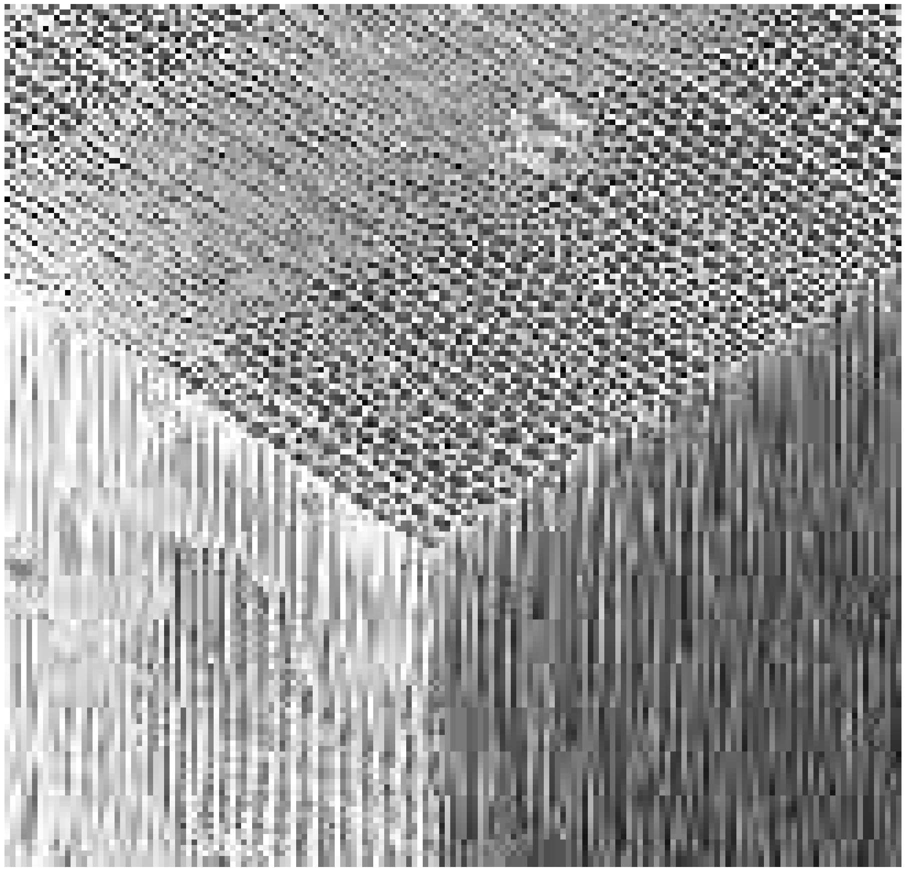
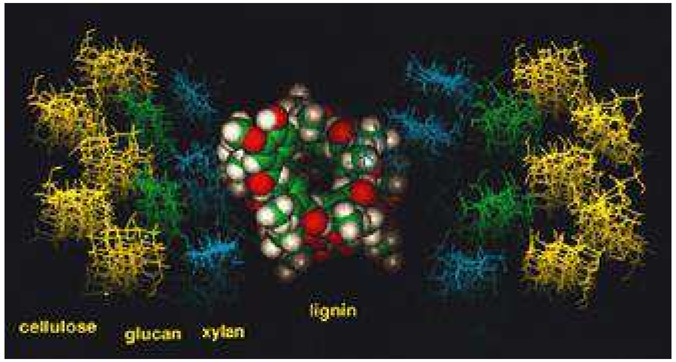
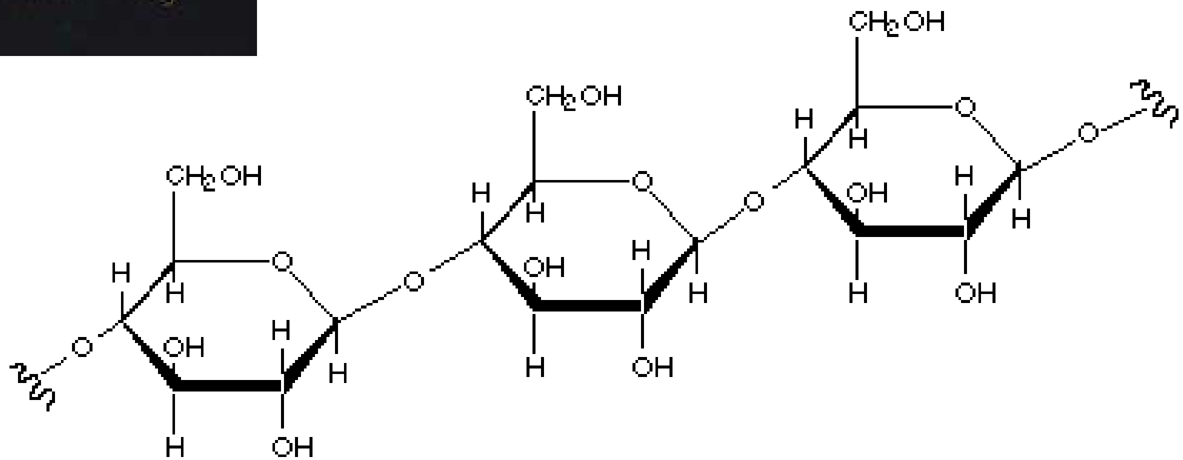
Compósitos

