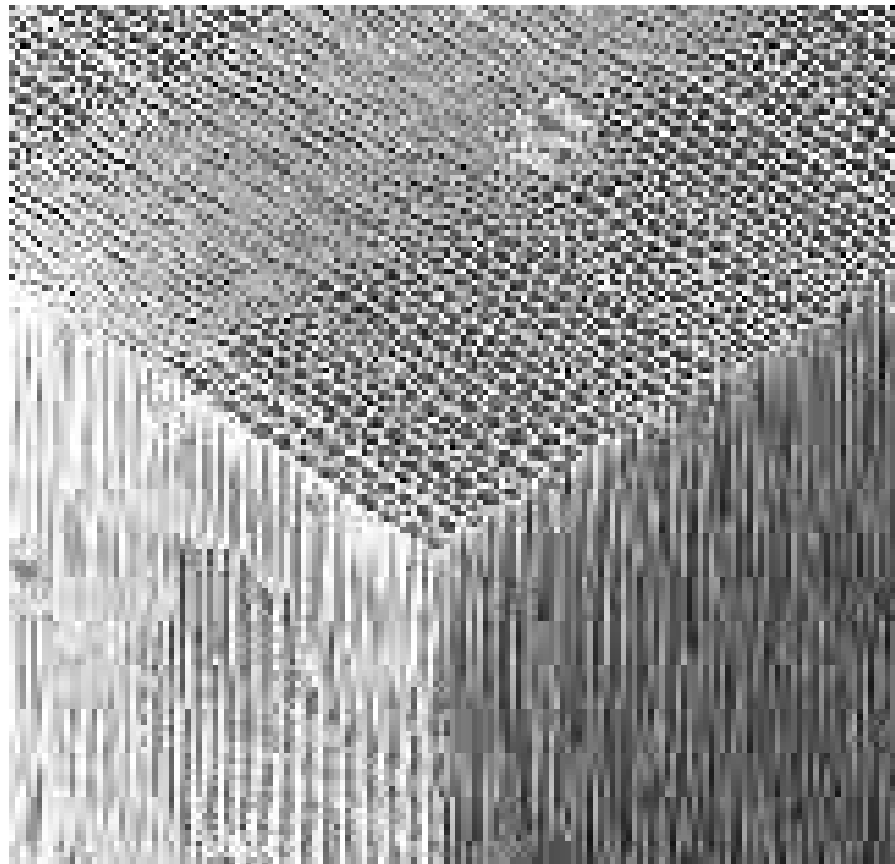


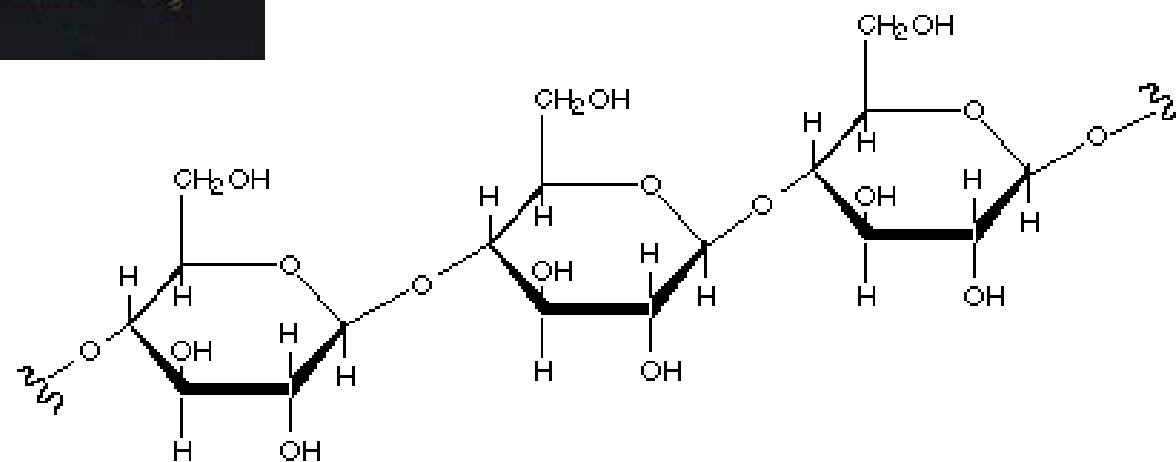
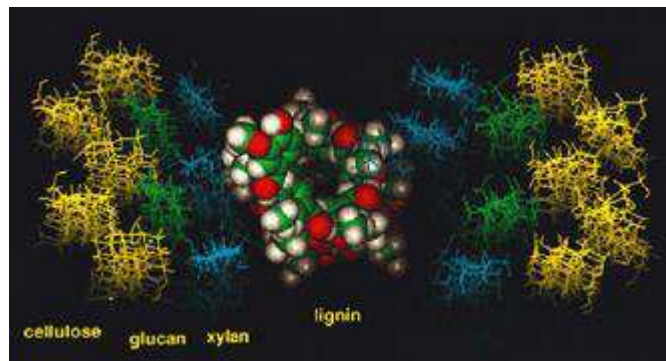
# Compósitos



