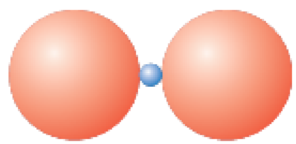
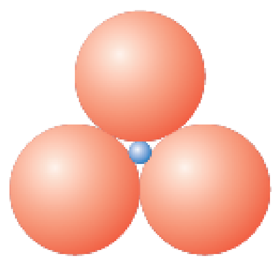
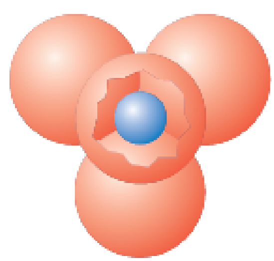
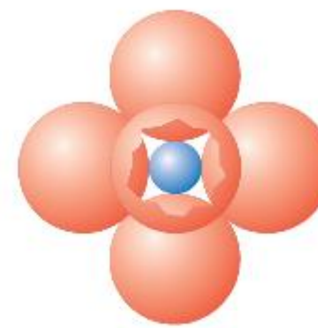
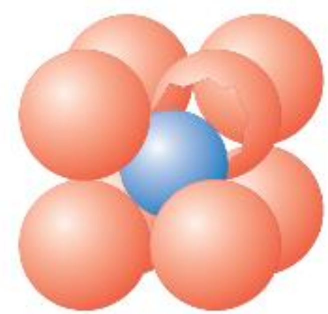
Rayons ioniques pour un nombre de coordination de 6 :

Cation	r_A (pm)	Anion	r_C (pm)
Al^{3+}	53	Cl^-	181
Ca^{2+}	100	F^-	133
Na^+	102	I^-	220
Si^{4+}	40	O^{2-}	140
Ti^{4+}	61	S^{2-}	184

Table 12.2 Coordination Numbers and Geometries for Various Cation–Anion Radius Ratios (r_C/r_A)

Coordination Number	*Cation–Anion Radius Ratio*	*Coordination Geometry*
2	<0.155	
3	0.155–0.225	
4	0.225–0.414	
6	0.414–0.732	
8	0.732–1.0	

