The Science and Engineering of Materials, 4th ed

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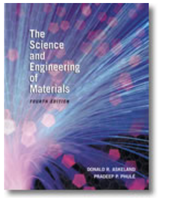
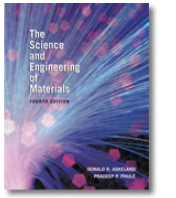
Chapter 1 – Introduction to Materials Science and Engineering

Objectives of Chapter 1



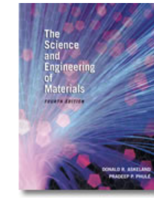
- Introduce the field of materials science and engineering (MSE)
- Provide introduction to the classification of materials

Chapter Outline

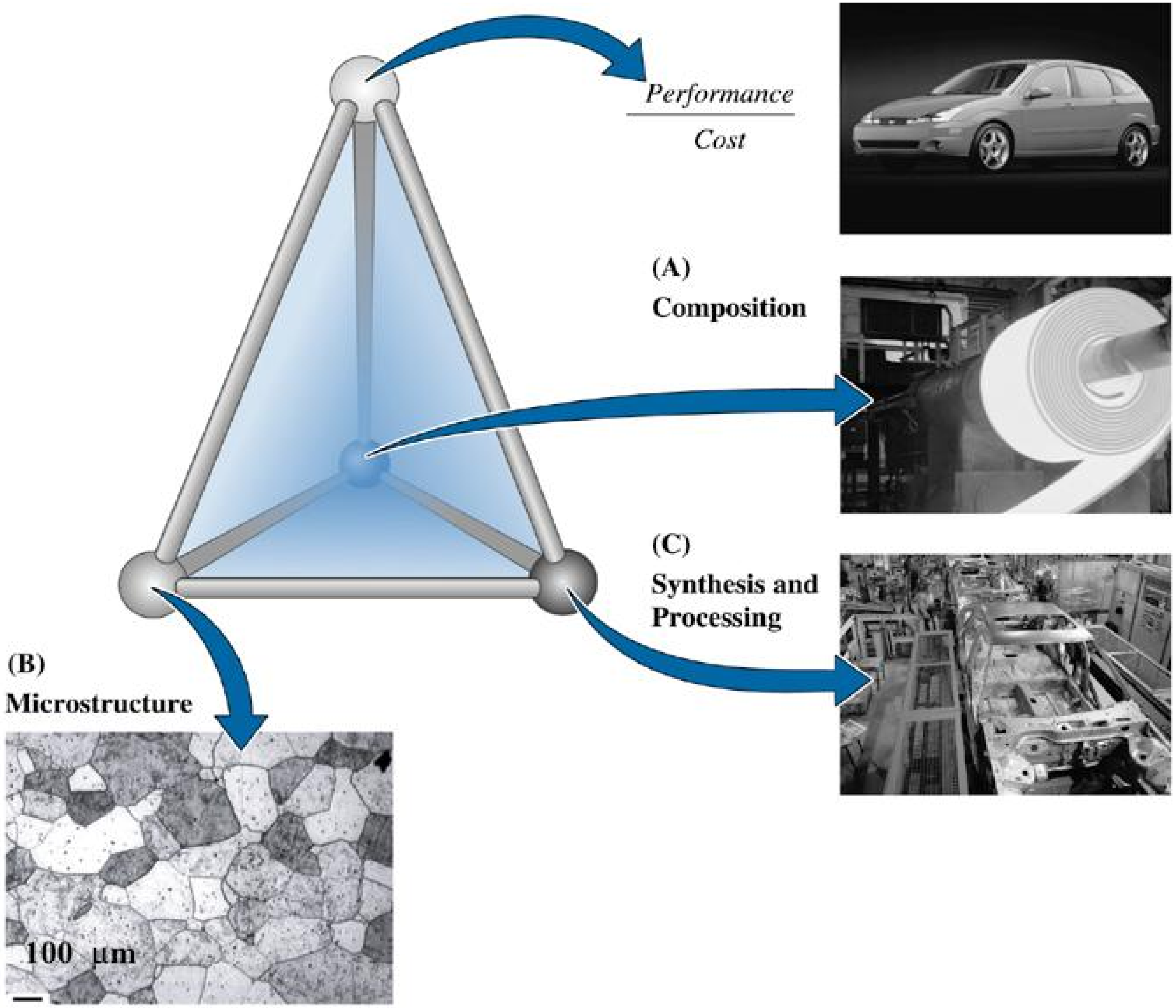


- 1.1 What is Materials Science and Engineering?
- 1.2 Classification of Materials
- 1.3 Functional Classification of Materials
- 1.4 Classification of Materials Based on Structure
- 1.5 Environmental and Other Effects
- 1.6 Materials Design and Selection

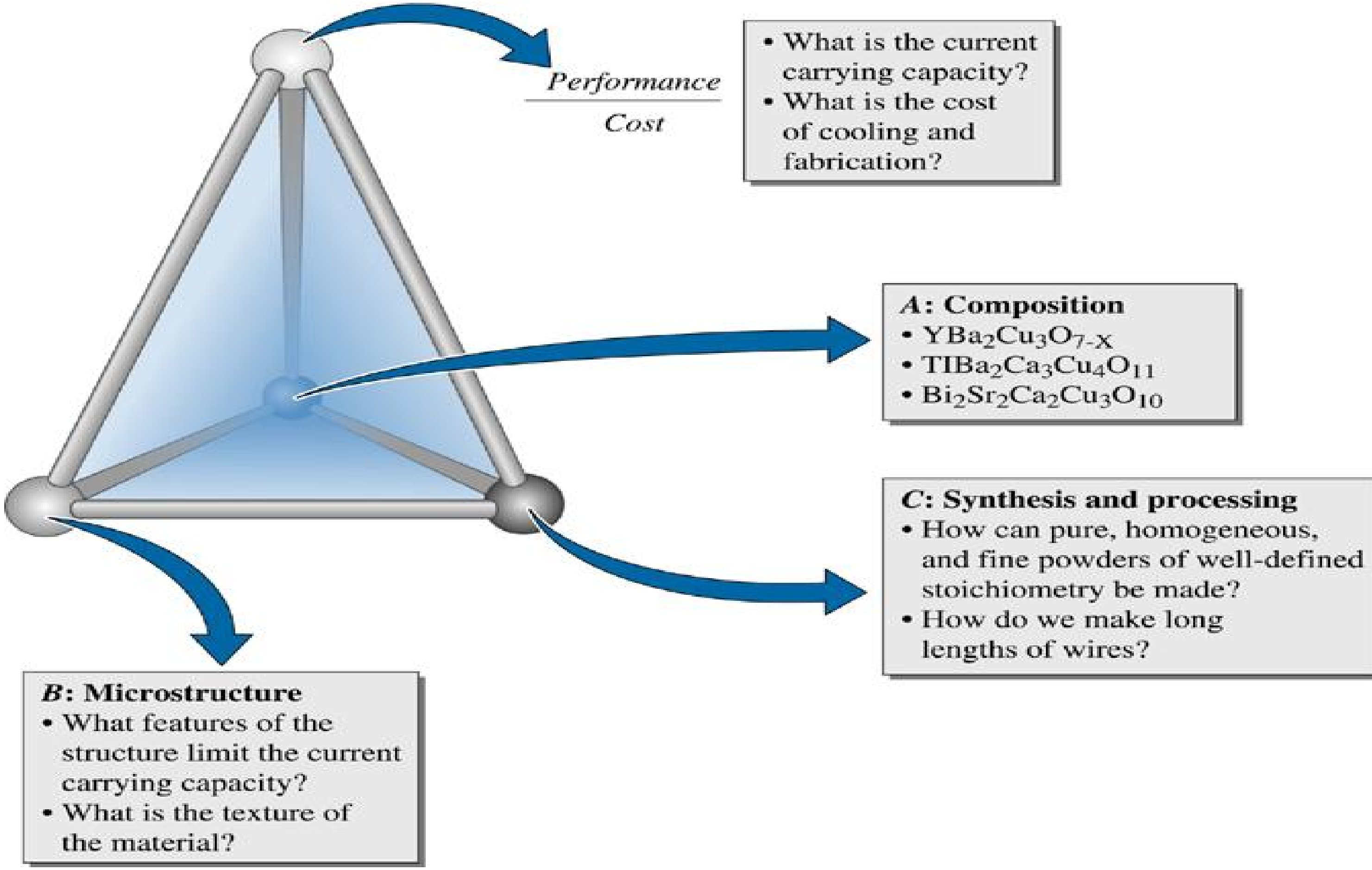
Section 1.1
What is Materials Science and Engineering?