# Exemplos



# Exemplos

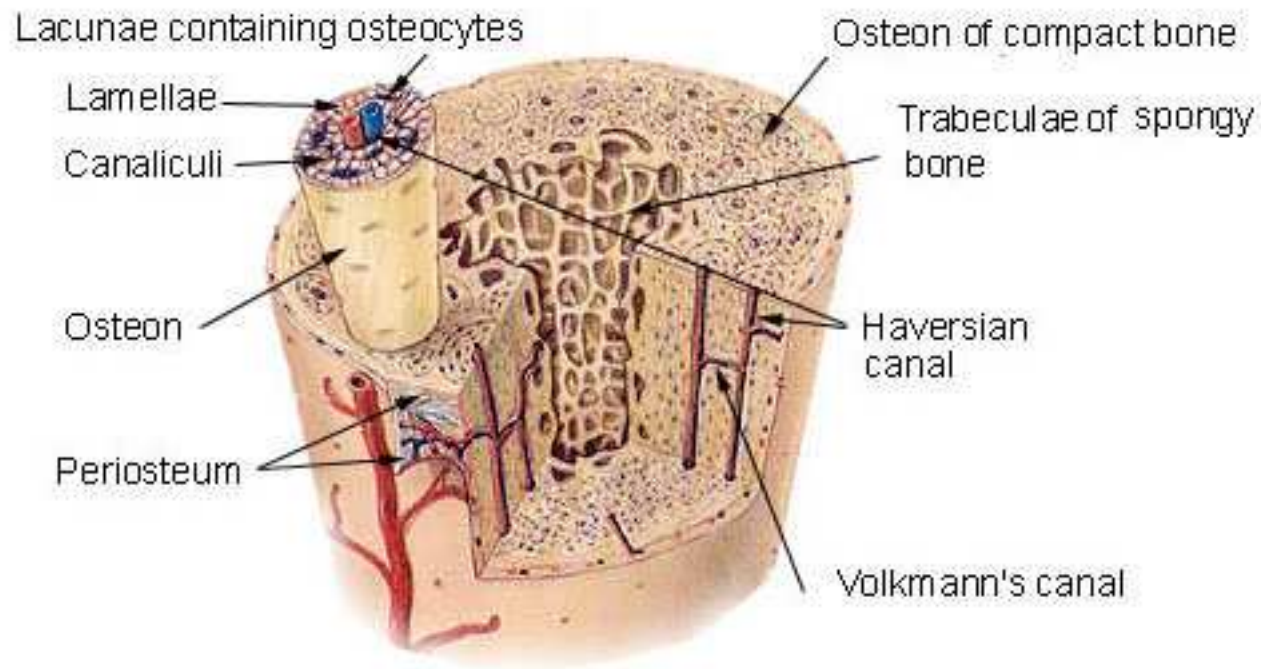


Cellulose

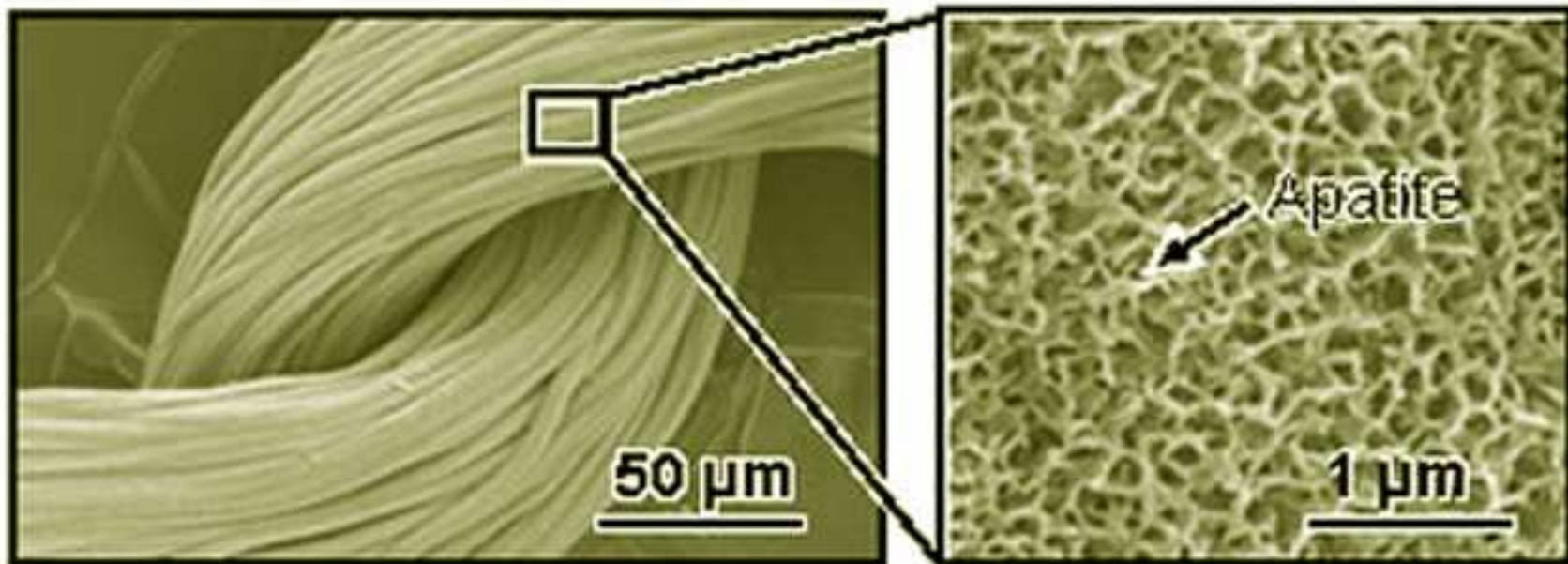
poly (1,4'-O-β-D-glucopyranoside)

# Exemplos

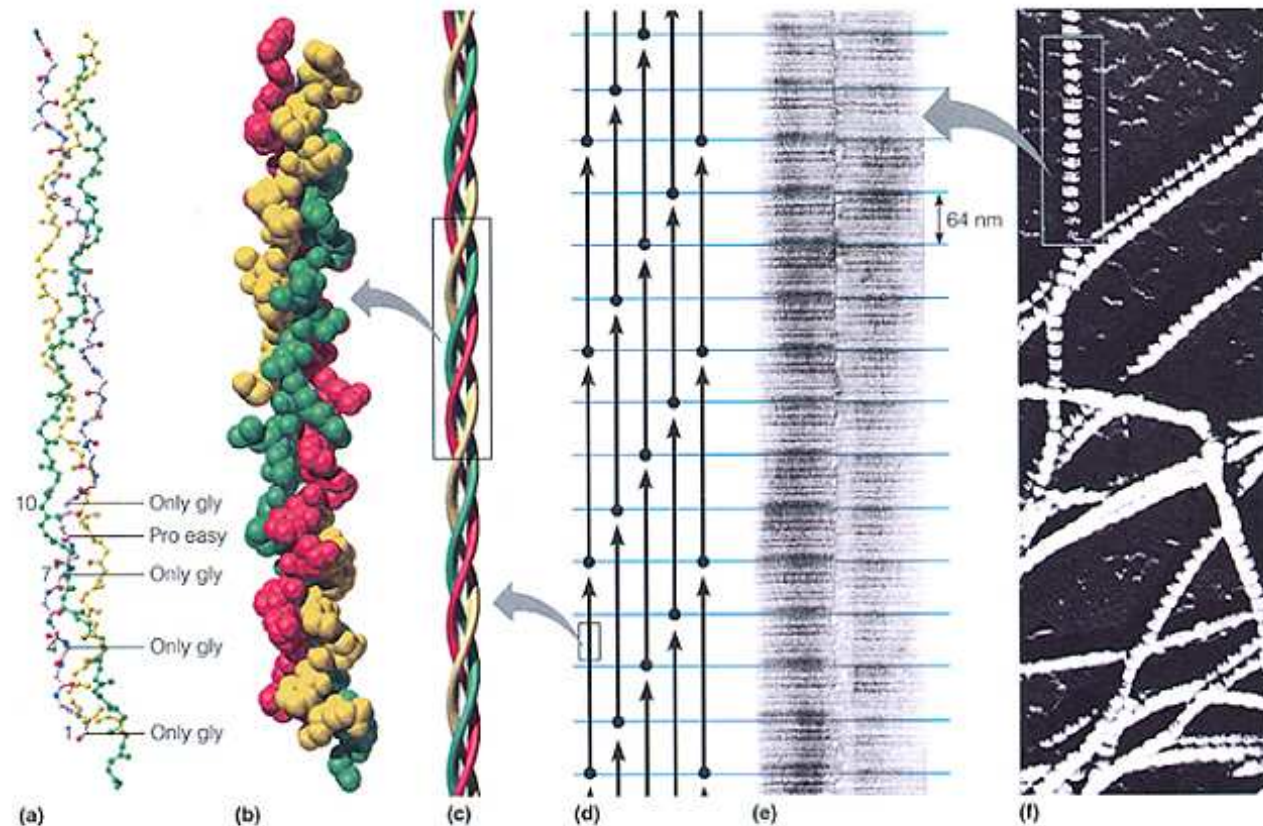
## Compact Bone & Spongy (Cancellous Bone)



