

Thermosets and Composites

Material Selection, Applications,
Manufacturing and Cost Analysis

Second Edition

Michel Biron

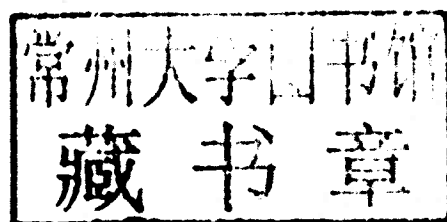


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Acronyms and Abbreviations

<i>5V</i>	UL fire rating	<i>CPE or CM</i>	Chlorinated polyethylene
<i>AAGR</i>	Average annual growth rate	<i>CPVC or PVC-C</i>	Chlorinated PVC
<i>ABS</i>	Acrylonitrile-butadiene-styrene	<i>CS</i>	Compression set
<i>ACM-V</i>	Vulcanized acrylate rubber	<i>CTLE</i>	Coefficient of thermal linear expansion
<i>ACS</i>	Acrylonitrile chlorinated polyethylene styrene	<i>CUT</i>	Continuous use temperature under unstressed state
<i>AES or AEPDS</i>	Acrylonitrile EPDM styrene	<i>Cy</i>	Polycyanate
<i>AMC</i>	Alkyd molding compound	<i>DAP</i>	Diallyl phthalate
<i>ArF or AF</i>	Aramid fiber	<i>DCPD</i>	Poly(dicyclopentadiene)
<i>ASA</i>	Acrylonitrile styrene acrylate	<i>DMC</i>	Dough molding compound
<i>ASTM</i>	American Society for Testing and Materials	<i>DMTA</i>	Dynamic mechanical thermal analysis
<i>ATBC</i>	Acetyltributyl citrate	<i>DRIV</i>	Direct resin injection and venting
<i>ATH</i>	Aluminum trihydrate	<i>DSC</i>	Differential scanning calorimeter
<i>BF</i>	Boron fiber	<i>DTA</i>	Differential thermal analysis
<i>BMC</i>	Bulk molding compound	<i>EB</i>	Elongation at break
<i>BMI</i>	Bismaleimide	<i>EBA, EGMA, EMAH, EEA, EAA</i>	Ethylene-acid and ethylene-ester copolymers, e.g., ethylene-butylacrylate
<i>BOPLA</i>	Bi-axially oriented polylactic acid	<i>ECTFE</i>	Ethylene monochlorotrifluoroethylene
<i>BOPP</i>	Bi-axially oriented Polypropylene	<i>EE, E&E</i>	Electricity & electronics
<i>BRIC</i>	Brazil-Russia-India-China	<i>EMA</i>	Ethylene-methacrylate ionomers
<i>CA</i>	Cellulose acetate	<i>EMI</i>	Electromagnetic interference
<i>CAB</i>	Cellulose acetobutyrate	<i>EP</i>	Epoxy
<i>CAD</i>	Computer Aided Design	<i>EPA</i>	Environmental Protection Agency
<i>CAGR</i>	Compound annual growth rate	<i>EPDM rubber</i>	Terpolymer ethylene, propylene, diene
<i>CBT</i>	Cyclic polybutadiene	<i>EPS</i>	Expandable (or expanded) polystyrene
<i>CE</i>	Cyanate ester	<i>ESBO</i>	Epoxidized soybean oil
<i>CF</i>	Carbon fiber	<i>ESC</i>	Environmental stress cracking
<i>CFC</i>	Chlorofluorocarbon	<i>ESD</i>	Electrostatic discharge
<i>CIC</i>	Continuous impregnated compound	<i>ETFE</i>	Ethylene-tetrafluoroethylene
<i>CM or CPE</i>	Chlorinated polyethylene	<i>EVA, E/VAC,</i>	
<i>CNT</i>	Carbon nanotube	<i>EVAC, VAE, EVM</i>	Ethylene-vinylacetate copolymers
<i>COC or COP</i>	Cyclic olefin copolymers or cyclic olefin polymers		
<i>CONC</i>	Concentrated solution		
<i>COP or COC</i>	Cyclic olefin polymers or cyclic olefin copolymers		
<i>COPE or TPEE</i>	COPolyester TPE		
<i>CP</i>	Cellulose propionate		