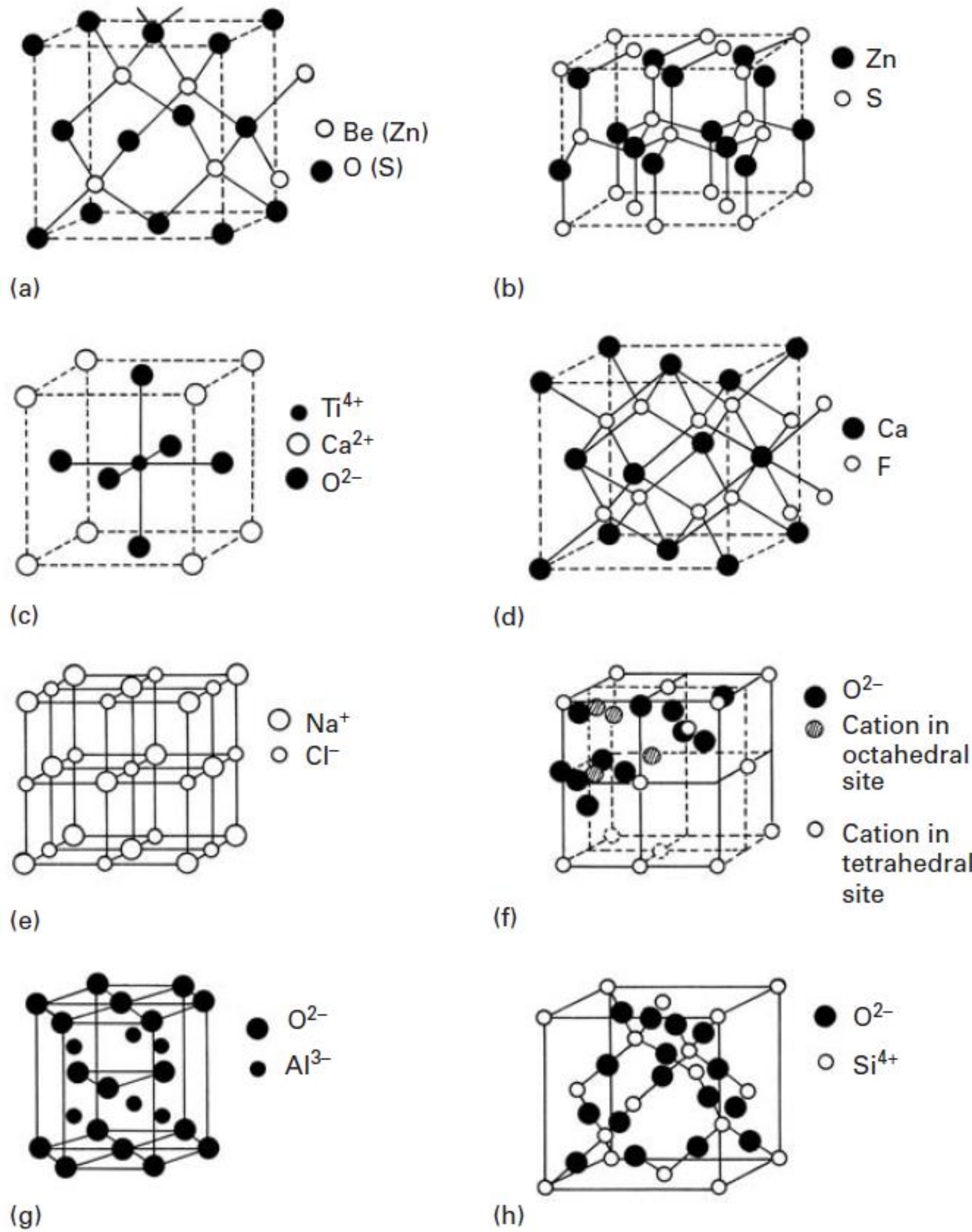
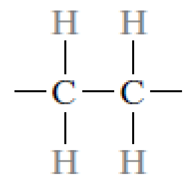
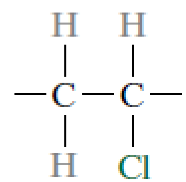
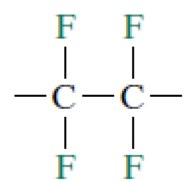
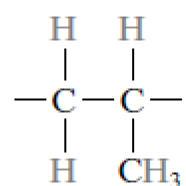
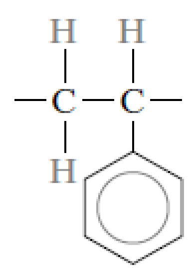