# Exemplos

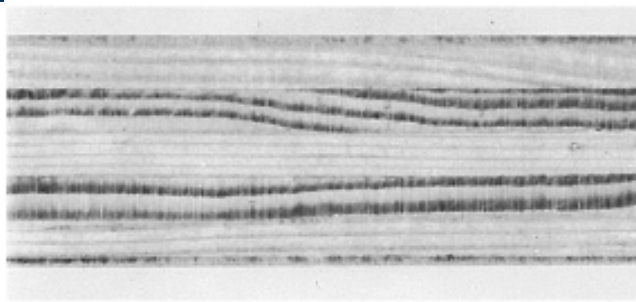


# Exemplos

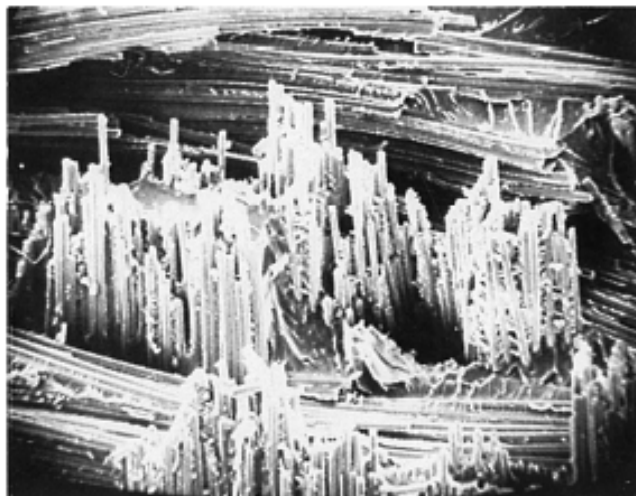


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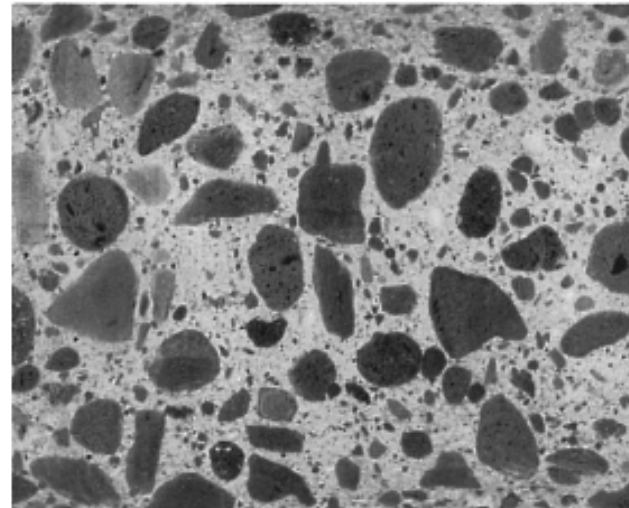
# Exemplos



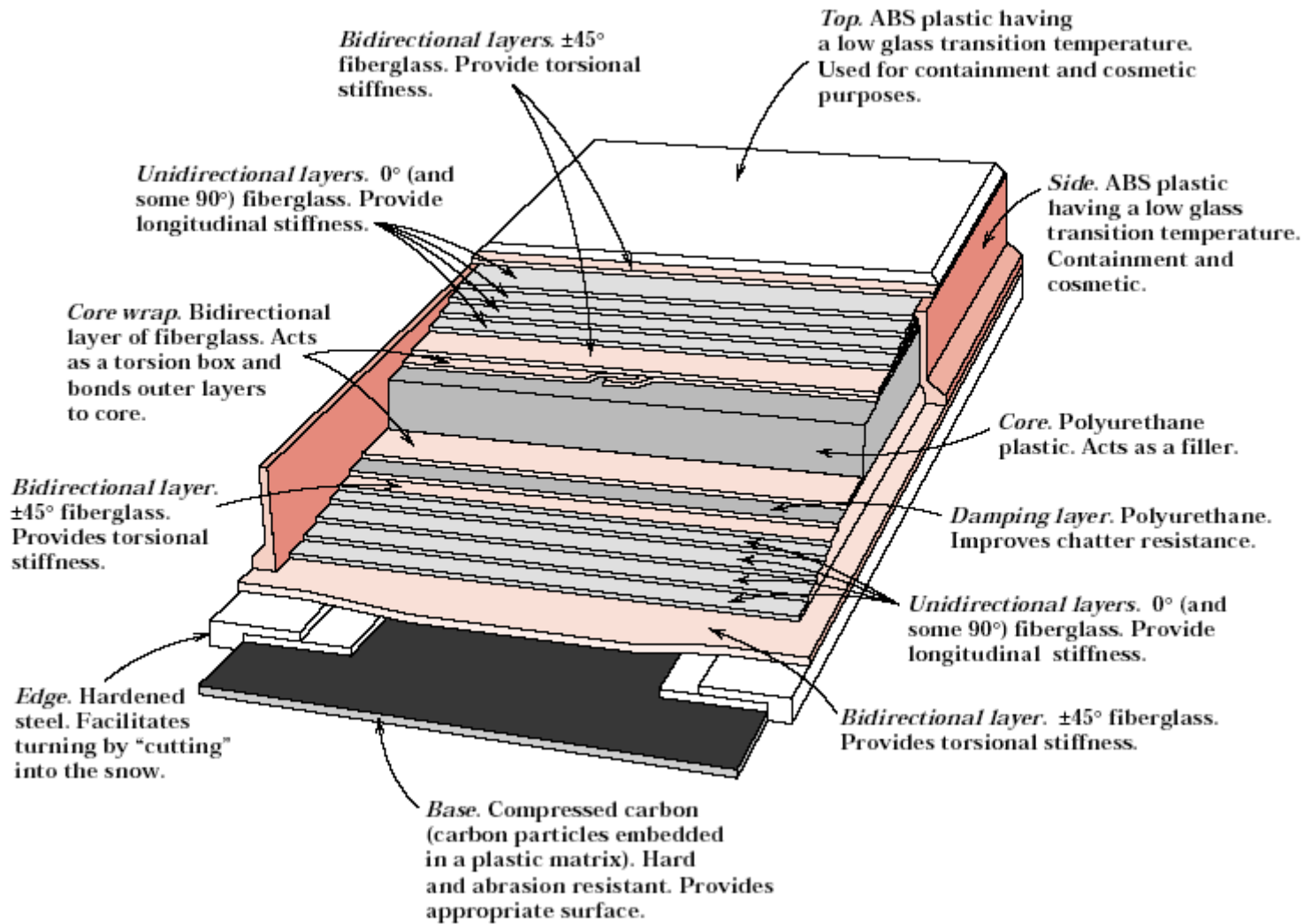
(a)



(b)



(c)





# FIGHTER AIRCRAFT MATERIALS

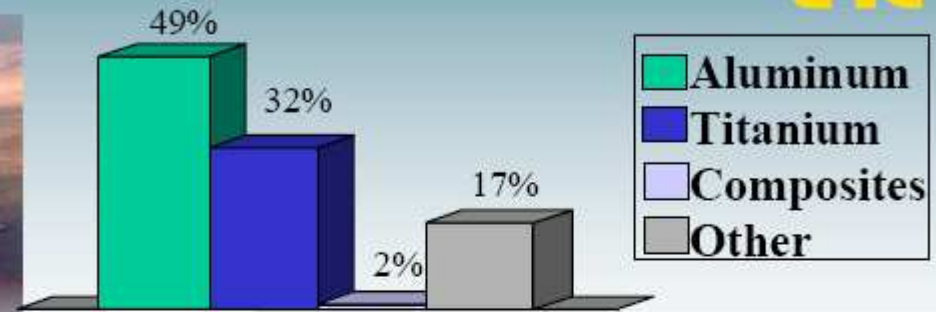
Utilization Of High Cost Airframe Materials Has Been Increasing To Improve Aircraft Performance