Exemplos



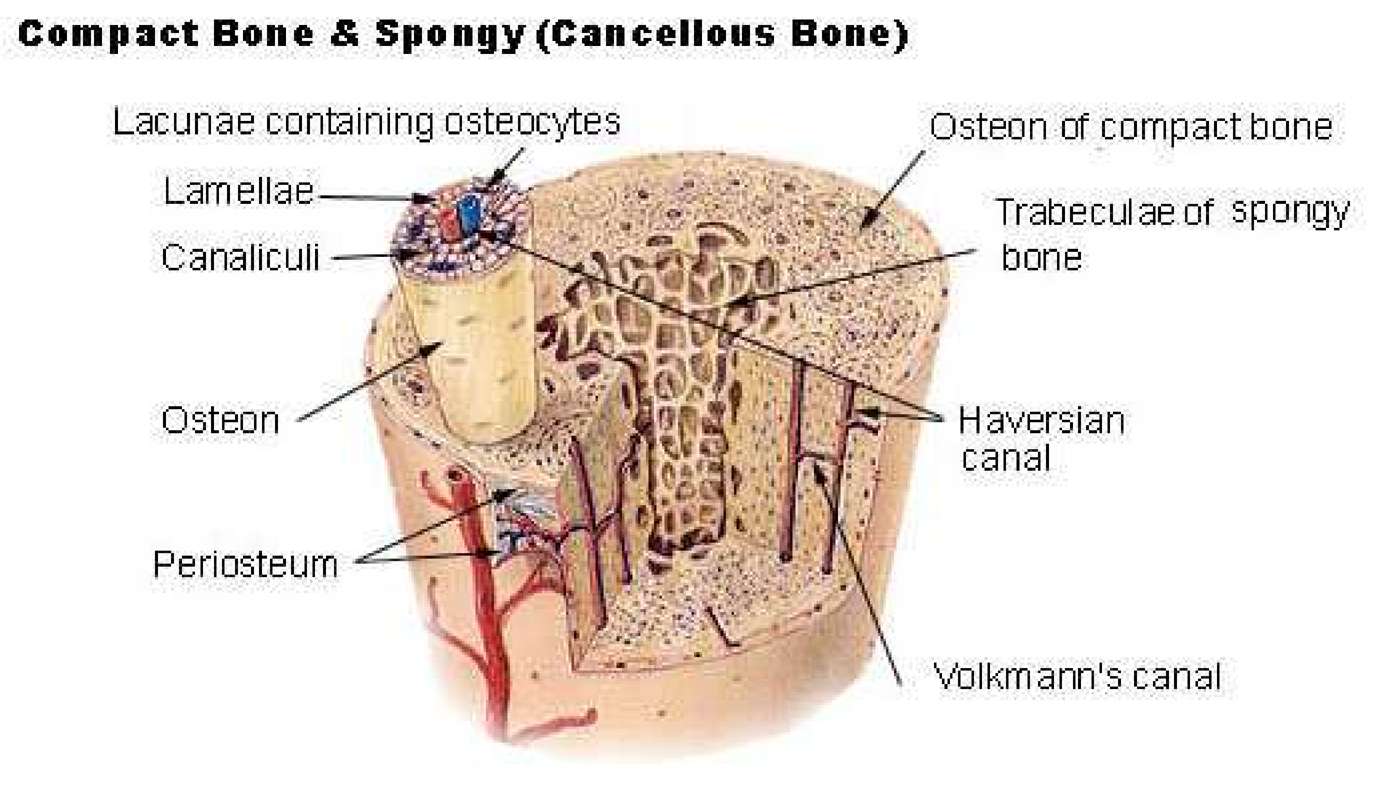
Exemplos



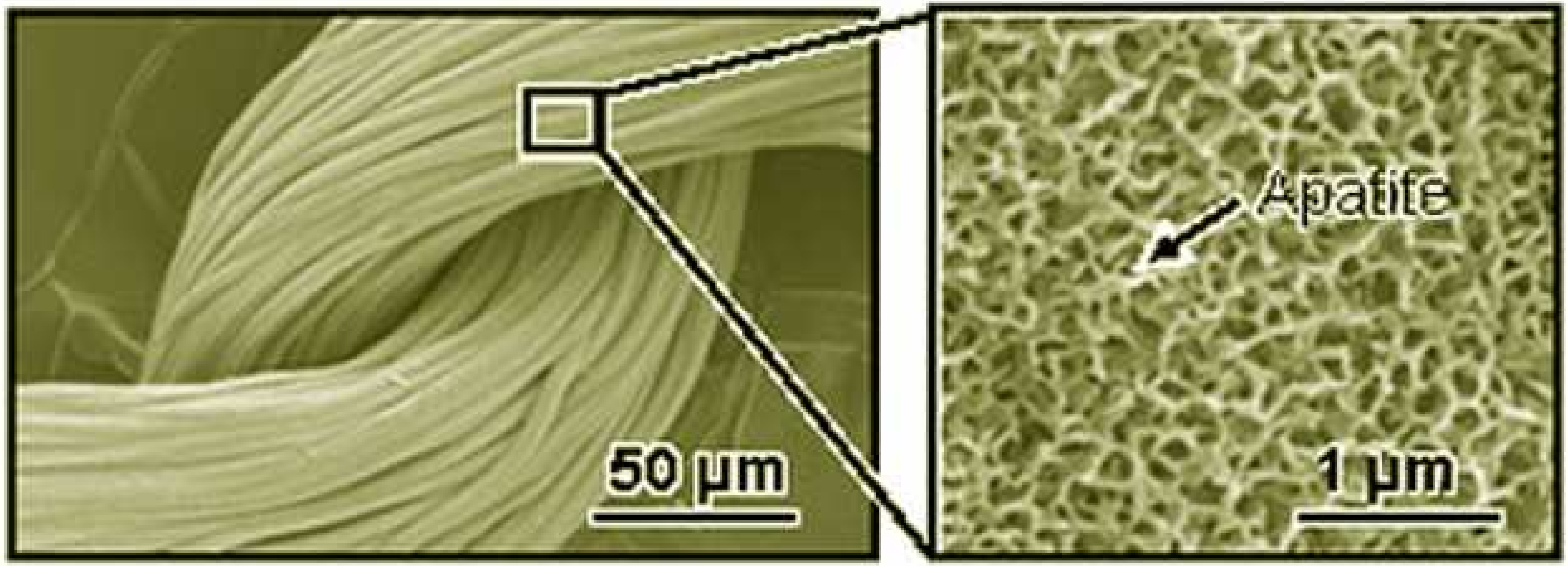


Cellulose
poly (1,4'-O-β-D-glucopyranoside)

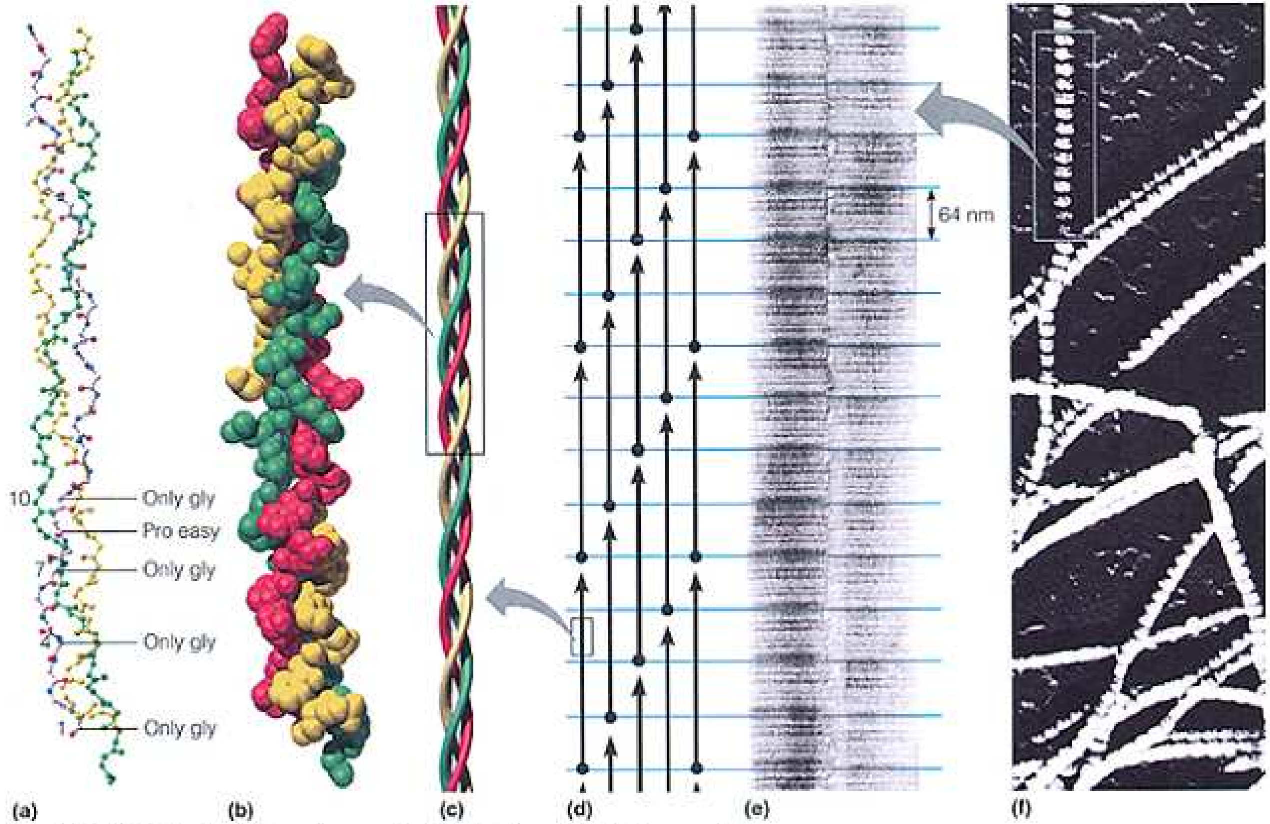
Exemplos


Compact Bone & Spongy (Cancellous Bone)
Lacunae containing osteocytes
Lamellae
Canaliculi
Osteon
Periosteum
Osteon of compact bone
Trabeculae of spongy bone
Haversian canal
Volkmann's canal