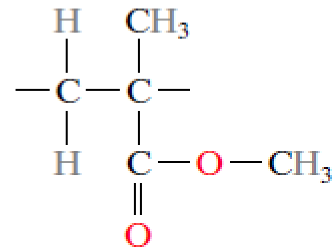
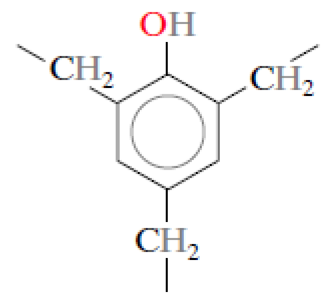
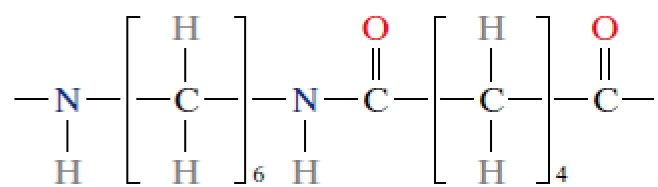
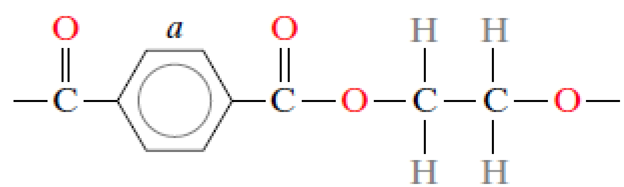
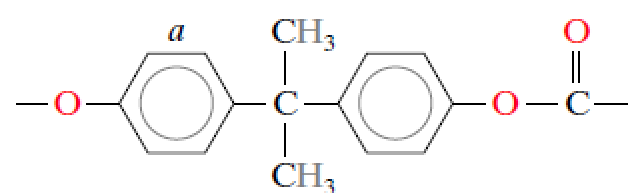
Fig. 1.17 Most common structures for ceramics. (a) Zinc blende (ZnS, BeO, SiC). (b) Wurtzite (ZnS, ZnO, SiC, BN). (c) Perovskite ($CoTiO_3$, $BaTiO_3$, $YCu_2Ba_3O_{7-x}$). (d) Fluorite (ThO_2, UO_2, CeO_2, ZrO_2, PuO_2). (e) NaCl (KCl, LiF, KBr, MgO, CaO, VO, MnO, NiO). (f) Spinel ($FeAl_2O_4$, $ZnAl_2O_4$, $MoAl_2O_4$). (g) Corundum (Al_2O_3, Fe_2O_3, Cr_2O_3, Ti_2O_3, V_2O_3). (h) Crystobalite (SiO_2 – quartz). The CsCl stucture, which has one Cs^+ surrounded by four Cl^- ions in cube edges, is not shown.

Table 14.3 A Listing of Repeat Units for 10 of the More Common Polymeric Materials

Polymer	*Repeat Unit*
Polyethylene (PE)	
Poly(vinyl chloride) (PVC)	
Polytetrafluoroethylene (PTFE)	
Polypropylene (PP)	
Polystyrene (PS)	

Issu de « Materials science and engineering – an introduction, W.D. Callister et D.J. Rethwisch »

Table 14.3 (Continued)

Polymer	*Repeat Unit*
Poly(methyl methacrylate) (PMMA)	
Phenol-formaldehyde (Bakelite)	
Poly(hexamethylene adipamide) (nylon 6,6)	
Poly(ethylene terephthalate) (PET, a polyester)	
Polycarbonate (PC)	

Issu de « Materials science and engineering – an introduction, W.D. Callister et D.J. Rethwisch »

Polymères – propriétés mécaniques

Material	*Specific Gravity*	*Tensile Modulus [GPa (ksi)]*	*Tensile Strength [MPa (ksi)]*	*Yield Strength [MPa (ksi)]*	*Elongation at Break (%)*
Polyethylene (low density)	0.917–0.932	0.17–0.28 (25–41)	8.3–31.4 (1.2–4.55)	9.0–14.5 (1.3–2.1)	100–650
Polyethylene (high density)	0.952–0.965	1.06–1.09 (155–158)	22.1–31.0 (3.2–4.5)	26.2–33.1 (3.8–4.8)	10–1200
Poly(vinyl chloride)	1.30–1.58	2.4–4.1 (350–600)	40.7–51.7 (5.9–7.5)	40.7–44.8 (5.9–6.5)	40–80
Polytetrafluoroethylene	2.14–2.20	0.40–0.55 (58–80)	20.7–34.5 (3.0–5.0)	13.8–15.2 (2.0–2.2)	200–400
Polypropylene	0.90–0.91	1.14–1.55 (165–225)	31–41.4 (4.5–6.0)	31.0–37.2 (4.5–5.4)	100–600
Polystyrene	1.04–1.05	2.28–3.28 (330–475)	35.9–51.7 (5.2–7.5)	25.0–69.0 (3.63–10.0)	1.2–2.5
Poly(methyl methacrylate)	1.17–1.20	2.24–3.24 (325–470)	48.3–72.4 (7.0–10.5)	53.8–73.1 (7.8–10.6)	2.0–5.5
Phenol-formaldehyde	1.24–1.32	2.76–4.83 (400–700)	34.5–62.1 (5.0–9.0)	—	1.5–2.0
Nylon 6,6	1.13–1.15	1.58–3.80 (230–550)	75.9–94.5 (11.0–13.7)	44.8–82.8 (6.5–12)	15–300
Polyester (PET)	1.29–1.40	2.8–4.1 (400–600)	48.3–72.4 (7.0–10.5)	59.3 (8.6)	30–300
Polycarbonate	1.20	2.38 (345)	62.8–72.4 (9.1–10.5)	62.1 (9.0)	110–150