- Materials Science and Engineering
- Composition means the chemical make-up of a material.
- Structure means a description of the arrangements of atoms or ions in a material.
- Synthesis is the process by which materials are made from naturally occurring or other chemicals.
- Processing means different ways for shaping materials into useful components or changing their properties.



Introduction to Chapter 1



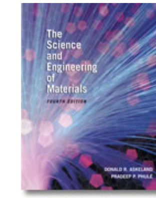
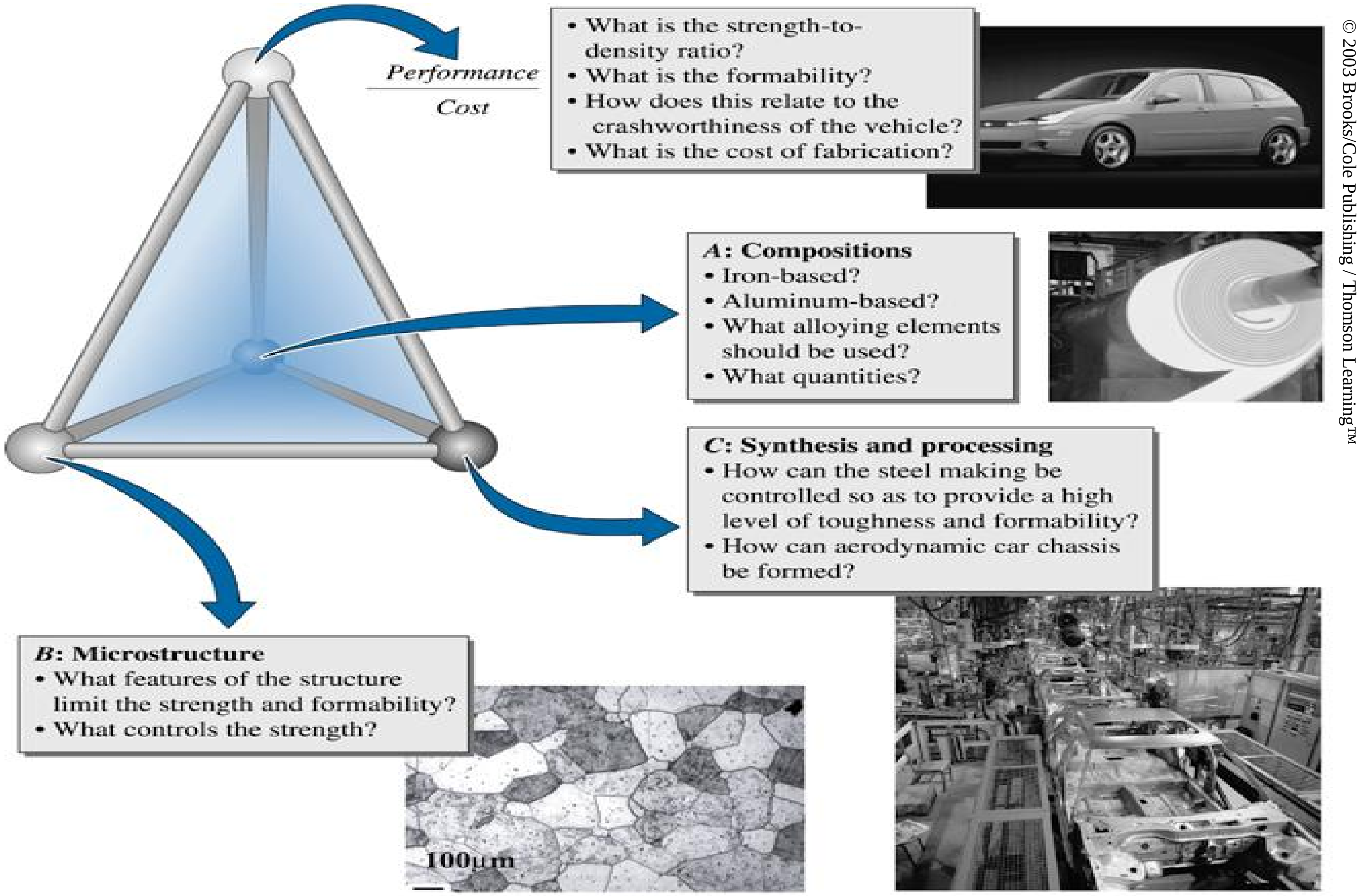