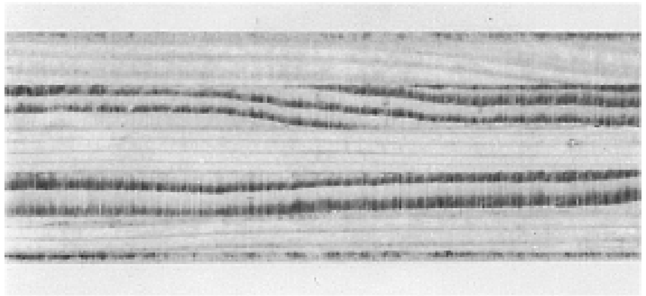
Exemplos



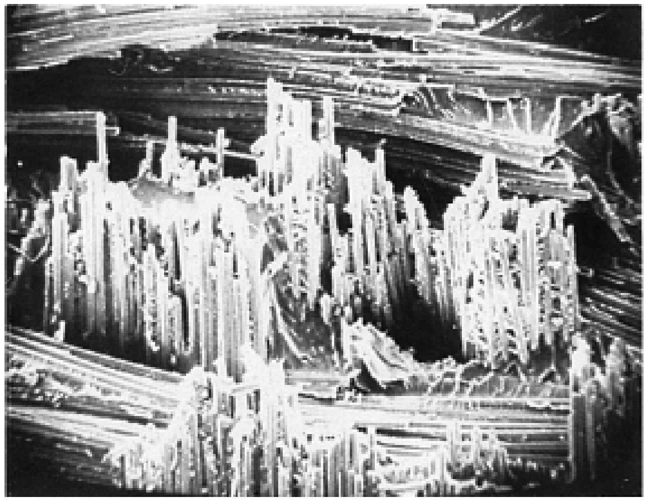
Exemplos


10
Only gly
Pro easy
7
Only gly
4
Only gly
1
Only gly
64 nm
(a)
(b)
(c)
(d)
(e)
(f)

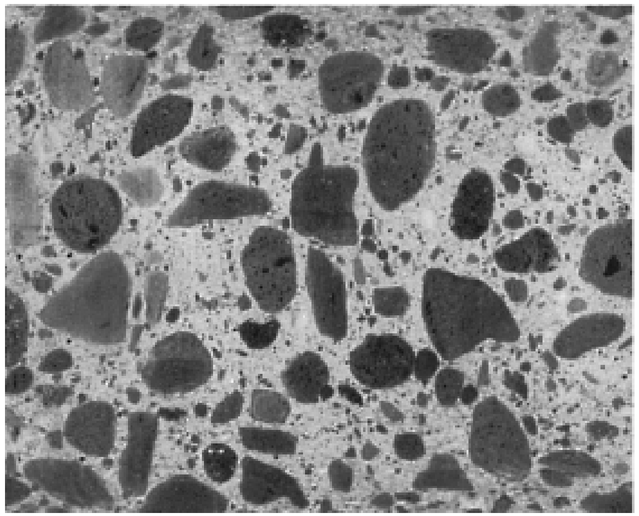
Exemplos



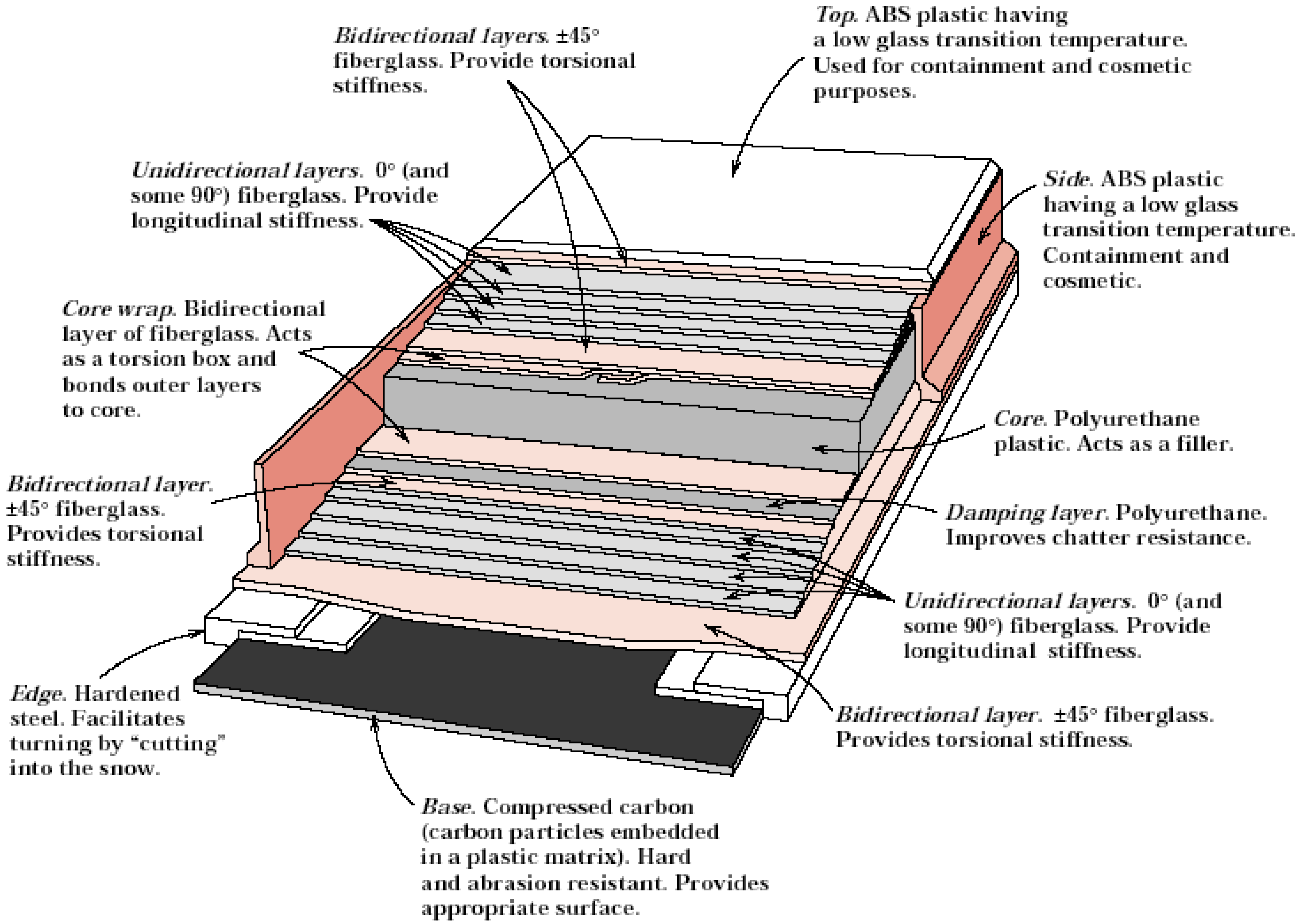
(a)



(b)



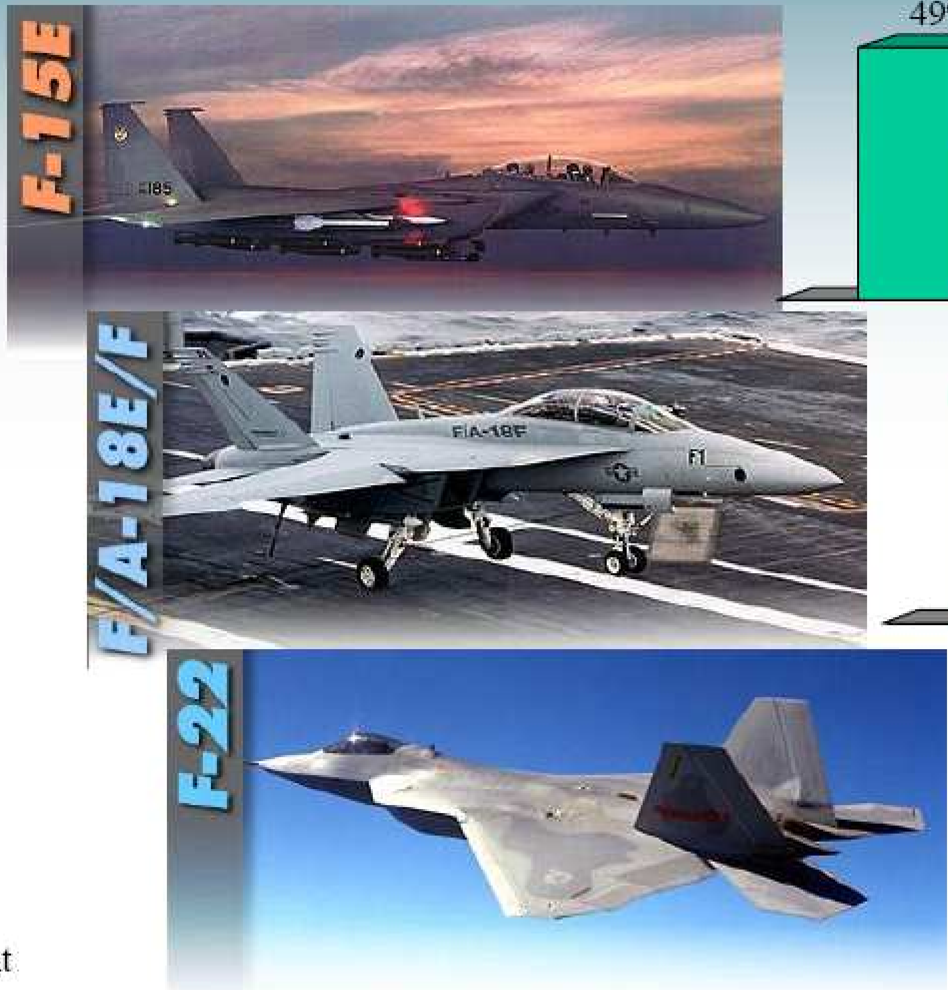
(c)

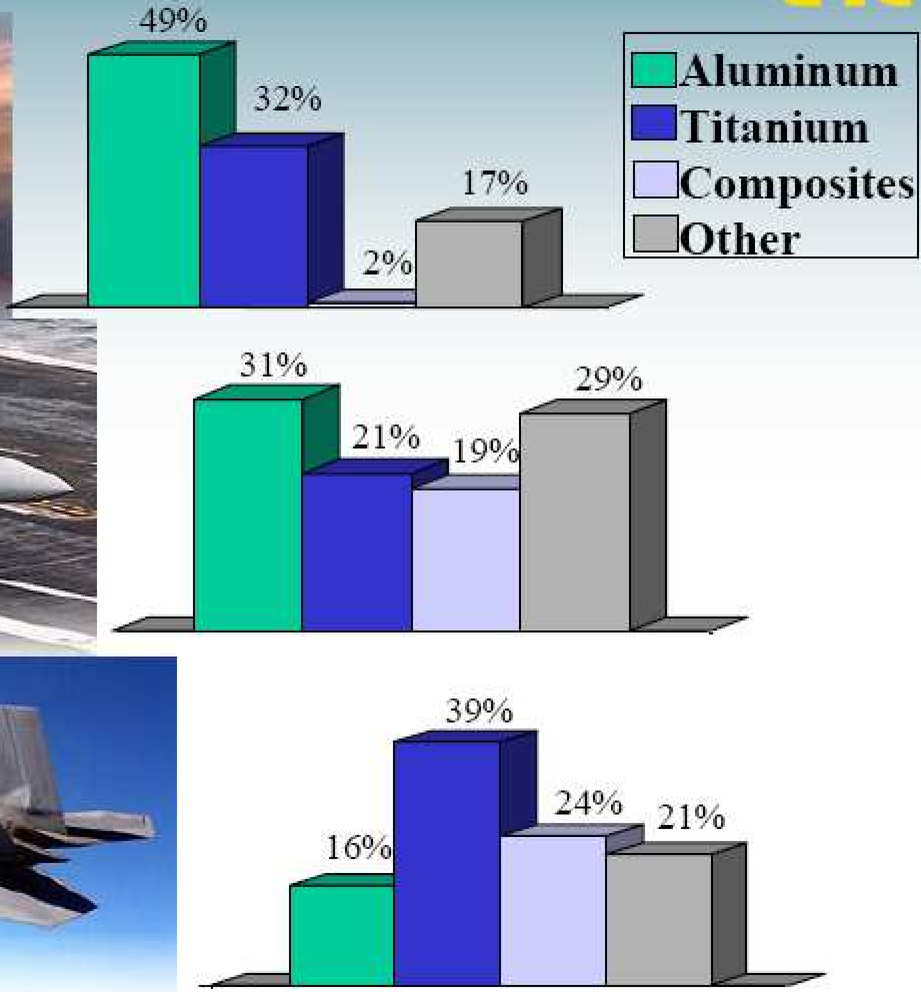

Bidirectional layers. ±45° fiberglass. Provide torsional stiffness.
Top. ABS plastic having a low glass transition temperature. Used for containment and cosmetic purposes.
Unidirectional layers. 0° (and some 90°) fiberglass. Provide longitudinal stiffness.
Side. ABS plastic having a low glass transition temperature. Containment and cosmetic.
Core wrap. Bidirectional layer of fiberglass. Acts as a torsion box and bonds outer layers to core.
Core. Polyurethane plastic. Acts as a filler.
Bidirectional layer. ±45° fiberglass. Provides torsional stiffness.
Damping layer. Polyurethane. Improves chatter resistance.
Unidirectional layers. 0° (and some 90°) fiberglass. Provide longitudinal stiffness.
Edge. Hardened steel. Facilitates turning by "cutting" into the snow.
Bidirectional layer. ±45° fiberglass. Provides torsional stiffness.
Base. Compressed carbon (carbon particles embedded in a plastic matrix). Hard and abrasion resistant. Provides appropriate surface.