Issu de « Materials science and engineering – an introduction, W.D. Callister et D.J. Rethwisch »

Plastiques - thermoplastiques

Material Type	*Trade Names*	*Major Application Characteristics*	*Typical Applications*
		Thermoplastics	
Acrylonitrile-butadiene-styrene (ABS)	Abson Cycolac Kralastic Lustran Novodur Tybrene	Outstanding strength and toughness, resistant to heat distortion; good electrical properties; flammable and soluble in some organic solvents	Refrigerator linings, lawn and garden equipment, toys, highway safety devices
Acrylics [poly(methyl methacrylate)]	Acrylite Diakon Lucite Plexiglas	Outstanding light transmission and resistance to weathering; only fair mechanical properties	Lenses, transparent aircraft enclosures, drafting equipment, outdoor signs
Fluorocarbons (PTFE or TFE)	Teflon Fluon Halar Hostaflon TF Neoflon	Chemically inert in almost all environments, excellent electrical properties; low coefficient of friction; may be used to 260°C (500°F); relatively weak and poor cold-flow properties	Anticorrosive seals, chemical pipes and valves, bearings, antiadhesive coatings, high-temperature electronic parts
Polyamides (nylons)	Nylon Baylon Durethan Herox Nomex Ultramid Zytel	Good mechanical strength, abrasion resistance, and toughness; low coefficient of friction; absorbs water and some other liquids	Bearings, gears, cams, bushings, handles, and jacketing for wires and cables

Issu de « Materials science and engineering – an introduction, W.D. Callister et D.J. Rethwisch »

Plastiques - thermoplastiques

Material Type	*Trade Names*	*Major Application Characteristics*	*Typical Applications*
Polycarbonates	Calibre Iupilon Lexan Makrolon Merlon	Dimensionally stable; low water absorption; transparent; very good impact resistance and ductility; chemical resistance not outstanding	Safety helmets, lenses, light globes, base for photographic film
Polyethylenes	Alathon Alkathene Fortiflex Hi-fax Petrothene Rigidex Rotothene Zendel	Chemically resistant and electrically insulating; tough and relatively low coefficient of friction; low strength and poor resistance to weathering	Flexible bottles, toys, tumblers, battery parts, ice trays, film wrapping materials
Polypropylenes	Herculon Meraklon Moplen Poly-pro Pro-fax Propak Propathene	Resistant to heat distortion; excellent electrical properties and fatigue strength; chemically inert; relatively inexpensive; poor resistance to UV light	Sterilizable bottles, packaging film, TV cabinets, luggage

Issu de « Materials science and engineering – an introduction, W.D. Callister et D.J. Rethwisch »

Plastiques - thermoplastiques

Material Type	Trade Names	Major Application Characteristics	Typical Applications
Polystyrenes	Carinex Dylene Hostyren Lustrex Styron Vestyron	Excellent electrical properties and optical clarity; good thermal and dimensional stability; relatively inexpensive	Wall tile, battery cases, toys, indoor lighting panels, appliance housings
Vinyls	Darvic Exon Geon Pliovic Saran Tygon Vista	Good low-cost, general-purpose materials; ordinarily rigid, but may be made flexible with plasticizers; often copolymerized; susceptible to heat distortion	Floor coverings, pipe, electrical wire insulation, garden hose, phonograph records
Polyesters (PET or PETE)	Celanar Dacron Eastapak Hylar Melinex Mylar Petra	One of the toughest of plastic films; excellent fatigue and tear strength, and resistance to humidity, acids, greases, oils, and solvents	Magnetic recording tapes, clothing, automotive tire cords, beverage containers