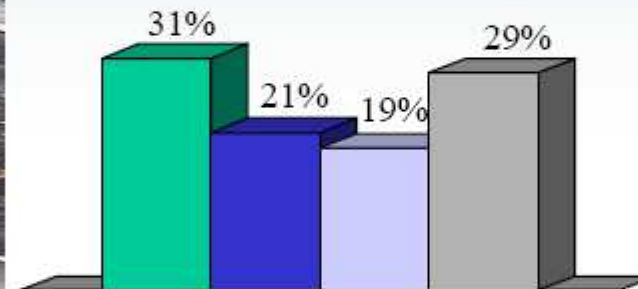
1987



F-15E



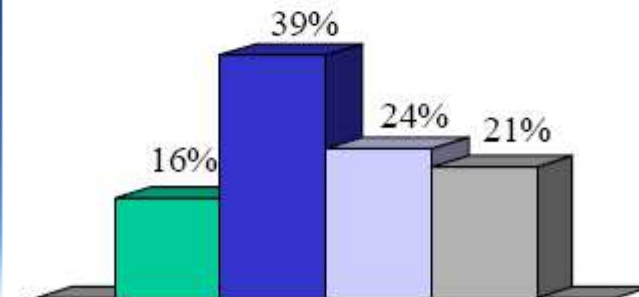
F/A-18E/F



present



F-22



*Affordability Is Now Being Emphasized When Selecting Airframe Materials*

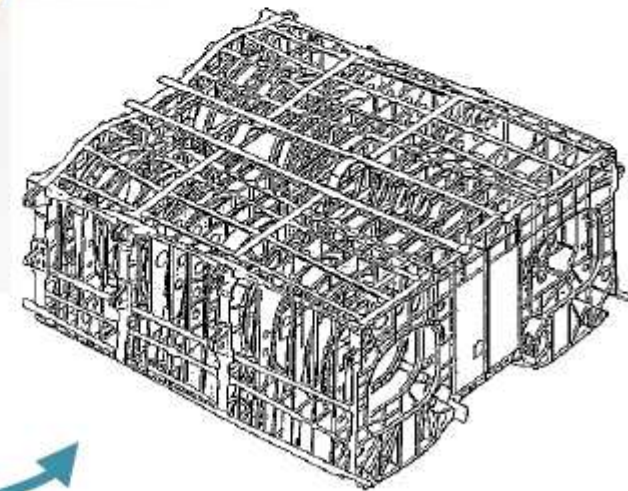
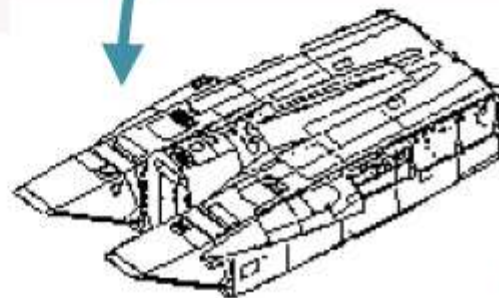
# F-15 SKIN/STRINGER CONSTRUCTION



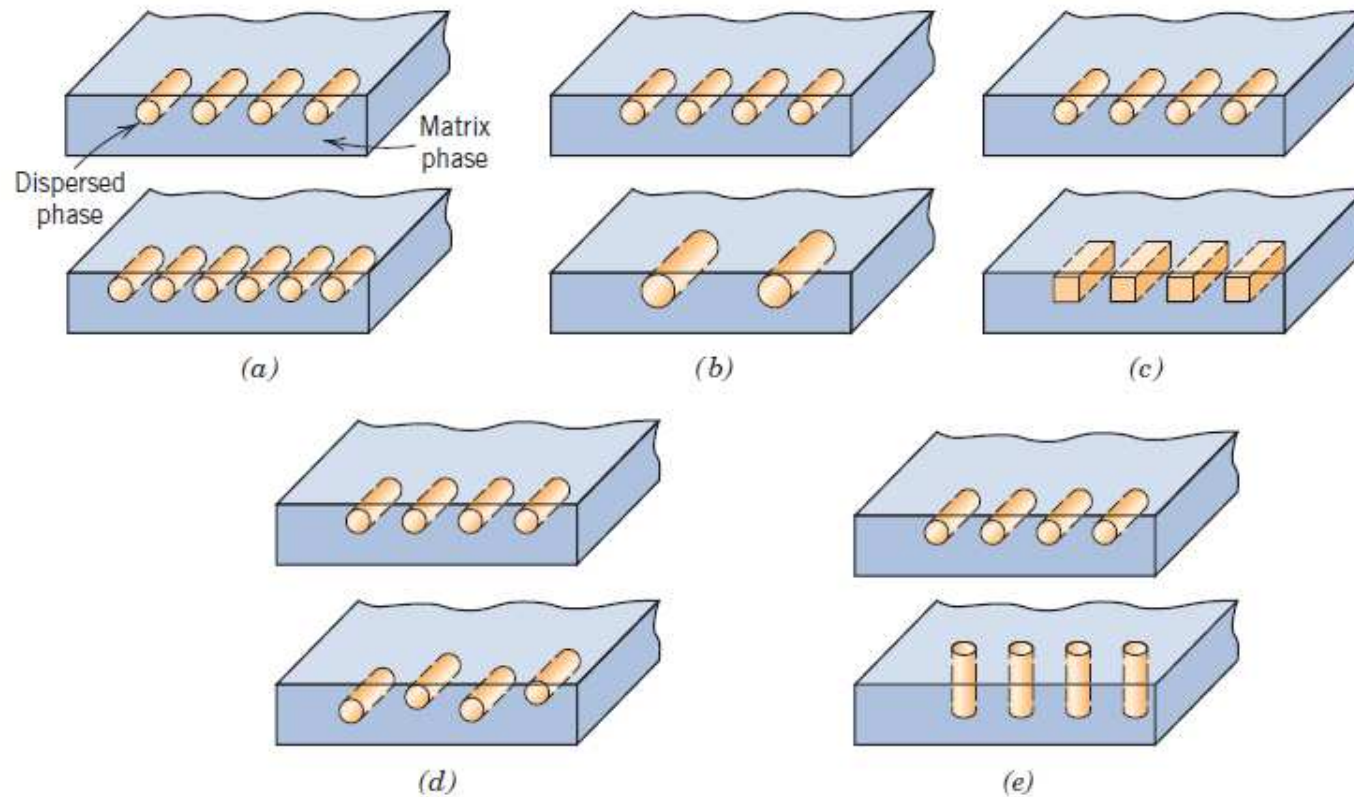
- 48.8%  Aluminum
- 8.5%  Steel
- 32.4%  Titanium
- 0.3%  Graphite/Epoxy
- 1.1%  Boron
- 1.6%  Aluminum Honeycomb
- 7.7%  Other
- 100%



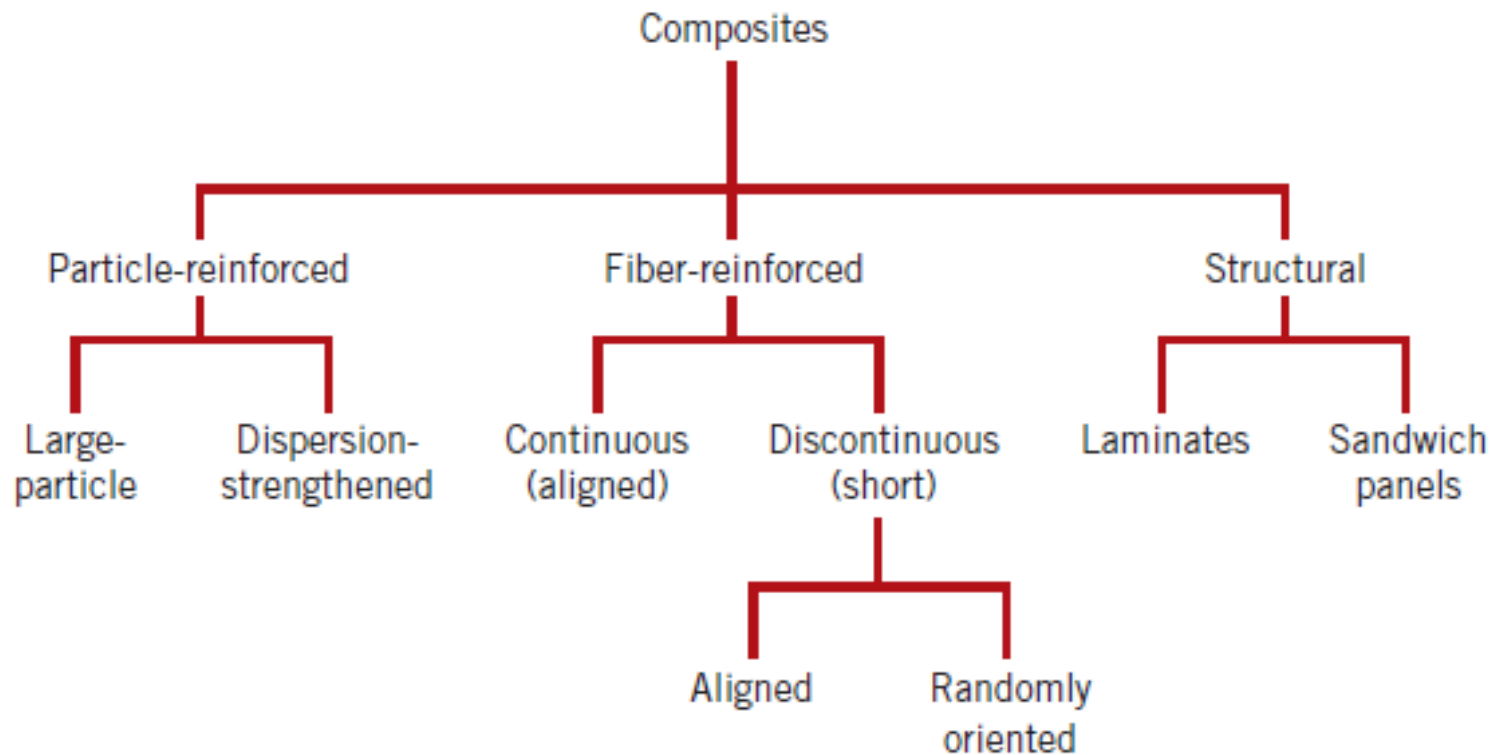
Advanced Metallic  
Materials With Greater  
Structural Efficiency,  
And Processes That  
Produce Complex  
Unitized Components  
*Improve Affordability*