FIGHTER AIRCRAFT MATERIALS

Utilization Of High Cost Airframe Materials Has Been Increasing To Improve Aircraft Performance

1987

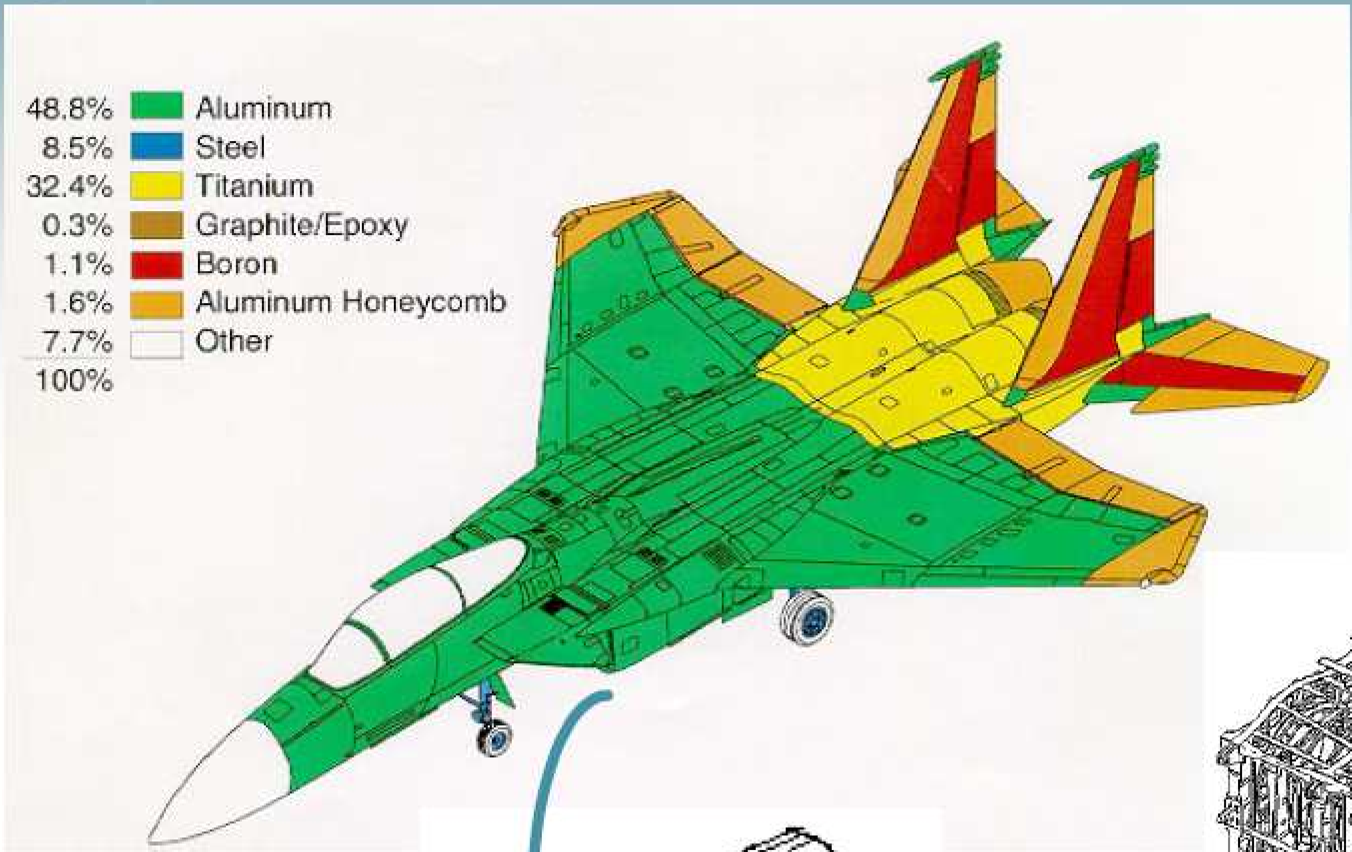




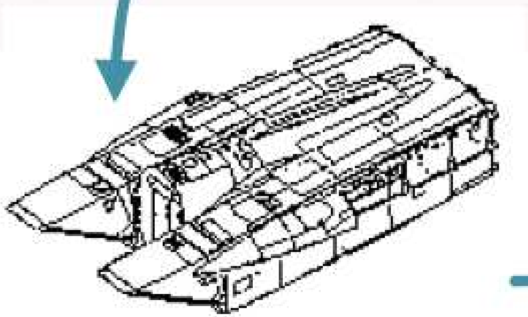
present

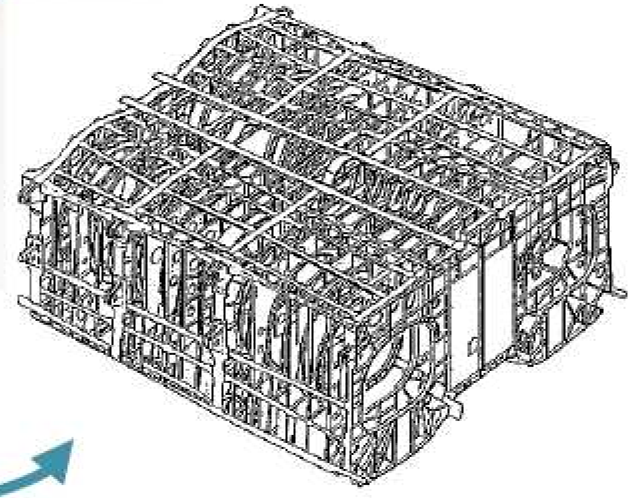
Affordability Is Now Being Emphasized When Selecting Airframe Materials

F-15 SKIN/STRINGER CONSTRUCTION

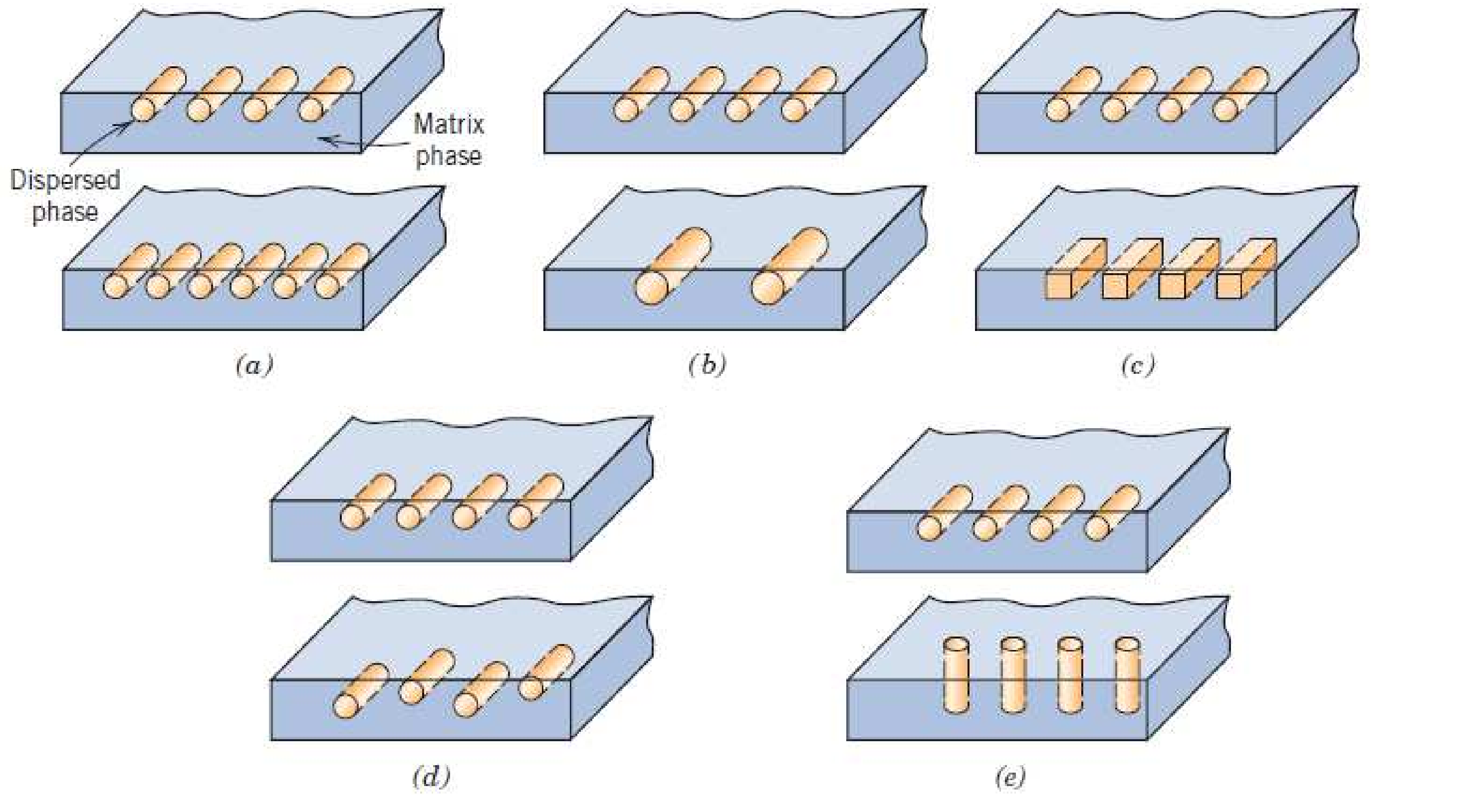


Advanced Metallic Materials With Greater Structural Efficiency, And Processes That Produce Complex Unitized Components *Improve Affordability*