Figure 1.1 Application of the tetrahedron of materials science and engineering to ceramic superconductors. Note that the microstructure-synthesis and processing-composition are all interconnected and affect the performance-to-cost ratio



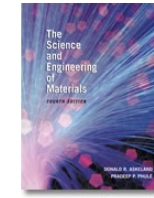
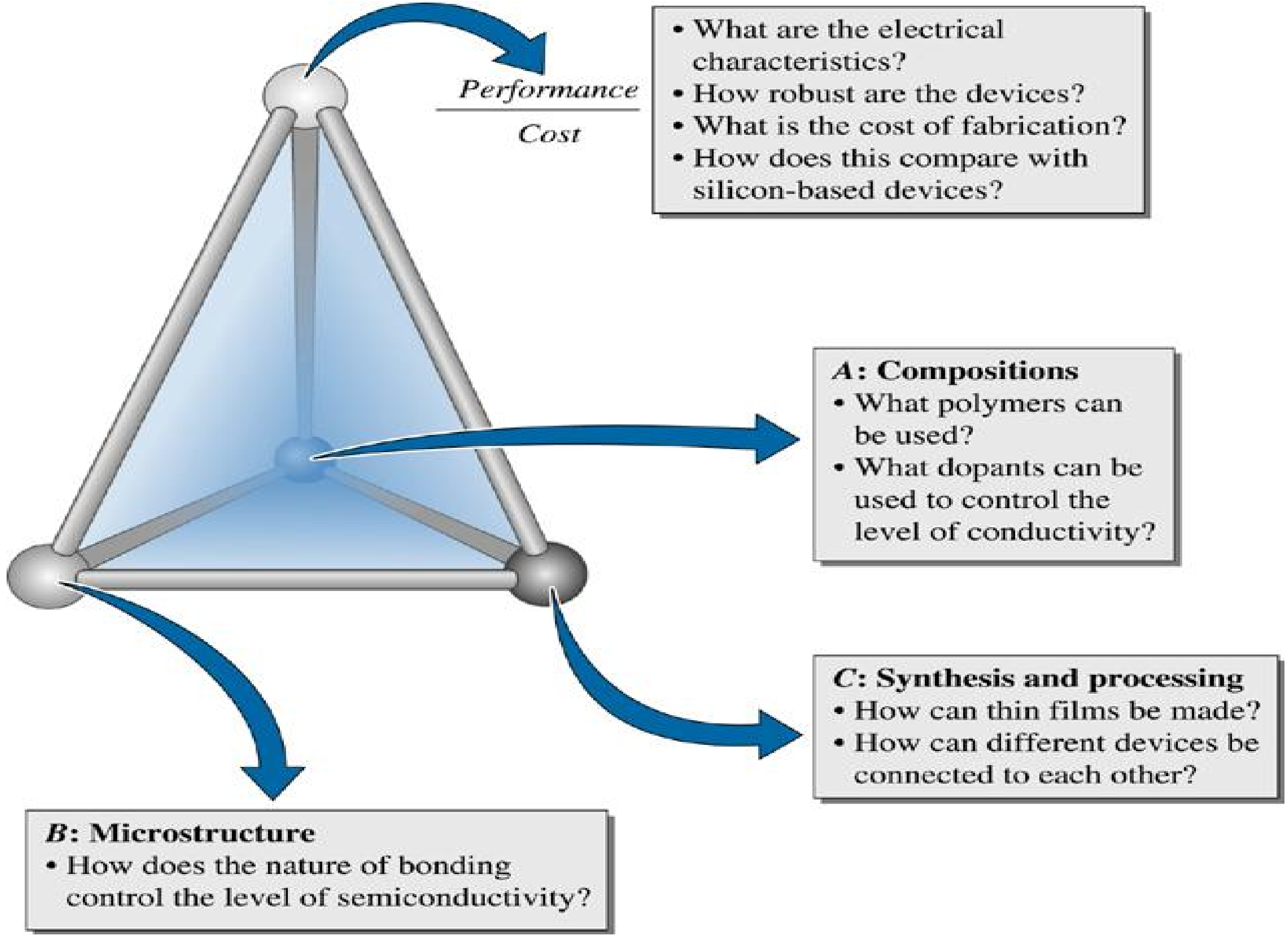