# Geometria, Orientação e Distribuição



# Classificação dos reforços



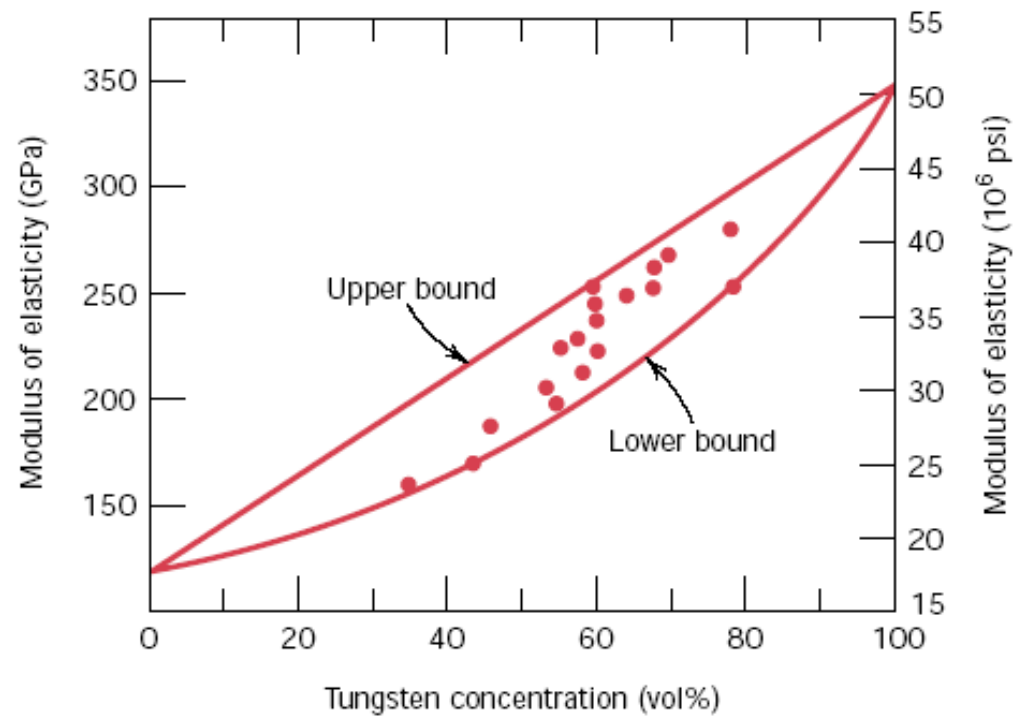
# Reforço com partículas

Regra das misturas

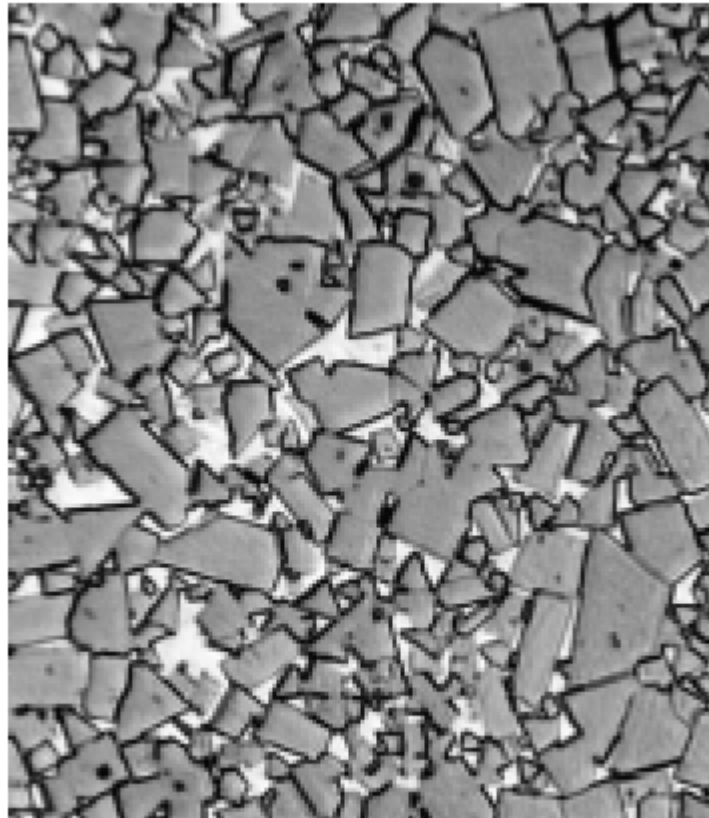
$$E_C (s) = E_m V_m + E_p V_p$$

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

# *Módulo de Elasticidade*

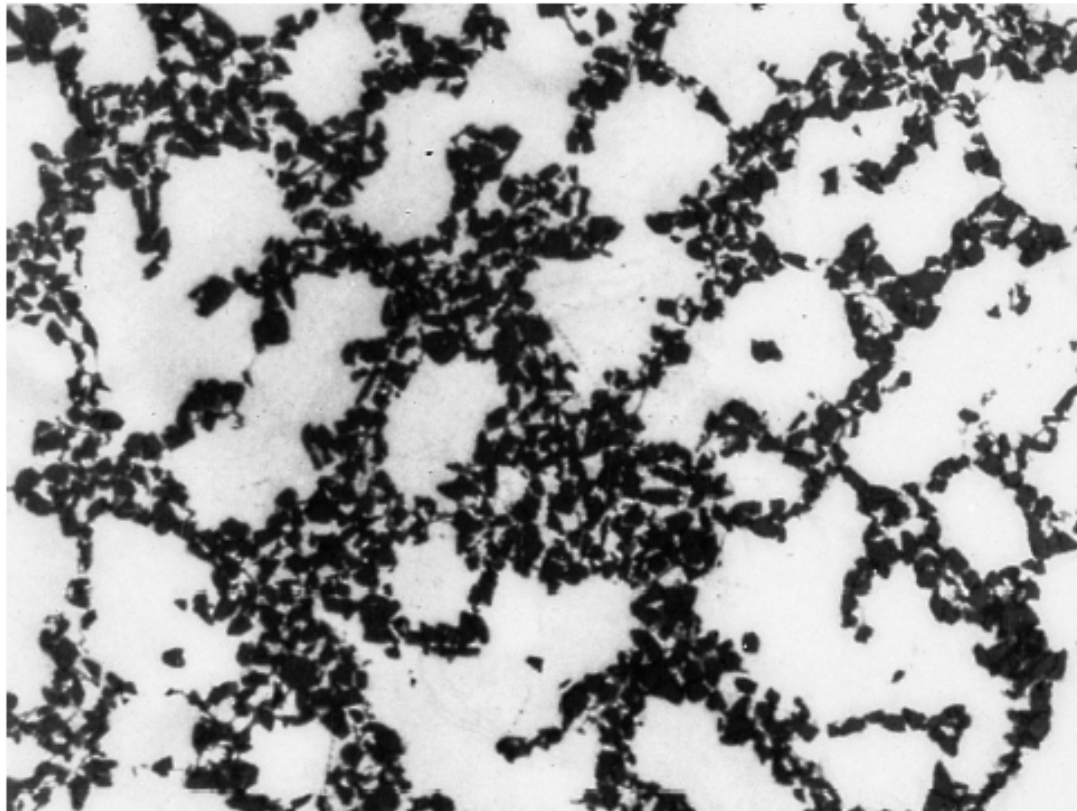