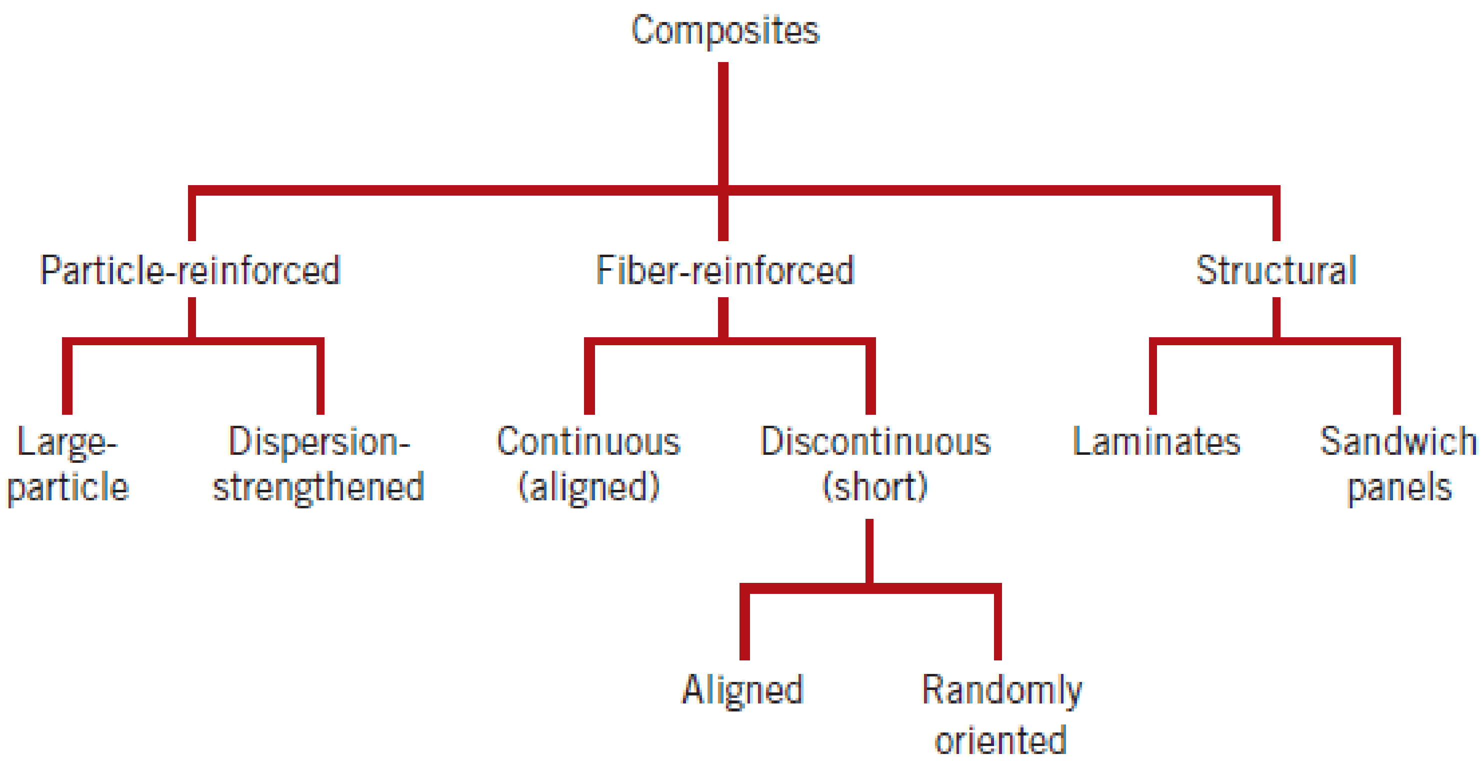




Geometria, Orientação e Distribuição



Classificação dos reforços



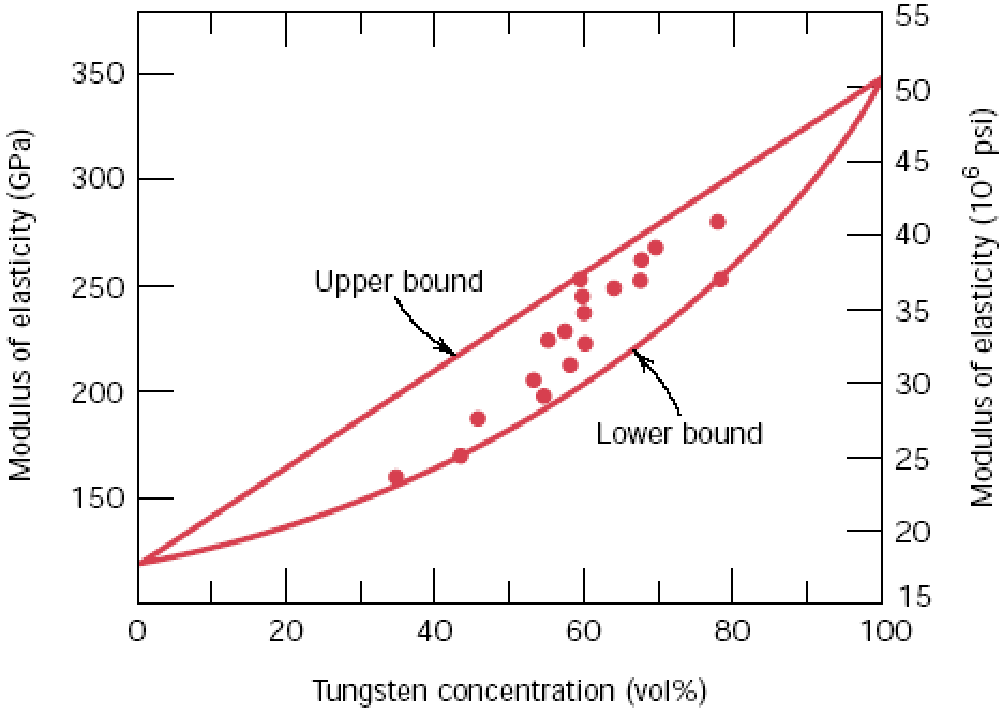
Reforço com partículas

Regra das misturas

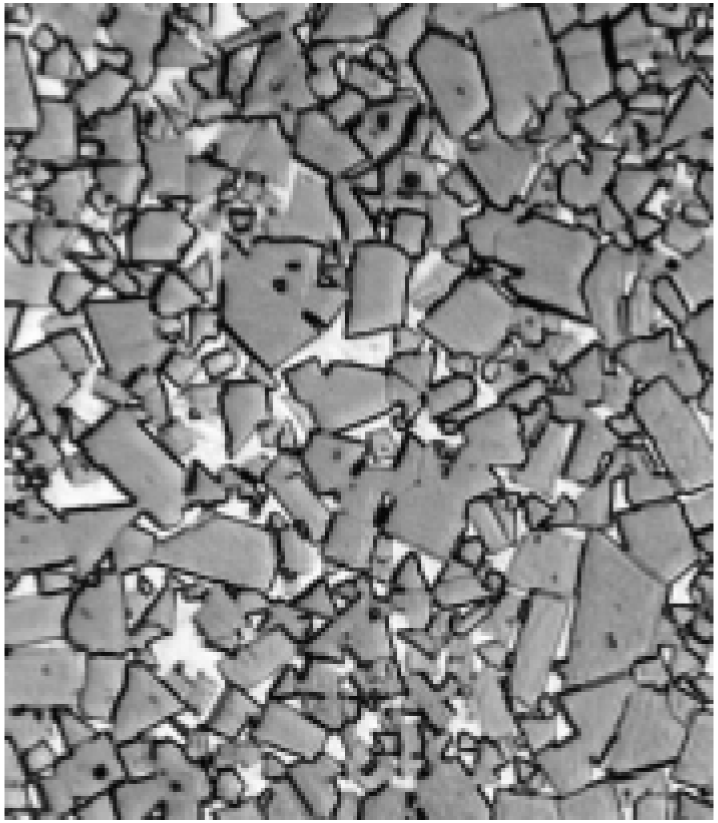
$$E_C(s) = E_m V_m + E_p V_p$$

$$E_C(i) = \frac{E_m E_p}{V_m E_p + V_p E_m}$$

Módulo de Elasticidade