Figure 1.2 Application of the tetrahedron of materials science and engineering to sheet steels for automotive chassis. Note that the microstructure-synthesis and processing-composition are all interconnected and affect the performance-to-cost ratio



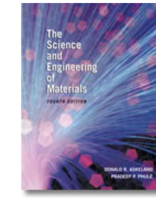
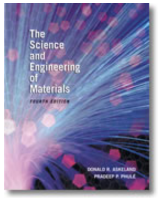


Figure 1.3 Application of the tetrahedron of materials science and engineering to semiconducting polymers for microelectronics

Section 1.2
Classification of Materials



- Metals and Alloys
- Ceramics, Glasses,and Glass-ceramics
- Polymers (plastics), Thermoplastics and Thermosets
- Semiconductors
- Composite Materials

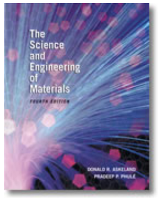
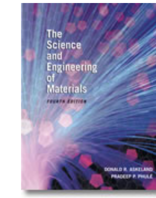


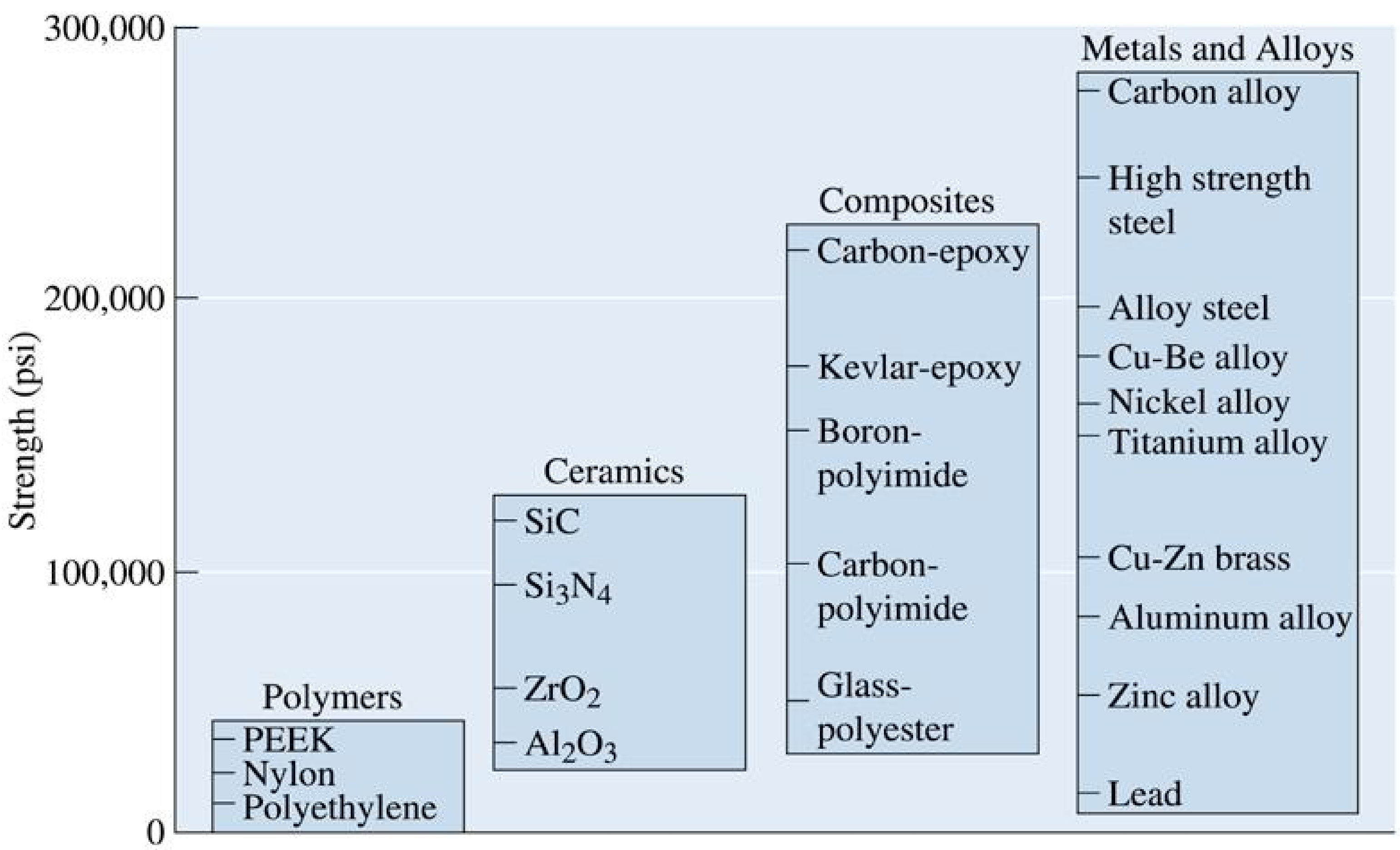
Table 1.1 Representative examples, applications, and properties for each category of materials

	Example of Applications	Properties
Metals and Alloys		
Gray cast iron	Automobile engine blocks	Castable, machinable, vibration damping
Ceramics and Glasses		
SiO_2-Na_2O-CaO	Window glass	Optically transparent, thermally insulating
Polymers		
Polyethylene	Food packaging	Easily formed into thin, flexible, airtight film

Table 1.1 Continued



	Example of Applications	Properties
Semiconductors Silicon	Transistors and integrated circuits	Unique electrical behavior
Composites Tungsten carbide -cobalt (WC-Co)	Carbide cutting tools for machining	High hardness, yet good shock resistance



