-pentamethyl-4-piperidinyl)-; poly[[(6-[1,1,3,3-tetramethylbutyl)amino]-1,3,5-triazine-2,4-diyl][2,2,6,6-tetramethyl-4-piperidinyl)imino]-1,6-hexanediyl[2,2,6,6-tetramethyl-4-piperidinyl)imino]]; 1,6-hexanediamine- N,N'-bis(2,2,6,6-tetramethyl-4-piperidinyl)-polymer with 2,4,6-trichloro-1,3,5-triazine, reaction products with N-butyl-1-butanamine an N-butyl-2,2,6,6-tetramethyl-4-piperidinamine; butanedioic acid, dimethylester, polymer with 4-hydroxy-2,2,6,6-tetramethyl-1-piperidine ethanol; Phenolic antioxidant: pentaerythritol tetrakis(3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate); Amine: benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene; Optical brightener: 2,2'-(1,2-ethenediyldi-4,1-phenylene)bisbenzoxazole, C.I.F.B. 367	
TOXICITY			
NFPA: Health, Flammability, Reactivity rating	-	0/1/0	
Carcinogenic effect	-	not listed by ACGIH, NIOSH, NTP	
Reproductive toxicity	-	not expected	
OSHA	mg m^{-3}	5 (respirable), 15 (total)	
Oral rat, LD_{50}	mg kg^{-1}	3,080	
Skin rabbit, LD_{50}	mg kg^{-1}	7,940	
PROCESSING			
Typical processing methods	-	Banbury mixer, coextrusion, cold feed extruders, extrusion, injection molding, mixing/compounding, reaction injection molding, two-roll mills	
Processing temperature	^{o}C	150-230	
Processing pressure	MPa	8-10 (injection); <2 (back pressure)	
Additives used in final products	-	Fillers: aluminum hydroxide, calcium carbonate, clay, carbon nanotubes, magnesium hydroxide, montmorillonite, red phosphorus, quartz, silica, wood fiber, zinc oxide, zinc powder; Plasticizers: EVAC is used as plasticizer in PVC and PLA therefore it seldom requires plasticization; Antistatics: 2-methyl-3-propyl benzothiazolium iodide, alkylether triethyl ammonium sulfate, organic amide; Antiblocking: fatty amide, laponite, silica; Release: methylstyryl silicone oil; Slip: erucamide, oleamide, stearamide; Thermal stabilizer: BHT	
Applications	-	asphalt modification, automotive wire, automotive ignition, baby products, cap liners, controlled release devices, encapsulant of photovoltaic cells, footwear, greenhouse film, hot-melt adhesives, hot-melt coatings, low-smoke cable, paints, semiconductor shields, slow burning candles, sporting goods, tubing, wall covering adhesives, wire and cable	
Outstanding properties	-	toughness, clarity, impact strength	
BLENDS			
Suitable polymers	-	HDPE, LDPE, LLDPE, NBR, PA, PBT, PMMA, PP, PPy, PVC	

EVAC ethylene-vinyl acetate copolymer

PARAMETER	UNIT	VALUE	REFERENCES
ANALYSIS			
FTIR (wavenumber-assignment)	cm^{-1}/-	C=O ´ 1715, 1175-1163; C-O-C ´ 1160	Jin, J; Chen, S; Zhang, J, Polym. Deg. Stab., 95, 725-32, 2010.
Raman (wavenumber-assignment)	cm^{-1}/-	O-C=O ´ 629, 630; C=O ´ 1730-1740; C-H ´ 2800, 3000	Deshpande, B J; Dhamdhere, M S; Li, J; Hansen, M G, Antec, 1672-6, 1998.