# Exemplos



WC-Co

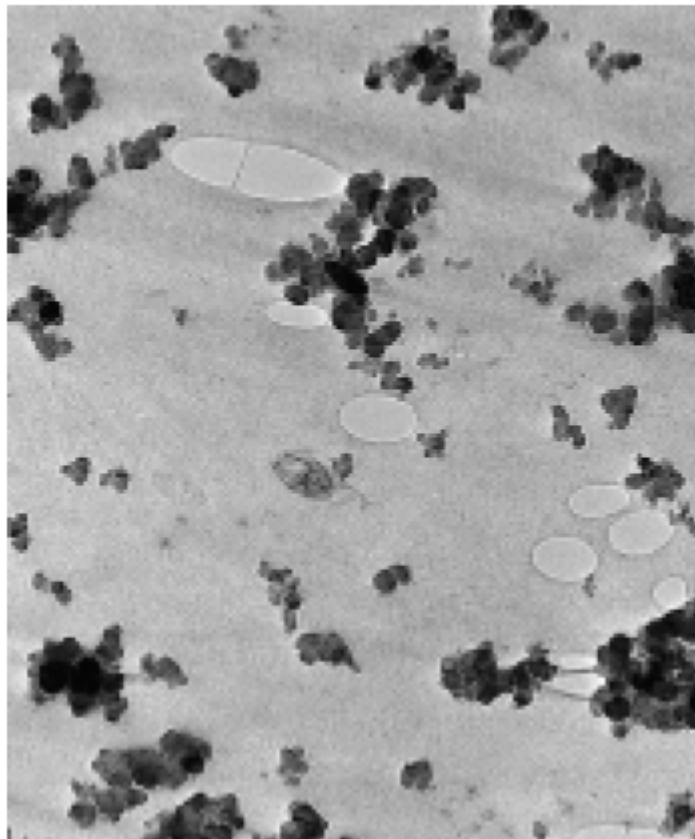
# Exemplos



Al-SiC

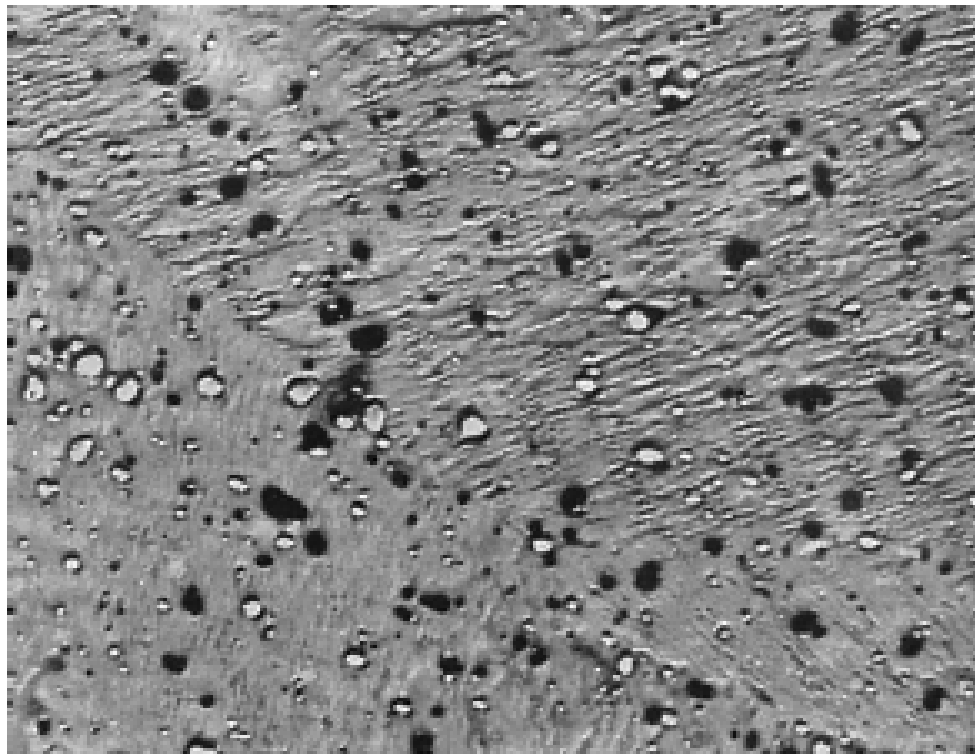


# Exemplos



Borracha com  
Negro de fumo

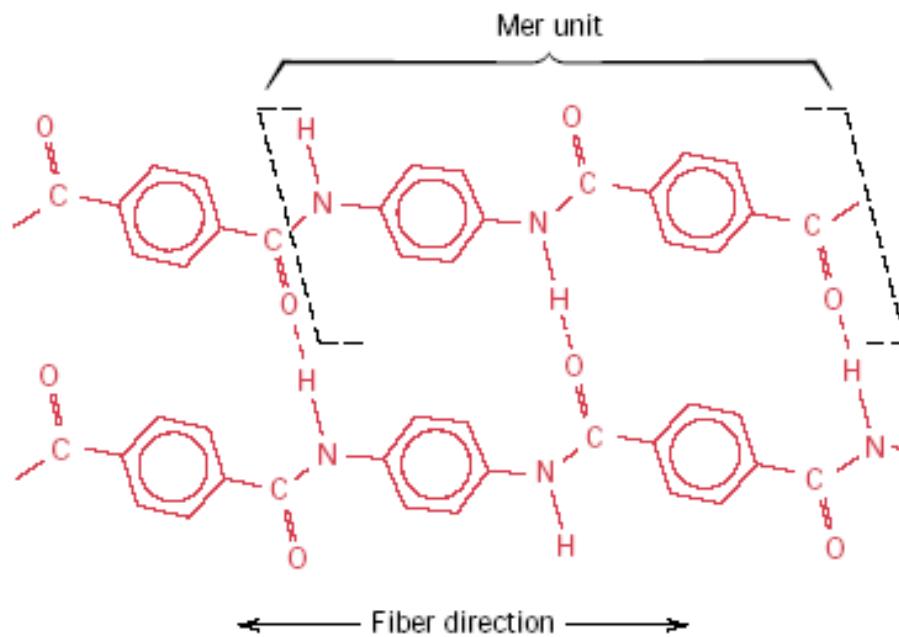
# Exemplos



Ni-ThO

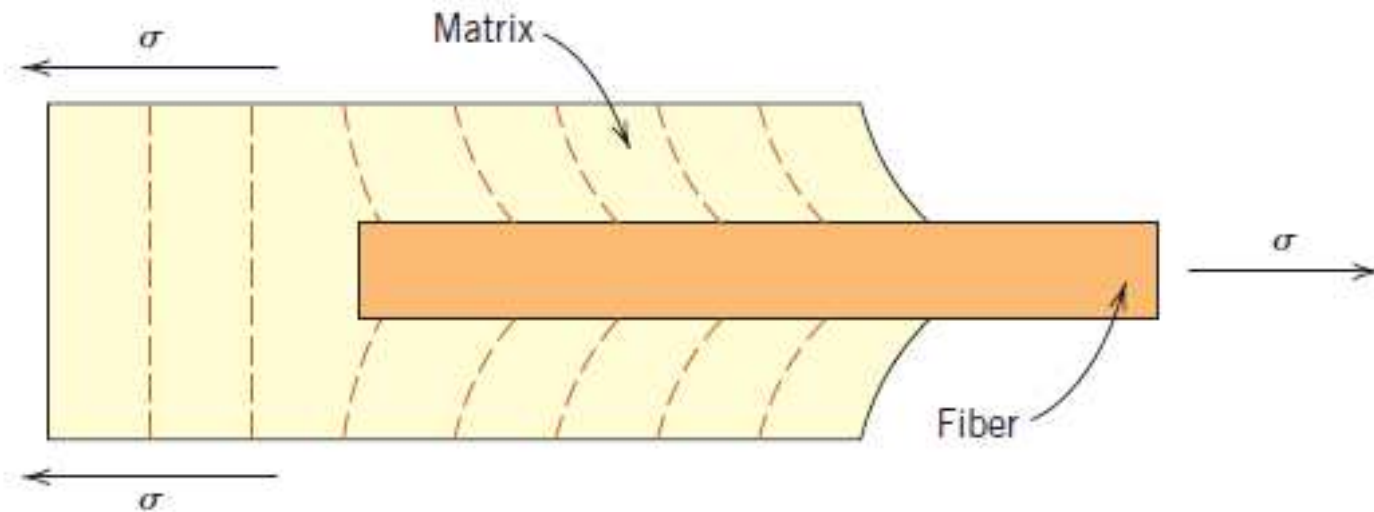
# Reforço com fibras

Por que usar fibras?