Issu de « Materials science and engineering – an introduction, W.D. Callister et D.J. Rethwisch »

Plastiques thermodurcissables

Material Type	*Trade Names*	*Major Application Characteristics*	*Typical Applications*
		Thermosetting Polymers	
Epoxies	Araldite Epikote Epon Epi-rez Lekutherm Lytex	Excellent combination of mechanical properties and corrosion resistance; dimensionally stable; good adhesion; relatively inexpensive; good electrical properties	Electrical moldings, sinks, adhesives, protective coatings, used with fiberglass laminates
Phenolics	Bakelite Amberol Arofene Durite Resinox	Excellent thermal stability to over 150°C (300°F); may be compounded with a large number of resins, fillers, etc.; inexpensive	Motor housings, telephones, auto distributors, electrical fixtures
Polyesters	Aropol Baygal Derakane Laminac Selectron	Excellent electrical properties and low cost; can be formulated for room- or high-temperature use; often fiber reinforced	Helmets, fiberglass boats, auto body components, chairs, fans

Issu de « Materials science and engineering – an introduction, W.D. Callister et D.J. Rethwisch »

Elastomères

Chemical Type	*Trade (Common) Names*	*Elongation (%)*	*Useful Temperature Range [°C (°F)]*	*Major Application Characteristics*	*Typical Applications*
Natural polyisoprene	Natural rubber (NR)	500–760	−60 to 120 (−75 to 250)	Excellent physical properties; good resistance to cutting, gouging, and abrasion; low heat, ozone, and oil resistance; good electrical properties	Pneumatic tires and tubes; heels and soles; gaskets
Styrene-butadiene copolymer	GRS, Buna S (SBR)	450–500	−60 to 120 (−75 to 250)	Good physical properties; excellent abrasion resistance; not oil, ozone, or weather resistant; electrical properties good, but not outstanding	Same as natural rubber
Acrylonitrile-butadiene copolymer	Buna A, Nitrile (NBR)	400–600	−50 to 150 (−60 to 300)	Excellent resistance to vegetable, animal, and petroleum oils; poor low-temperature properties; electrical properties not outstanding	Gasoline, chemical, and oil hose; seals and O-rings; heels and soles
Chloroprene	Neoprene (CR)	100–800	−50 to 105 (−60 to 225)	Excellent ozone, heat, and weathering resistance; good oil resistance; excellent flame resistance; not as good in electrical applications as natural rubber	Wire and cable; chemical tank linings; belts, seals, hoses, and gaskets
Polysiloxane	Silicone (VMQ)	100–800	−115 to 315 (−175 to 600)	Excellent resistance to high and low temperatures; low strength; excellent electrical properties	High- and low-temperature insulation; seals, diaphragms; tubing for food and medical uses

Issu de « Materials science and engineering – an introduction, W.D. Callister et D.J. Rethwisch »