<i>EVOH</i>	Ethylene-vinyl alcohol copolymers	<i>LLDPE</i>	Linear low density polyethylene
<i>F-PVC</i>	Flexible PVC	<i>LOI</i>	Limiting oxygen index
<i>FDA</i>	Food and Drug Administration	<i>LRI</i>	Liquid resin infusion
<i>FEP</i>	Fluorinated ethylene propylene	<i>LRTM</i>	Light RTM
<i>FIM</i>	Film insert molding	<i>LSR</i>	Liquid silicone rubber
<i>FR</i>	Fire retardant	<i>LWRT</i>	Lightweight reinforced thermoplastic
<i>GF</i>	Glass fiber	<i>MABS</i>	Methylmethacrylate-acrylonitrile-butadiene-styrene
<i>GFRP</i>	Glass fiber reinforced plastic	<i>MAH</i>	Maleic anhydride
<i>GMT</i>	Glass mat thermoplastic	<i>MBS</i>	Methylmethacrylate butadiene styrene
<i>HB</i>	UL fire rating	<i>MDPE</i>	Medium density polyethylene
<i>HDPE or PE HD</i>	High density polyethylene	<i>MF</i>	Melamine
<i>HDT</i>	Heat deflection temperature	<i>MPR</i>	Melt processable rubber (TPE)
<i>HFRR</i>	Halogen free fire retardant	<i>MVTR</i>	Moisture vapor transmission rate
<i>HIPS</i>	High impact PS	<i>MWNT</i>	Multiwalled carbon nanotubes
<i>HPGF</i>	High-performance short glass fiber reinforced polypropylene	<i>NB</i>	No break
<i>HSCT</i>	High speed civil transport (aircraft)	<i>NVH</i>	Noise vibration harshness
<i>HTPC</i>	Hybrid thermoplastic composite	<i>O&M</i>	Organization & methods department
<i>HTV</i>	High temperature vulcanization	<i>OIT</i>	Oxygen induction time
<i>ICP</i>	Inherently conductive polymer	<i>OPET</i>	Oriented PET
<i>IDP</i>	Inherently dissipative polymer	<i>OPP</i>	Oriented PP
<i>ILSS</i>	Interlaminar shear strength	<i>OPS</i>	Oriented PS
<i>IMC</i>	In-mold coating	<i>OTR</i>	Oxygen transmission rate
<i>IMD</i>	In-mold decoration	<i>PA</i>	Polyamide
<i>IML</i>	In-mold labeling	<i>PA-T</i>	Transparent amorphous polyamide
<i>IPN</i>	Interpenetrating polymer network	<i>PAA</i>	Polyarylamide
<i>IRHD</i>	International rubber hardness	<i>PAI</i>	Polyamideimide
<i>IRM</i>	International referee material	<i>PAEK</i>	Polyaryletherketone
<i>ISO</i>	International Standardization Organization	<i>PAN</i>	Polyacrylonitrile
<i>LCA</i>	Life cycle assessment	<i>PAS</i>	Polyarylsulfone
<i>LCP</i>	Liquid crystal polymer	<i>PB</i>	Polybutene-1 or polybutylene-1
<i>LCTC</i>	Low cost tooling for composites	<i>PBB</i>	Polybrominated biphenyls
<i>LDPE or PE LD</i>	Low density polyethylene	<i>PBDE</i>	Polybrominated diphenyl ethers
<i>LED</i>	Light emitting diode	<i>PBI</i>	Polybenzimidazole
<i>LEFM</i>	Linear elastic fracture mechanics	<i>PBO</i>	Polyphenylenebenzoxazole
<i>LFRT</i>	Long fiber reinforced thermoplastic	<i>PBT or PBTP</i>	Polybutyleneterephthalate
<i>LFT</i>	Long fiber reinforced thermoplastic	<i>PC</i>	Polycarbonate
<i>LGF</i>	Long glass fiber	<i>PCB</i>	Printed circuit board
<i>LIM</i>	Liquid injection molding	<i>PC-HT</i>	Polycarbonate – high temperature
		<i>PCL</i>	Polycaprolactone
		<i>PCT</i>	Polycyclohexylene-dimethylene terephthalate
		<i>PCTA</i>	Terephthalate/isophthalate