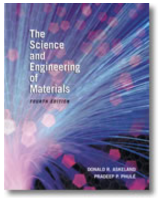


Figure 1.4 Representative strengths of various categories of materials

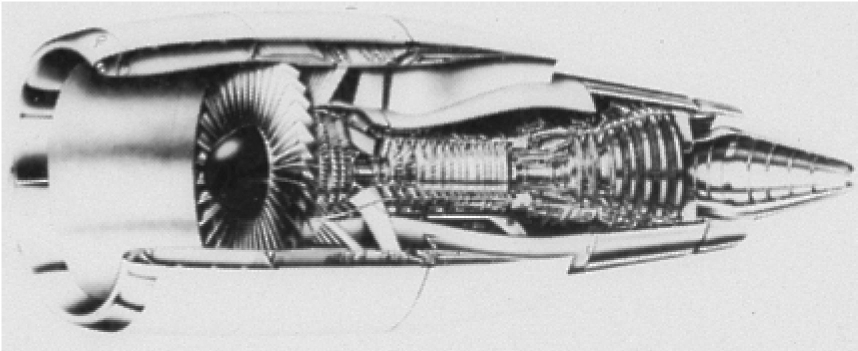
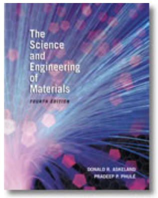


Figure 1.5 A section through a jet engine. The forward compression section operates at low to medium temperatures, and titanium parts are often used. The rear combustion section operates at high temperatures and nickel-based superalloys are required. The outside shell experiences low temperatures, and aluminum and composites are satisfactory. (Courtesy of GE Aircraft Engines.)

Figure 1.6 A variety of complex ceramic components, including impellers and blades, which allow turbine engines to operate more efficiently at higher temperatures. (Courtesy of Certech, Inc.)



