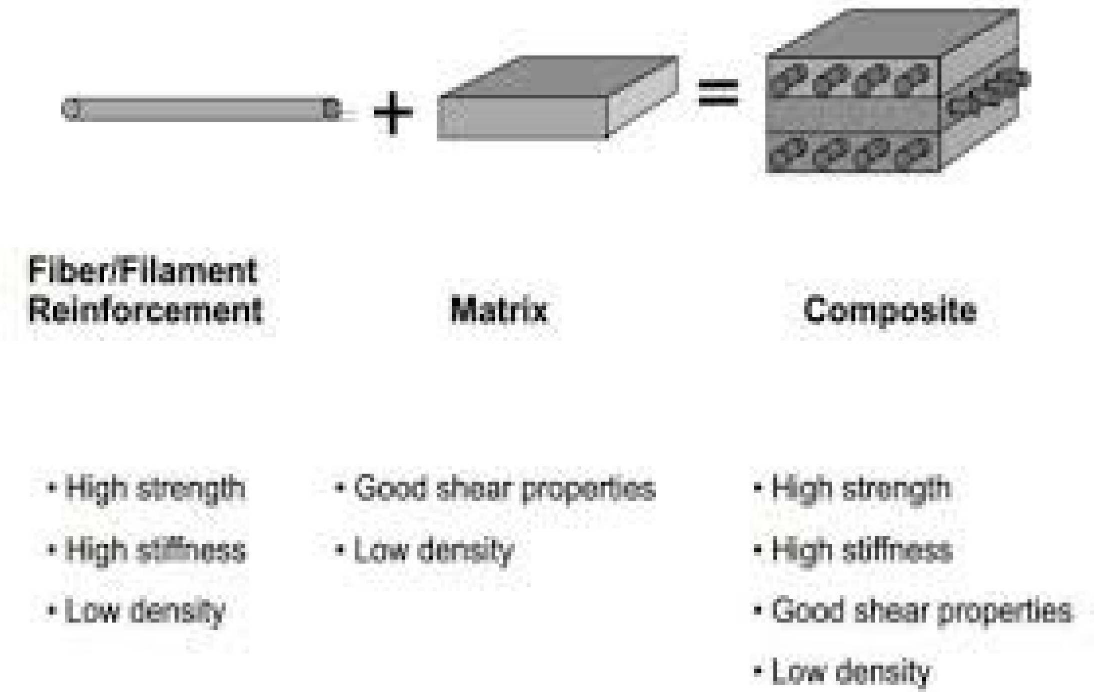
CHAPTER 10

COMPOSITE MATERIALS

What are they?

- Systems composed of two or more components with an interface separating them.
- The components of these materials are insoluble in each other and they have different chemical composition.
- Two phases: Matrix and dispersed phase



- Common Matrix Phase:
- Polymers, Ceramic, metals or Alloys

- Common Disperse phase:
- Powders and fibers

Types

- **Particulate composites:** Contains large amounts of coarse particles. The particulate composites are designed to produce unusual combinations of properties rather than to improve strength
- **Fiber composites:** Most fiber-reinforced composites provide improved strength, fatigue resistance, among other properties. The strength of the composite may be high at both room temperature and elevated temperatures
- **Laminar composites:** Laminar composites include very thin coatings. Designed to improve corrosion resistance while retaining low cost, high strength, or light weight. Other important characteristics include superior wear or abrasion resistance, improved appearance, and unusual thermal expansion characteristics.

Particulate Composites

- **RULE OF MIXTURES**
- $\rho_C = \sum_{i=1}^{n}(f_i\rho_i) = f_1\rho_1 + f_2\rho_2 + \cdots + f_n\rho_n$
- $\frac{\rho_1}{\rho_C} + \frac{\rho_2}{\rho_C} = f_1 + f_2 = 1$

- Examples…

Example

- Spherical silica particles (100 nm in diameter) are added to vulcanized rubber in tires to improve stiffness. If the density of the vulcanized rubber matrix is 1.1 g/cm3, the density of silica is 2.5 g/cm3, and the tire has a porosity of 4.5%, calculate the number of silica particles lost when a tire wears down 0.4 cm in thickness. The density of the tire is 1.2 g/cm3; the overall tire diameter is 63 cm; and it is 10 cm wide.

Calculate the number of silica particles lost when a tire wears down 0.4 cm in thickness

- $\rho(Rubber) = 1.1\frac{g}{cm^3}$
- $\rho(Silica) = 2.5\frac{\text{g}}{\text{cm}^3}$
- $Porosity = 4.5\%$
- $Thickness\ wear = 0.4\ cm$
- $diameter\ Silica = 100nm$
- $Diameter\ tire =$ 63 cm
- $Thickness\ tire = 10\ cm$
- $Density\ composite = 1.2\frac{g}{cm^3}$

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Recap

- Composite Materials: Systems composed of two or more components with an interface separating them. No chemical bonding.

  

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- $\frac{\rho_1}{\rho_C} + \frac{\rho_2}{\rho_C} = f_1 + f_2 = 1$
- Thermal Conductivity
- $k_C = f_2 k_2 + f_1 k_1$

Electric conductivity

$\sigma_c = f_2\sigma_2 + f_1\sigma_1$

Particulate Composites

- CEMENTED CARBIDES: Ceramic particles dispersed in a metallic matrix.
- ABRASIVES: Al_2O_3, SiC and BN bonded by glass, polymer or metallic matrix.
- ELECTRICAL CONTACTS: switches or relays. Metallic matrix
- POLYMERS: Vulcanized rubber! Polymeric matrix.

Fiber composites

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Electric conductivity

$\sigma_c = f_2 \sigma_2 + f_1 \sigma_1$

Example

- A copper–silver bimetallic wire, 1 cm in diameter, is prepared by co–extrusion with copper as the core and silver as the outer layer. The desired properties along the axis parallel to the length of the bimetallic wire are as follows:
- (a) Thermal conductivity > 410 W/(mK);
- (b) Electrical conductivity> 60 * 10^6 1/Ωm;
- (c) Weight< 750 g/m.

	Copper	Silver
Density (g/cm^3)	8.96	10.49
Electrical conductivity ($\Omega^{-1}m^{-1}$)	59×10^6	63×10^6
Thermal conductivity [W/(m–K)]	401	429

Determine the allowed range of the diameter of the copper core.

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Example

- 5 kg of continuous boron fibers are introduced in a unidirectional orientation into 8 kg of an aluminum matrix. Calculate
- (a) the density of the composite,
- (b) the modulus of elasticity parallel to the fibers

Properties	Al	B
Density (g/cm^3)	2.7	2.36
Elasticity modulus (psi)	10×10^6	55×10^6

Determine the density

$w_B = 5000$ g
$w_{Al} = 8000$ g

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Fiber composites

- **Metal-matrix composites:** strengthened by metal or ceramic fibers, provide high temperature resistance. A unique application for metal-matrix composites is in the superconducting wire required for fusion reactors.
- **Ceramic-Matrix Composites:** contain ceramic fibers in a ceramic matrix are also finding applications. Two important uses will be discussed to illustrate the unique properties that can be obtained with these materials.

Laminar Composites

- **Laminates:** are layers of materials joined by an organic adhesive. Laminates are used for insulation in motors, for gears, for printed circuit boards, and for decorative items such as Formica® countertops and furniture.
- **Clad Metals:** are metal-metal composites. Clad materials provide a combination of good corrosion resistance with high strength.
- **Multilayer Capacitors:** A laminar geometry is used to make enormous numbers of multilayer capacitors.