Aramida  
(Kevlar)

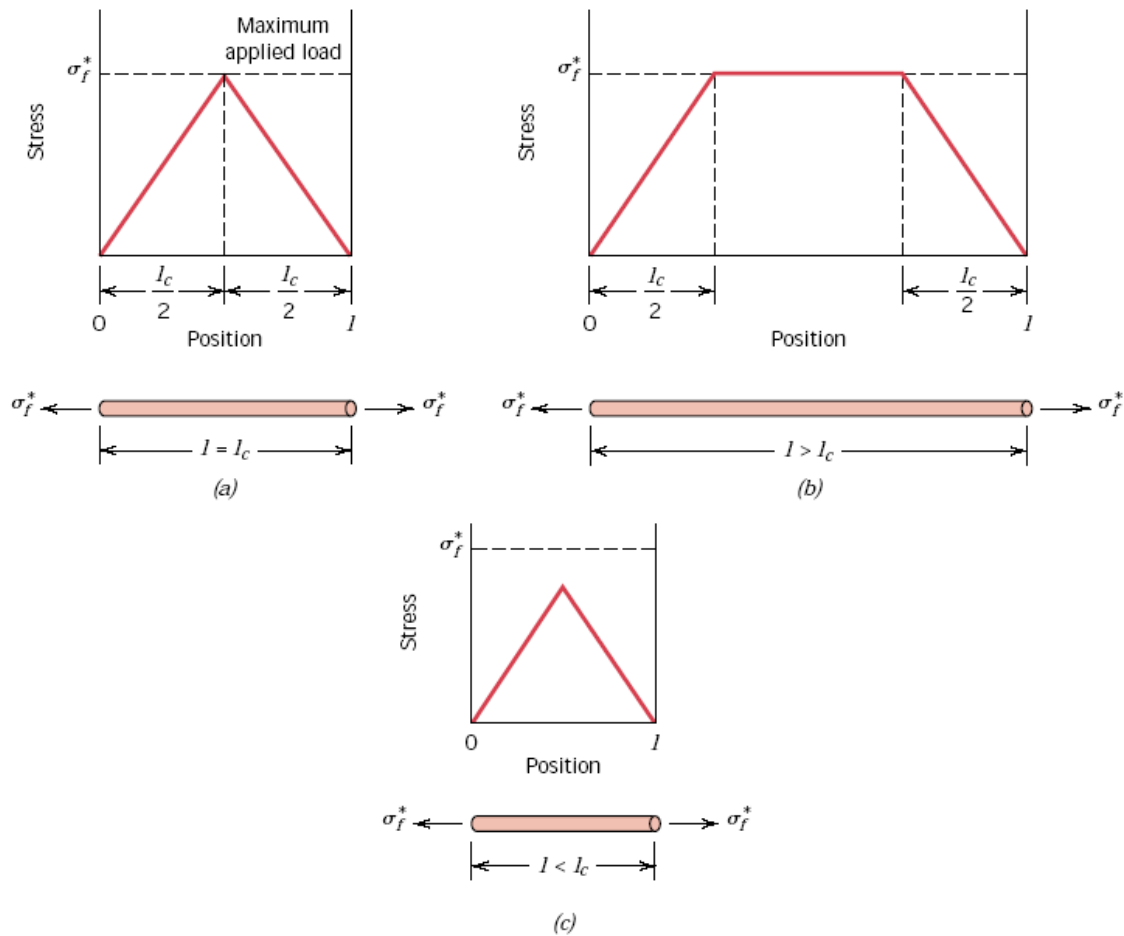
# Reforço com fibras



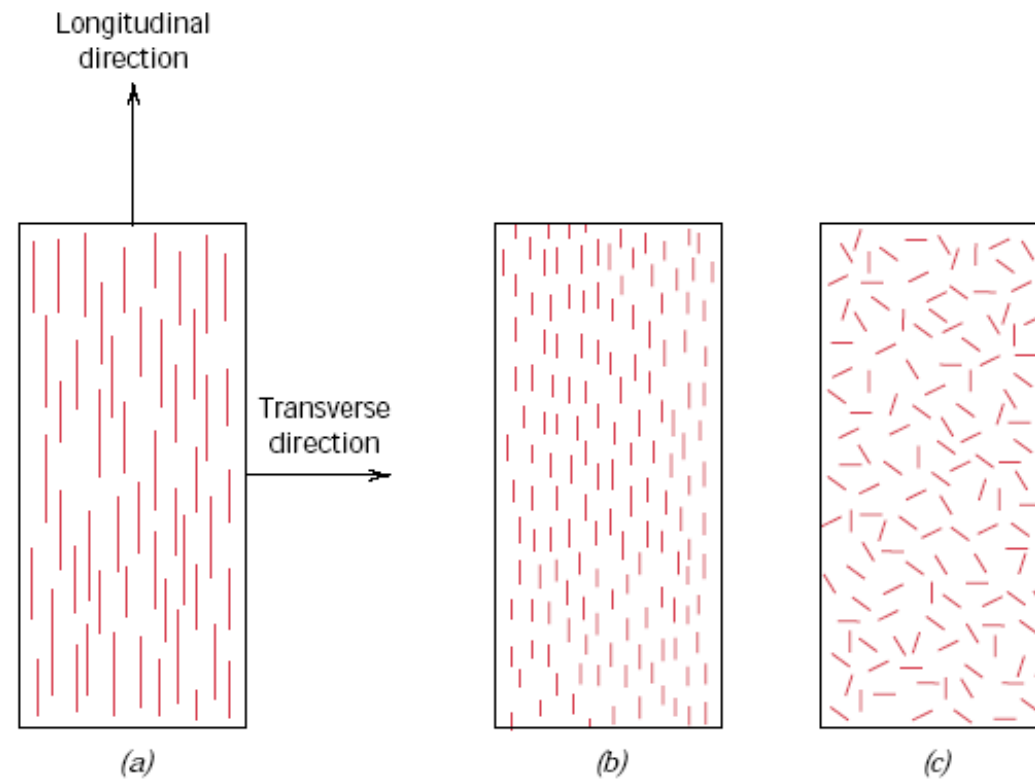
$$l_c = \frac{\sigma_f d}{2\tau_c}$$

Influência do comprimento da fibra

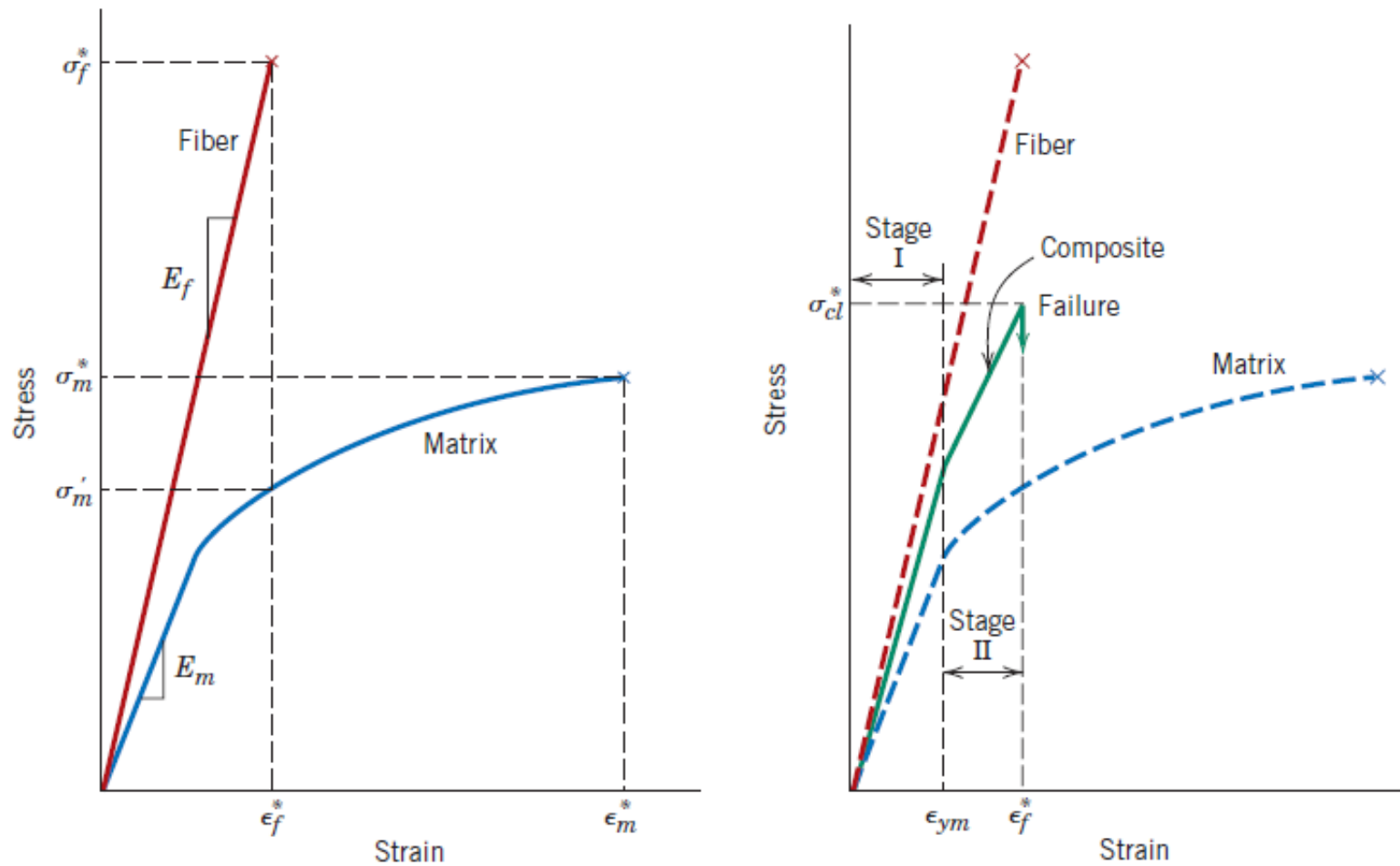
# Influência do comprimento



# 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

$$\begin{aligned}\sigma_c &= \nu_f \sigma_f + \nu_m \sigma_m & \frac{F_f}{F_m} &= \frac{E_f \nu_f}{E_m \nu_m} \\ E_c &= E_m \nu_m + E_f \nu_f\end{aligned}$$

Direção Transversal

$$\frac{1}{E_c} = \frac{\nu_f}{E_f} + \frac{\nu_m}{E_m}$$

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

<i>Material</i>	<i>Longitudinal Tensile Strength (MPa)</i>	<i>Transverse Tensile Strength (MPa)</i>
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

$$\text{para } l > l_c : \quad \sigma_c^* = \sigma_f^* \nu_f \left( 1 - \frac{l_c}{2l} \right) + \sigma_m' \nu_m$$

$$\text{para } l < l_c : \quad \sigma_c^* = \frac{l \tau_c}{d} \nu_f + \sigma_m' \nu_m$$

# Fibras descontinuas e aleatoriamente distribuídas

$$E_c = E_m \nu_m + K \cdot E_f \nu_f$$

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

<i>Fiber Orientation</i>	<i>Stress Direction</i>	<i>Reinforcement Efficiency</i>
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	$\frac{2}{3}$
Fibers randomly and uniformly distributed within three dimensions in space	Any direction	$\frac{1}{3}$