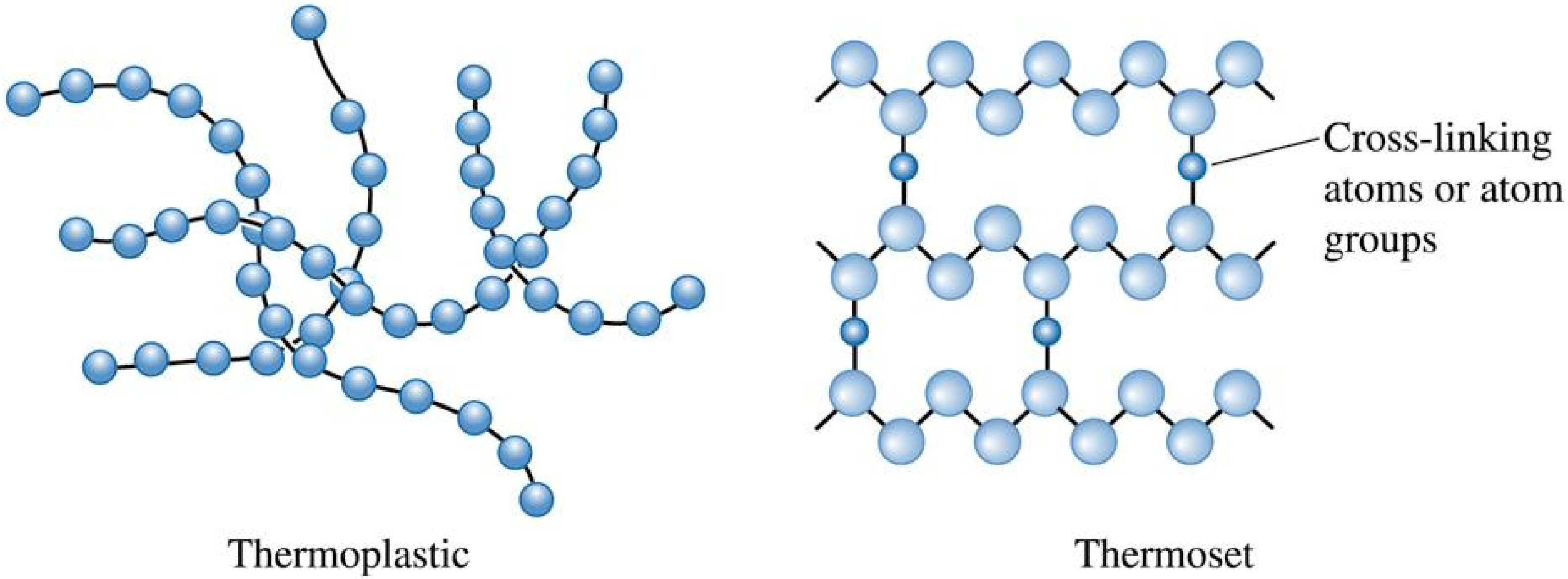


Figure 1.7 Polymerization occurs when small molecules, represented by the circles, combine to produce larger molecules, or polymers. The polymer molecules can have a structure that consists of many chains that are entangled but not connected (thermoplastics) or can form three-dimensional networks in which chains are cross-linked (thermosets)

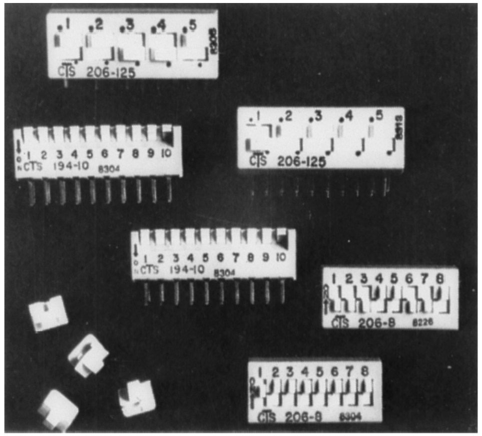


Figure 1.8 Polymers are used in a variety of electronic devices, including these computer dip switches, where moisture resistance and low conductivity are required. (Courtesy of CTS Corporation.)

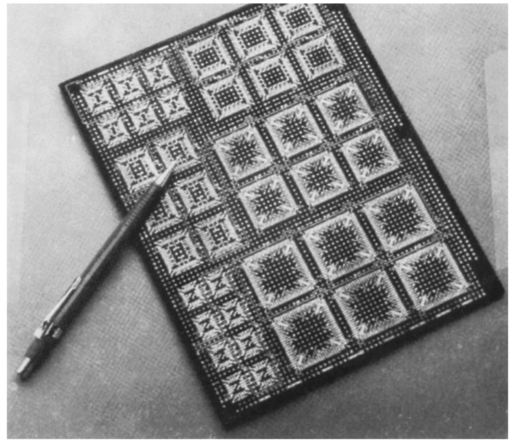