<i>PCTFE</i>	Polychlorotrifluoroethylene	<i>POP</i>	Polyolefin plastomer
<i>PCTG</i>	Polycyclohexylene- dimethylenediol/ethyleneglycol terephthalate	<i>POSS</i>	Polyhedral oligomeric silsesquioxane
<i>PDMS</i>	Polydimethylsiloxane	<i>PP</i>	Polypropylene
<i>PE</i>	Polyethylene	<i>PPA</i>	Polyphthalamide
<i>PEAA</i>	Polyethylene acrylic acid	<i>PPE</i>	Polyphenylene ether
<i>PEAR</i>	Polyetheramide resin	<i>PP/EPDM</i>	Unvulcanized EPDM blended with polypropylene or block copolymerized PP-EPDM
<i>PEBA</i>	Polyether block amide		(reactor TPO) – (TPE) (TPO)
<i>PEEK</i>	Polyetherether ketone	<i>PP/EPDM-V</i>	Vulcanized EPDM dispersed in polypropylene (TPE) (TPV)
<i>PEG</i>	Polyethylene glycol		Vulcanized butyl rubber dispersed in polypropylene (TPE) (TPV)
<i>PEI</i>	Polyetherimide	<i>PP/IIR-V</i>	Vulcanized nitrile rubber dispersed in polypropylene (TPE) (TPV)
<i>PEK</i>	Polyetherketone		
<i>PEKK</i>	Poly ether ketone ketone	<i>PP/NBR-V</i>	Vulcanized nitrile rubber dispersed in polypropylene (TPE) (TPV)
<i>PEN</i>	Polyethylene naphthalenedicarboxylate		
<i>PES or PESU</i>	Polyethersulfone	<i>PPO</i>	Polyphenylene oxide
<i>PET or PETP</i>	Polyethylene terephthalate	<i>PPS</i>	Polyphenylene sulfide
<i>PETG</i>	Polyethyleneglycol/ cyclohexylene-dimethylenediol terephthalate	<i>PPSU</i>	Polyphenylenesulfone
<i>PETI</i>	Phenylethynyl with imide terminations	<i>Prepreg</i>	Preimpregnated
<i>PEX</i>	Crosslinked polyethylene	<i>PS</i>	Polystyrene
<i>PF</i>	Phenolic resin	<i>PSU</i>	Polysulfone
<i>PF1Ax</i>	PF general purpose, ammonia free	<i>PS-X or XPS</i>	Crosslinked polystyrene
<i>PF2Cx</i>	PF heat resistant, glass fiber reinforced	<i>PTFE</i>	Polytetrafluoroethylene
<i>PF2Dx</i>	PF impact resistant, cotton filled	<i>PTMT or PBT</i>	Polytetramethylene terephthalate or polybutyleneterephthalate
<i>PF2E1</i>	PF mica filled	<i>PTT</i>	Polytrimethylene terephthalate
<i>PFA</i>	Perfluoroalkoxy	<i>PUR</i>	Polyurethane
<i>PGA</i>	Polyglycolic acid	<i>PV</i>	Pressure*velocity
<i>PHA</i>	Polyhydroxyalkanoate	<i>PVA or PVAL</i> <i>or PVOH</i>	Polyvinyl alcohol
<i>PHB</i>	Polyhydroxybutyrate	<i>PVAC</i>	Polyvinyl acetate
<i>PHBH</i>	Polyhydroxybutyrate- hexanoate	<i>PVAL or PVA</i> <i>or PVOH</i>	Polyvinyl alcohol
<i>PHBV</i>	Polyhydroxybutyrate-co- hydroxyvalerate	<i>PVB</i>	Polyvinyl butyrate
<i>PI</i>	Polyimide	<i>PVC</i>	Polyvinyl chloride
<i>PIR</i>	Polyisocyanurate	<i>PVDC</i>	Polyvinylidene chloride
<i>PK</i>	Polyketone	<i>PVC-C or</i> <i>CPVC</i>	Chlorinated PVC
<i>PLA</i>	Polylactic acid	<i>PVC-U</i>	Unplasticized PVC
<i>PMI</i>	Polymethacrylimide	<i>PVDF</i>	Polyvinylidene fluoride
<i>PMMA</i>	Poly methylmethacrylate	<i>PVF</i>	Polyvinyl fluoride
<i>PMP</i>	Polymethylpentene	<i>PVOH or PVAL</i> <i>or PVA</i>	Polyvinyl a
<i>PO</i>	Polyolefin	<i>REACH</i>	Registration Evaluation Authorization and Restriction of Chemicals
<i>POE</i>	Polyolefin elastomer		
<i>POM</i>	Polyoxymethylene or polyacetal		