Table 15.4 Characteristics of Several Fiber-Reinforcement Materials

Material	*Specific Gravity*	*Tensile Strength [GPa (10^6 psi)]*	*Specific Strength (GPa)*	*Modulus of Elasticity [GPa (10^6 psi)]*
		Whiskers		
Graphite	2.2	20 (3)	9.1	700 (100)
Silicon nitride	3.2	5–7 (0.75–1.0)	1.56–2.2	350–380 (50–55)
Aluminum oxide	4.0	10–20 (1–3)	2.5–5.0	700–1500 (100–220)
Silicon carbide	3.2	20 (3)	6.25	480 (70)
		Fibers		
Aluminum oxide	3.95	1.38 (0.2)	0.35	379 (55)
Aramid (Kevlar 49™)	1.44	3.6–4.1 (0.525–0.600)	2.5–2.85	131 (19)
Carbon[a]	1.78–2.15	1.5–4.8 (0.22–0.70)	0.70–2.70	228–724 (32–100)
E-glass	2.58	3.45 (0.5)	1.34	72.5 (10.5)
Boron	2.57	3.6 (0.52)	1.40	400 (60)
Silicon carbide	3.0	3.9 (0.57)	1.30	400 (60)
UHMWPE (Spectra 900™)	0.97	2.6 (0.38)	2.68	117 (17)
		Metallic Wires		
High-strength steel	7.9	2.39 (0.35)	0.30	210 (30)
Molybdenum	10.2	2.2 (0.32)	0.22	324 (47)
Tungsten	19.3	2.89 (0.42)	0.15	407 (59)

[a] The term "carbon" instead of "graphite" is used to denote these fibers, since they are composed o graphite regions and also of noncrystalline material and areas of crystal misalignment.

Issu de « Materials science and engineering – an introduction, W.D. Callister et D.J. Rethwisch »

Table 15.1 Properties of Some Important Reinforcement Fibers

Materials (Fibers)	Tensile Modulus (GPa)	Tensile Strength (GPa)	Density (g/cm^3)
Alumina	350–380	1.7	3.9
Boron	415	3.5	2.5–2.6
SiC	300–400	2.8	2.8
E-Glass	71	1.8–3.0	2.5
Carbon P100 (pitch-based)	725	2.2	2.15
Carbon M60J (PAN-based)	585	3.8	1.94
Aramid	125	3.5	1.45
Polyethylene	110	3	0.97

Issu de « Mechanical behavior of materials, M. Meyers & K. Chawla »

TABLE 2.1
Properties of Selected Commercial Reinforcing Fibers

Fiber	Typical Diameter (μm)[a]	Density (g/cm^3)	Tensile Modulus GPa (Msi)	Tensile Strength GPa (ksi)	Strain-to-Failure (%)	Coefficient of Thermal Expansion ($10^{-6}/°C$)[b]	Poisson's Ratio
Glass							
E-glass	10 (round)	2.54	72.4 (10.5)	3.45 (500)	4.8	5	0.2
S-glass	10 (round)	2.49	86.9 (12.6)	4.30 (625)	5.0	2.9	0.22
PAN carbon							
T-300[c]	7 (round)	1.76	231 (33.5)	3.65 (530)	1.4	−0.6 (longitudinal) 7–12 (radial)	0.2
AS-1[d]	8 (round)	1.80	228 (33)	3.10 (450)	1.32		
AS-4[d]	7 (round)	1.80	248 (36)	4.07 (590)	1.65		
T-40[c]	5.1 (round)	1.81	290 (42)	5.65 (820)	1.8	−0.75 (longitudinal)	
IM-7[d]	5 (round)	1.78	301 (43.6)	5.31 (770)	1.81		
HMS-4[d]	8 (round)	1.80	345 (50)	2.48 (360)	0.7		
GY-70[e]	8.4 (bilobal)	1.96	483 (70)	1.52 (220)	0.38		
Pitch carbon							
P-55[c]	10	2.0	380 (55)	1.90 (275)	0.5	−1.3 (longitudinal)	
P-100[c]	10	2.15	758 (110)	2.41 (350)	0.32	−1.45 (longitudinal)	
Aramid							
Kevlar 49[f]	11.9 (round)	1.45	131 (19)	3.62 (525)	2.8	−2 (longitudinal) 59 (radial)	0.35
Kevlar 149[f]		1.47	179 (26)	3.45 (500)	1.9		
Technora[g]		1.39	70 (10.1)	3.0 (435)	4.6	−6 (longitudinal)	