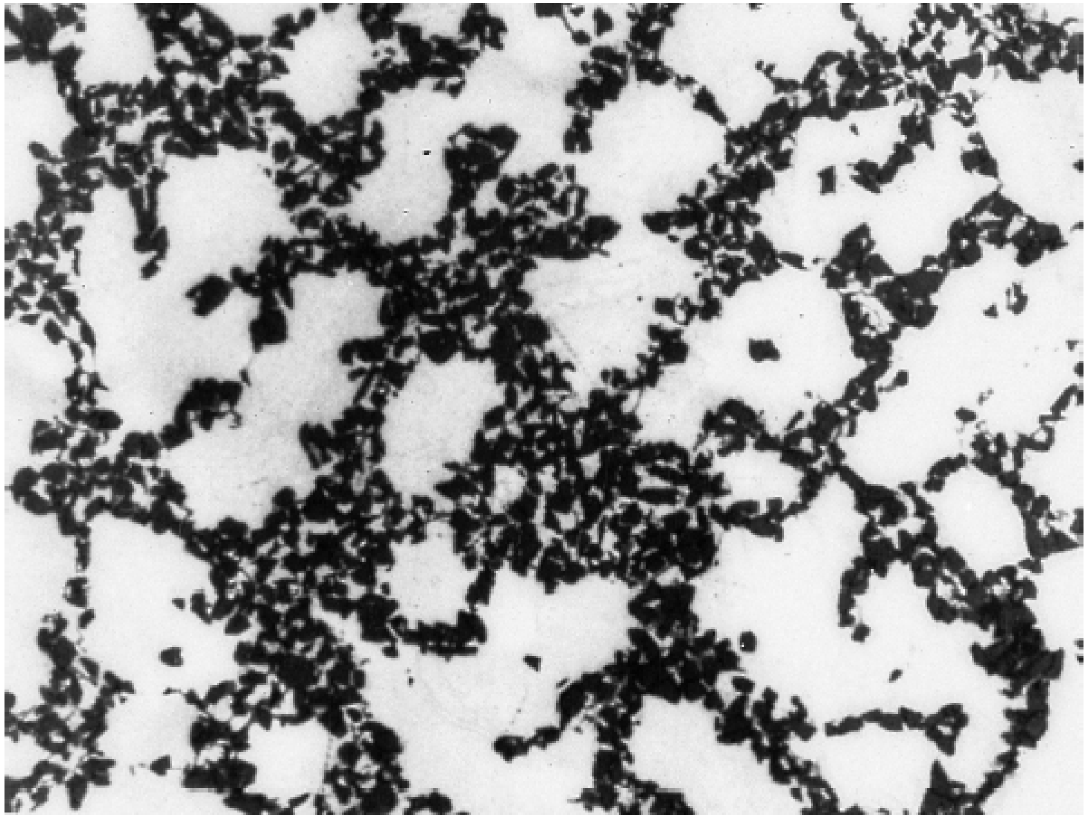


Exemplos



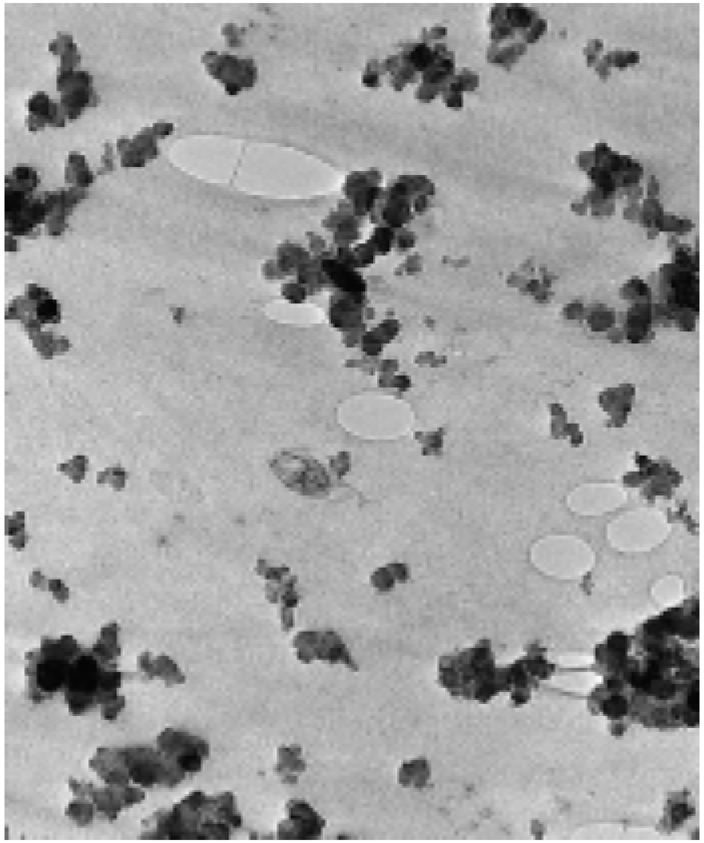
WC-Co

Exemplos



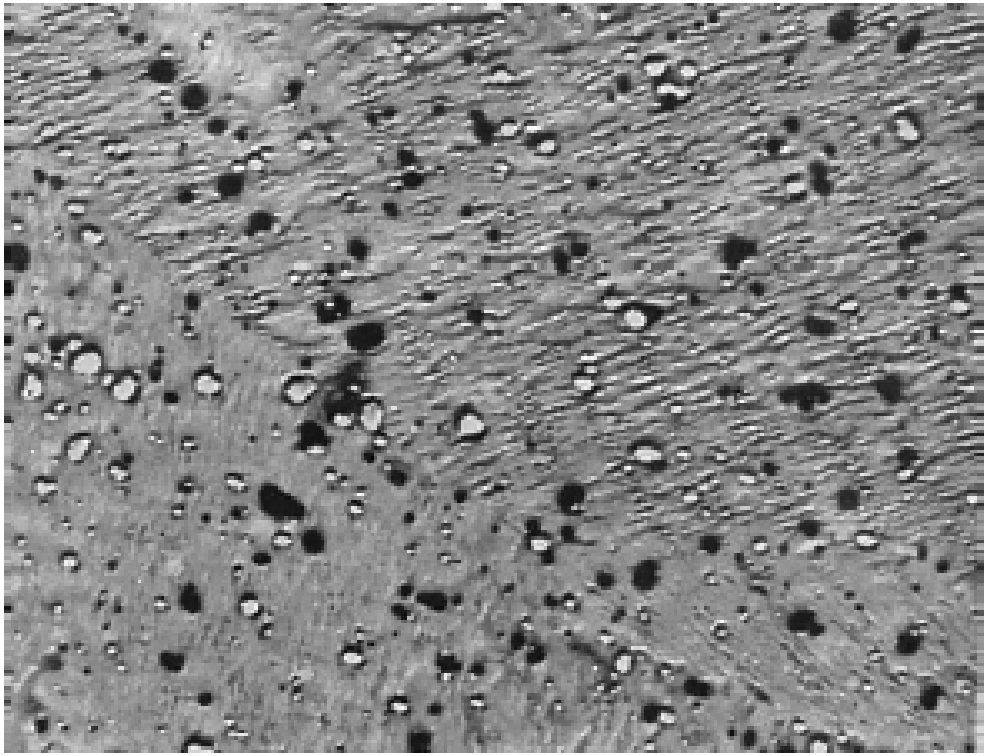
Al-SiC

Exemplos



Borracha com
Negro de fumo

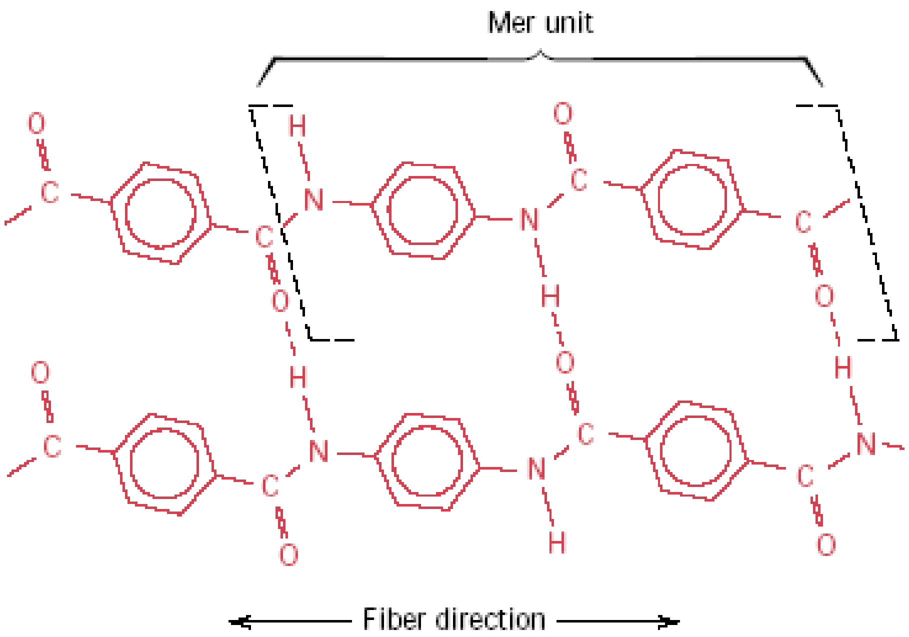
Exemplos



Ni-ThO

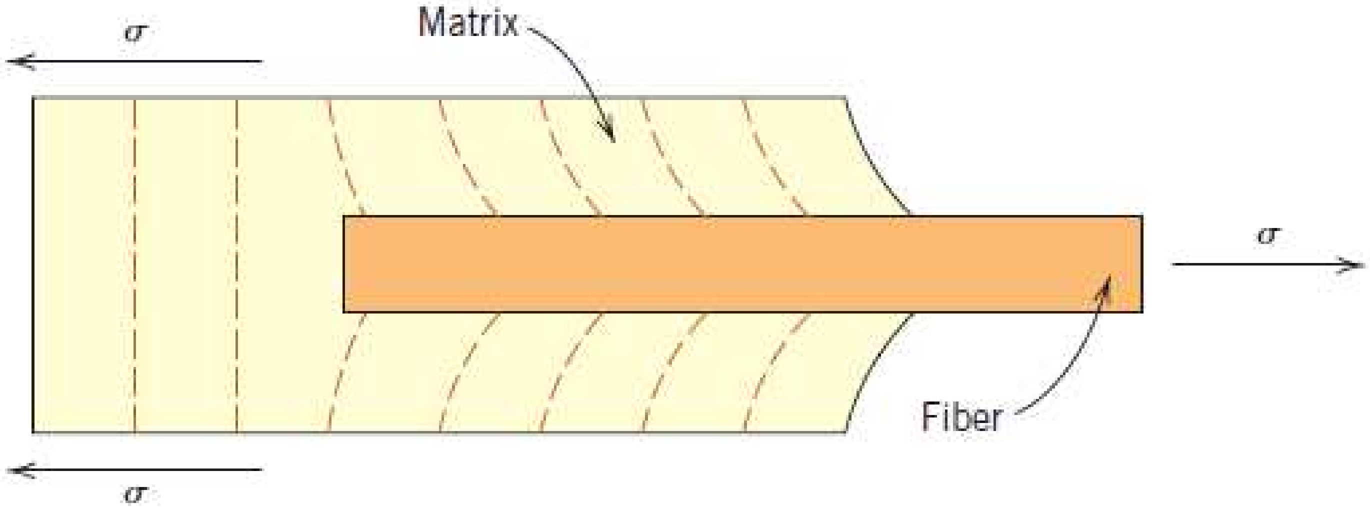
Reforço com fibras

Por que usar fibras?