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

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

<i>Property</i>	<i>Unreinforced</i>	<i>Fiber Reinforcement (vol%)</i>		
		<i>20</i>	<i>30</i>	<i>40</i>
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 ( $\text{lb}_f/\text{in.}$ )	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

<i>Material</i>	<i>Specific Gravity</i>	<i>Tensile Strength [GPa (10<sup>6</sup> psi)]</i>	<i>Specific Strength (GPa)</i>	<i>Modulus of Elasticity [GPa (10<sup>6</sup> psi)]</i>	<i>Specific Modulus (GPa)</i>
<i>Whiskers</i>					
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
<i>Fibers</i>					
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 <sup>a</sup>	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
<i>Metallic Wires</i>					
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

<sup>a</sup> 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.

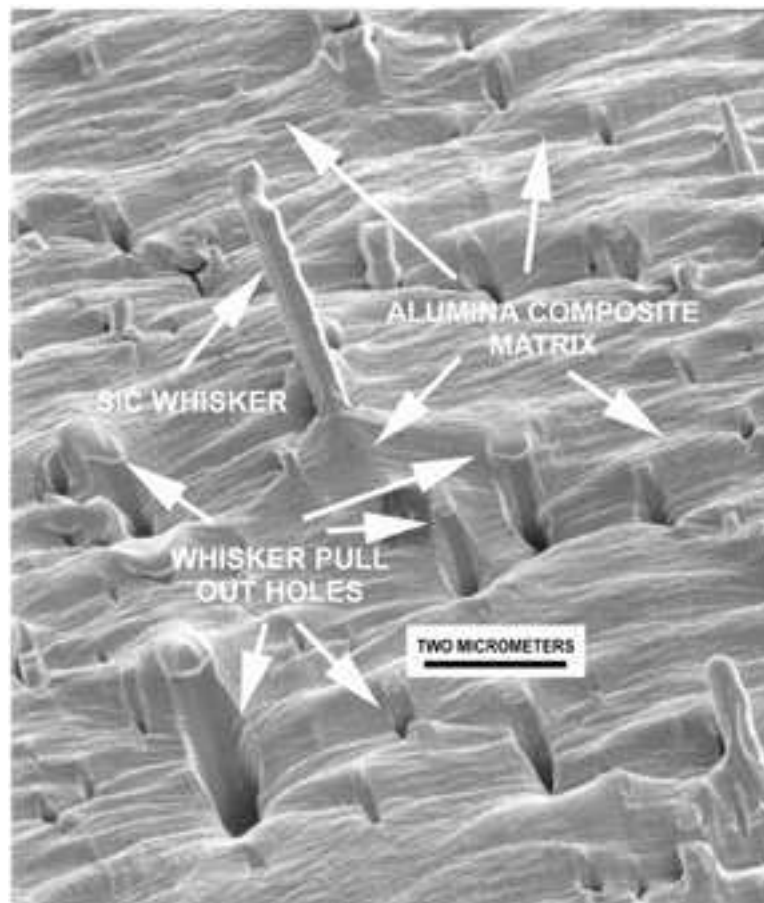
**Table 15.5** Properties of Continuous and Aligned Glass-, Carbon-, and Aramid-fiber Reinforced Epoxy-matrix Composites in Longitudinal and Transverse Directions. In All Cases the Fiber Volume Fraction is 0.60

<i>Property</i>	<i>Glass (E-glass)</i>	<i>Carbon (High Strength)</i>	<i>Aramid (Kevlar 49)</i>
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