TABLE 2.3
Typical Compositions of Glass Fibers (in wt%)

Type	SiO_2	Al_2O_3	CaO	MgO	B_2O_3	Na_2O
E-glass	54.5	14.5	17	4.5	8.5	0.5
S-glass	64	26	—	10	—	—

Issu de « Fiber reinforced composites, P.K. Mallick »

TABLE 2.1
Properties of Selected Commercial Reinforcing Fibers

Fiber	Typical Diameter (μm)[a]	Density (g/cm^3)	Tensile Modulus GPa (Msi)	Tensile Strength GPa (ksi)	Strain-to-Failure (%)	Coefficient of Thermal Expansion (10^{-6}/°C)[b]	Poisson's Ratio
Extended chain polyethylene							
Spectra 900[h]	38	0.97	117 (17)	2.59 (375)	3.5		
Spectra 1000[h]	27	0.97	172 (25)	3.0 (435)	2.7		
Boron	140 (round)	2.7	393 (57)	3.1 (450)	0.79	5	0.2
SiC							
Monofilament	140 (round)	3.08	400 (58)	3.44 (499)	0.86	1.5	
Nicalon[i] (multifilament)	14.5 (round)	2.55	196 (28.4)	2.75 (399)	1.4		
Al_2O_3							
Nextel 610[j]	10–12 (round)	3.9	380 (55)	3.1 (450)		8	
Nextel 720[j]	10–12	3.4	260 (38)	2.1 (300)		6	
Al_2O_3–SiO_2							
Fiberfrax (discontinuous)	2–12	2.73	103 (15)	1.03–1.72 (150–250)			

Issu de « Fiber reinforced composites, P.K. Mallick »

TABLE 2.6
Matrix Materials

Polymeric

Thermoset polymers

- Epoxies: principally used in aerospace and aircraft applications
- Polyesters, vinyl esters: commonly used in automotive, marine, chemical, and electrical applications
- Phenolics: used in bulk molding compounds
- Polyimides, polybenzimidazoles (PBI), polyphenylquinoxaline (PPQ): for high-temperature aerospace applications (temperature range: 250°C–400°C)
- Cyanate ester

Thermoplastic polymers

- Nylons (such as nylon 6, nylon 6,6), thermoplastic polyesters (such as PET, PBT), polycarbonate (PC), polyacetals: used with discontinuous fibers in injection-molded articles
- Polyamide-imide (PAI), polyether ether ketone (PEEK), polysulfone (PSUL), polyphenylene sulfide (PPS), polyetherimide (PEI): suitable for moderately high temperature applications with continuous fibers

Metallic

- Aluminum and its alloys, titanium alloys, magnesium alloys, copper-based alloys, nickel-based superalloys, stainless steel: suitable for high-temperature applications (temperature range: 300°C–500°C)

Ceramic

- Aluminum oxide (Al_2O_3), carbon, silicon carbide (SiC), silicon nitride (Si_3N_4): suitable for high-temperature applications

Issu de « Fiber reinforced composites, P.K. Mallick »

Table 15.9 **Properties of Several Metal-Matrix Composites Reinforced with Continuous and Aligned Fibers**

Fiber	*Matrix*	*Fiber Content (vol%)*	*Density (g/cm^3)*	*Longitudinal Tensile Modulus (GPa)*	*Longitudinal Tensile Strength (MPa)*
Carbon	6061 Al	41	2.44	320	620
Boron	6061 Al	48	—	207	1515
SiC	6061 Al	50	2.93	230	1480
Alumina	380.0 Al	24	—	120	340
Carbon	AZ31 Mg	38	1.83	300	510
Borsic	Ti	45	3.68	220	1270

Source: Adapted from J. W. Weeton, D. M. Peters, and K. L. Thomas, *Engineers' Guide to Composite Materials,* ASM International, Materials Park, OH, 1987.

Issu de « Materials science and engineering – an introduction, W.D. Callister et D.J. Rethwisch »