Aramida
(Kevlar)

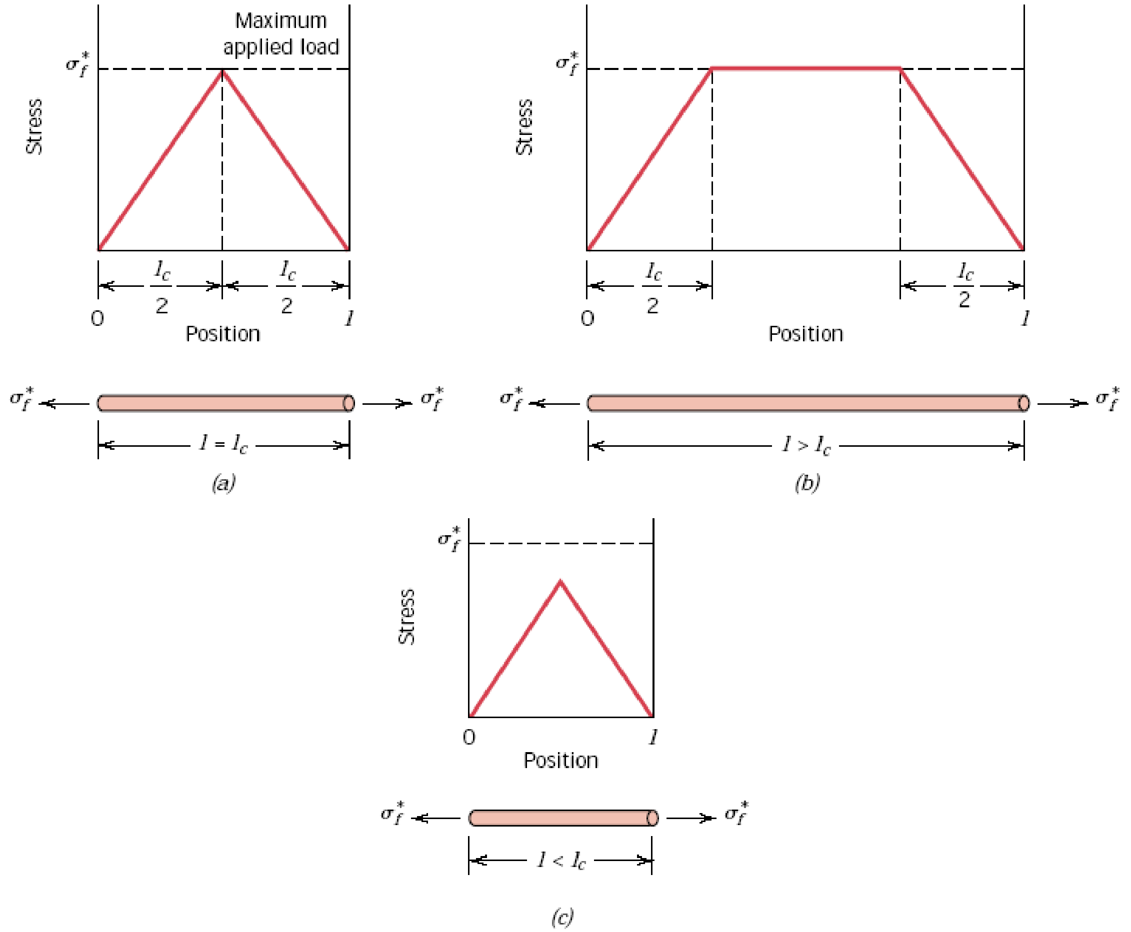
Reforço com fibras



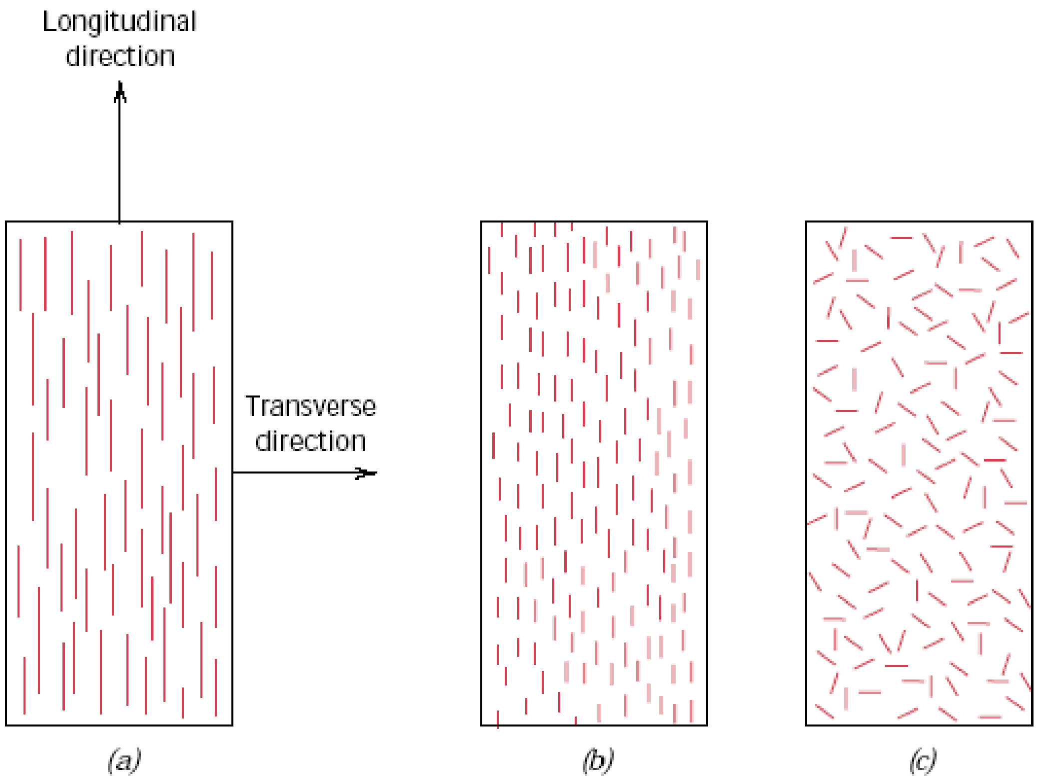
$$l_c = \frac{\sigma_f d}{2\tau_c}$$

Influência do comprimento da fibra

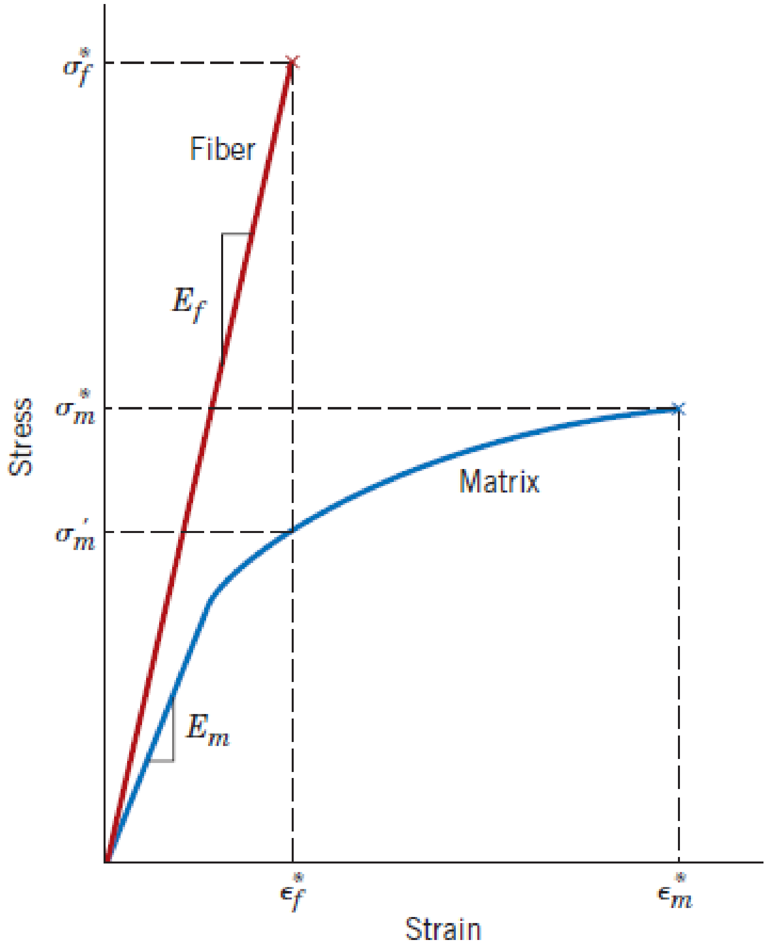
Influência do comprimento

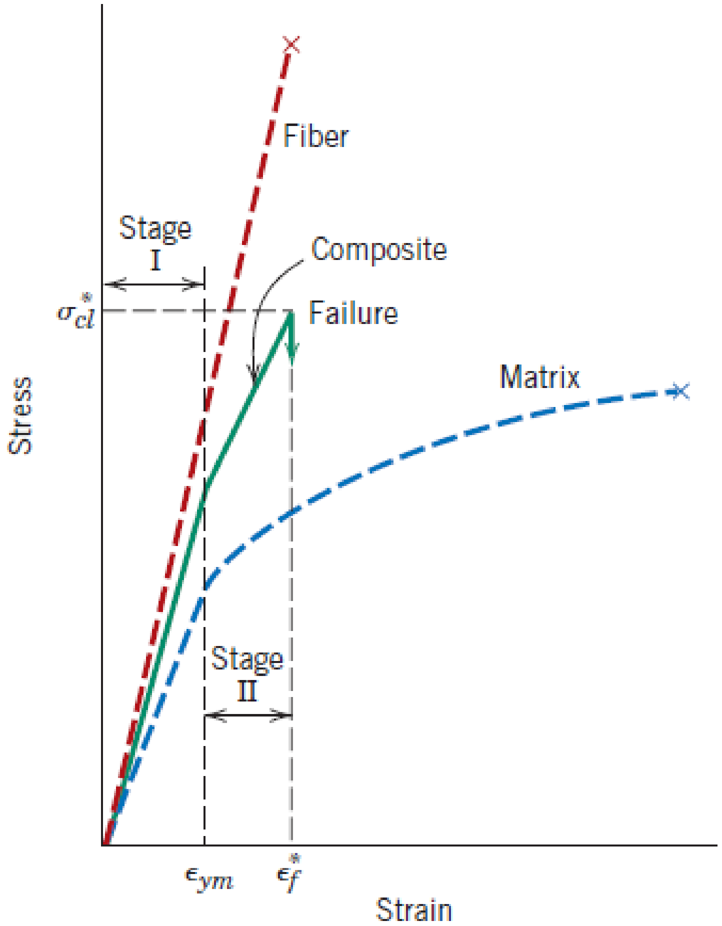


Orientação



Fibras alinhadas





Fibras contínuas e orientadas

Na direção longitudinal:

-Assume-se deformação igual para fibra e matriz:

$$\varepsilon_c = \varepsilon_m = \varepsilon_f$$

Na direção transversal:

-Assume-se tensão igual para fibra e matriz:

$$\sigma_c = \sigma_m = \sigma_f$$

Fibras contínuas orientadas

Direção longitudinal

$$\sigma_c = \upsilon_f \sigma_f + \upsilon_m \sigma_m$$

$$E_c = E_m \upsilon_m + E_f \upsilon_f$$

$$\frac{F_f}{F_m} = \frac{E_f \upsilon_f}{E_m \upsilon_m}$$

Direção Transversal

$$\frac{1}{E_c} = \frac{\upsilon_f}{E_f} + \frac{\upsilon_m}{E_m}$$

Table 15.1 Typical Longitudinal and Transverse Tensile Strengths for Three Unidirectional Fiber-Reinforced Composites. The Fiber Content for Each is Approximately 50 Vol%

Material	*Longitudinal Tensile Strength (MPa)*	*Transverse Tensile Strength (MPa)*
Glass–Polyester	700	20
Carbon (High Modulus)–Epoxy	1000	35
Kevlar–Epoxy	1200	20

Source: D. Hull and T. W. Clyne, *An Introduction to Composite Materials*, 2nd edition, Cambridge University Press, 1996, p. 179.

Fibras descontínuas e alinhadas

Direção longitudinal

para $l > l_c$:

$$\sigma_c^* = \sigma_f^* \upsilon_f \left(1 - \frac{l_c}{2l}\right) + \sigma_m' \upsilon_m$$

para $l < l_c$:

$$\sigma_c^* = \frac{l\tau_c}{d} \upsilon_f + \sigma_m' \upsilon_m$$

Fibras descontínuas e aleatoriamente distribuídas

$$E_c = E_m \upsilon_m + K.E_f \upsilon_f$$

Normalmente 0,1 < K < 0,6

Table 15.3 Reinforcement Efficiency of Fiber-Reinforced Composites for Several Fiber Orientations and at Various Directions of Stress Application

Fiber Orientation	*Stress Direction*	*Reinforcement Efficiency*
All fibers parallel	Parallel to fibers	1
	Perpendicular to fibers	0
Fibers randomly and uniformly distributed within a specific plane	Any direction in the plane of the fibers	$\frac{3}{8}$
Fibers randomly and uniformly distributed within three dimensions in space	Any direction	$\frac{1}{5}$

Source: H. Krenchel, *Fibre Reinforcement,* Copenhagen: Akademisk Forlag, 1964 [33].

Table 15.2 **Properties of Unreinforced and Reinforced Polycarbonates with Randomly Oriented Glass Fibers**

		Fiber Reinforcement (vol%)		
Property	*Unreinforced*	*20*	*30*	*40*
Specific gravity	1.19–1.22	1.35	1.43	1.52
Tensile strength [MPa (ksi)]	59–62 (8.5–9.0)	110 (16)	131 (19)	159 (23)
Modulus of elasticity [GPa (10^6 psi)]	2.24–2.345 (0.325–0.340)	5.93 (0.86)	8.62 (1.25)	11.6 (1.68)
Elongation (%)	90–115	4–6	3–5	3–5
Impact strength, notched Izod (lb_f/in.)	12–16	2.0	2.0	2.5

Source: Adapted from Materials Engineering's *Materials Selector*, copyright © Penton/IPC.

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)]*	*Specific Modulus (GPa)*
		Whiskers			
Graphite	2.2	20 (3)	9.1	700 (100)	318
Silicon nitride	3.2	5–7 (0.75–1.0)	1.56–2.2	350–380 (50–55)	109–118
Aluminum oxide	4.0	10–20 (1–3)	2.5–5.0	700–1500 (100–220)	175–375
Silicon carbide	3.2	20 (3)	6.25	480 (70)	150
		Fibers			
Aluminum oxide	3.95	1.38 (0.2)	0.35	379 (55)	96
Aramid (Kevlar 49)	1.44	3.6–4.1 (0.525–0.600)	2.5–2.85	131 (19)	91
Carbon[a]	1.78–2.15	1.5–4.8 (0.22–0.70)	0.70–2.70	228–724 (32–100)	106–407
E-Glass	2.58	3.45 (0.5)	1.34	72.5 (10.5)	28.1
Boron	2.57	3.6 (0.52)	1.40	400 (60)	156
Silicon carbide	3.0	3.9 (0.57)	1.30	400 (60)	133
UHMWPE (Spectra 900)	0.97	2.6 (0.38)	2.68	117 (17)	121
		Metallic Wires			
High-strength steel	7.9	2.39 (0.35)	0.30	210 (30)	26.6
Molybdenum	10.2	2.2 (0.32)	0.22	324 (47)	31.8
Tungsten	19.3	2.89 (0.42)	0.15	407 (59)	21.1

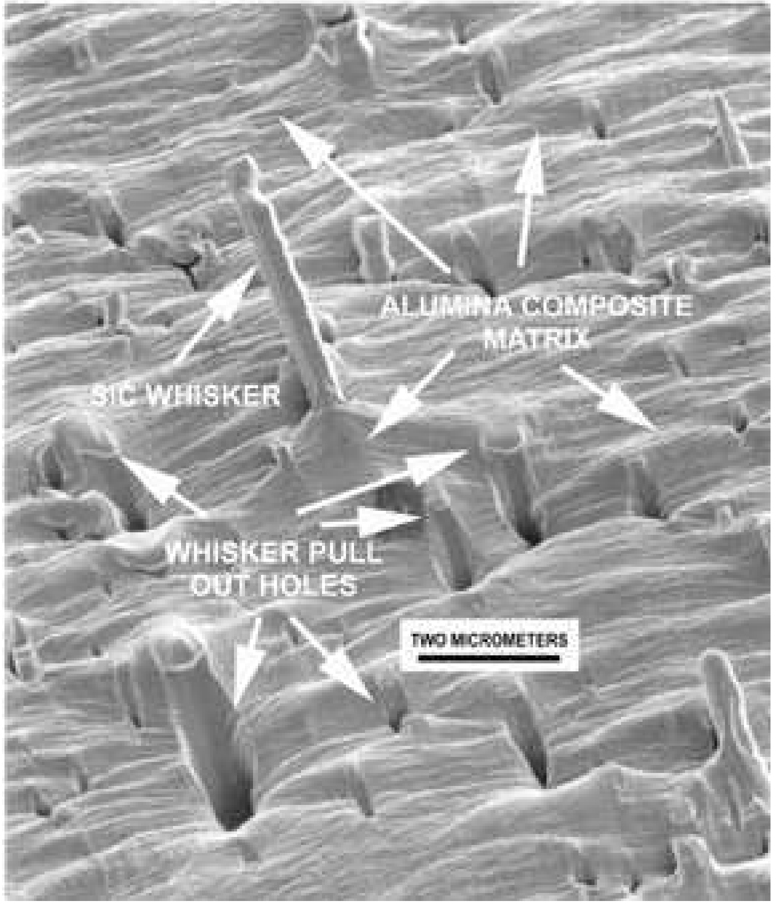
[a] The term "carbon" instead of "graphite" is used to denote these fibers, since they are composed of crystalline graphite regions, and also of noncrystalline material and areas of crystal misalignment.

Table 15.5 Properties of Continuous and Aligned Glass-, Carbon-, and Aramid-fiber Reinforced Epoxy-matrix Composites in Longitudinal and Transverse Directions. In All Cases the Fiber Volume Fraction is 0.60

Property	*Glass (E-glass)*	*Carbon (High Strength)*	*Aramid (Kevlar 49)*
Specific gravity	2.1	1.6	1.4
Tensile modulus			
Longitudinal [GPa (10^6 psi)]	45 (6.5)	145 (21)	76 (11)
Transverse [GPa (10^6 psi)]	12 (1.8)	10 (1.5)	5.5 (0.8)
Tensile strength			
Longitudinal [MPa (ksi)]	1020 (150)	1240 (180)	1380 (200)
Transverse [MPa (ksi)]	40 (5.8)	41 (6)	30 (4.3)
Ultimate tensile strain			
Longitudinal	2.3	0.9	1.8
Transverse	0.4	0.4	0.5

Source: Adapted from R. F. Floral and S. T. Peters, "Composite Structures and Technologies," tutorial notes, 1989.

Fratura de cerâmica com whiskers



"pull out"

Tenacificação com partículas de zircônia