<i>RF</i>	Radio frequency	<i>TAC</i>	Triallyl cyanurate
<i>RFI</i>	Resin film impregnation	<i>TDI</i>	Toluene-2,4-diisocyanate
<i>RH</i>	Relative humidity or hygrometry	<i>TFE</i>	Tetrafluoroethylene
<i>RIM</i>	Reaction injection molding	<i>T_g</i>	Glass transition temperature
<i>RIRM</i>	Resin injection recirculation molding	<i>TGA</i>	Thermogravimetric analysis
<i>RoHS</i>	Restriction of Hazardous Substances	<i>TGV</i>	High-speed train
<i>RP</i>	Reinforced plastic	<i>TMC</i>	Thick molding compound
<i>RRIM</i>	Reinforced reaction injection molding	<i>TP</i>	Thermoplastic
<i>RT</i>	Room temperature	<i>TPE</i>	Thermoplastic elastomer
<i>RTM</i>	Resin transfer molding	<i>TPE/PVC</i>	PVC-based TPE, alloys of PVC and rubber (TPE) (TPO or TPV)
<i>RTP</i>	Reinforced thermoplastic	<i>TPEE or COPE</i>	Thermoplastic elastomer ester
<i>RTV</i>	Room temperature vulcanization	<i>TPI</i>	Thermoplastic imide
<i>SAN</i>	Styrene acrylonitrile	<i>TPO</i>	Thermoplastic olefin
<i>SAP</i>	Super absorbent polymer	<i>TPR</i>	Thermoplastic rubber
<i>SATUR</i>	Saturated solution	<i>TPS</i>	Thermoplastic styrenic
<i>SB</i>	Styrene butadiene	<i>TP/Si-V</i>	TPV of a vulcanized silicone rubber dispersed in a thermoplastic phase
<i>SBC</i>	Styrenic block copolymer	<i>TPU</i>	Thermoplastic polyurethane
<i>SBS</i>	Styrene-butadiene-styrene (TPE)	<i>TPV</i>	Thermoplastic vulcanizate
<i>SCRIMP</i>	Seemann Composites resin infusion molding process	<i>TR</i>	Temperature-retraction procedure
<i>SEBS</i>	Styrene ethylene/butylene styrene (TPE)	<i>TS</i>	Tensile strength
<i>SEPS</i>	Styrene ethylene/propylene styrene (TPE)	<i>UD</i>	Unidirectional composite
<i>SFRT</i>	Short fiber reinforced thermoplastic	<i>UF</i>	Urea-formaldehyde
<i>SGF</i>	Short glass fiber	<i>UHMWPE or</i>	
<i>Si</i>	Silicone	<i>PE-UHMW</i>	Ultrahigh molecular weight PE
<i>SIS</i>	Styrene isoprene styrene (TPE)	<i>UL</i>	Underwriters Laboratories
<i>SMA</i>	Styrene maleic anhydride	<i>Unkn.</i>	Unknown
<i>SMC</i>	Sheet molding compound	<i>UP</i>	Unsaturated polyester
<i>SMMA</i>	Styrene-methyl methacrylate	<i>USB</i>	United Soybean Board
<i>SN curve</i>	Plot of stress or strain (S) leading to failure after N cycles of repeated loading	<i>UV</i>	Ultraviolet
<i>SOL</i>	Solution	<i>V0 to V2</i>	UL fire rating
<i>SP-polyimides</i>	Condensation polyimides	<i>VAE</i>	Ethylene-vinylacetate copolymers
<i>SPC</i>	Statistical process control	<i>VARI</i>	Vacuum-assisted resin injection
<i>SPDF</i>	Super plastic diaphragm forming	<i>VARTM</i>	Vacuum Assisted RTM
<i>SR</i>	Self-reinforced	<i>VE</i>	Vinylester
<i>SRRIM</i>	Structural (reinforced) resin injection molding	<i>VGCNF</i>	Vapor grown carbon nanofibers
<i>SWNT</i>	Single-walled carbon nanotubes	<i>VIP</i>	Vacuum infusion process
		<i>VOC</i>	Volatile organic compounds
		<i>VST</i>	Vicat softening temperature
		<i>WPC</i>	Wood plastic composite
		<i>XLPE</i>	Crosslinked LDPE
		<i>XPE or PEX</i>	Crosslinked polyethylene
		<i>XPS or PS-X</i>	Crosslinked polystyrene
		<i>ZMC</i>	A highly automated process using molding compounds

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