Figure 1.9 Integrated circuits for computers and other electronic devices rely on the unique electrical behavior of semiconducting materials. (Courtesy of Rogers Corporation.)

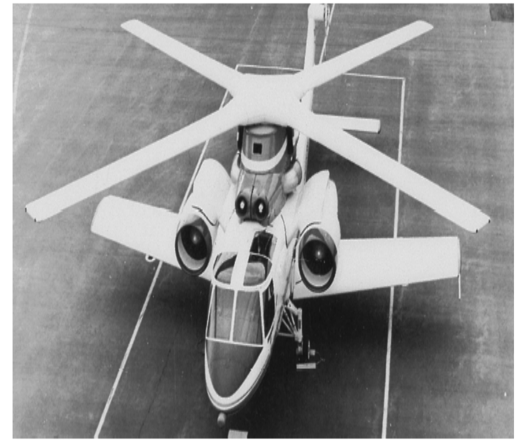
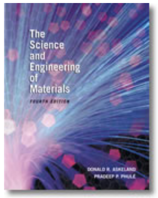


Figure 1.10 The X-wing for advanced helicopters relies on a material composed of a carbon-fiber-reinforced polymer. (Courtesy of Sikorsky Aircraft Division—United Technologies Corporation.)



Section 1.3 Functional Classification of Materials

- Aerospace
- Biomedical
- Electronic Materials
- Energy Technology and Environmental Technology
- Magnetic Materials
- Photonic or Optical Materials
- Smart Materials
- Structural Materials

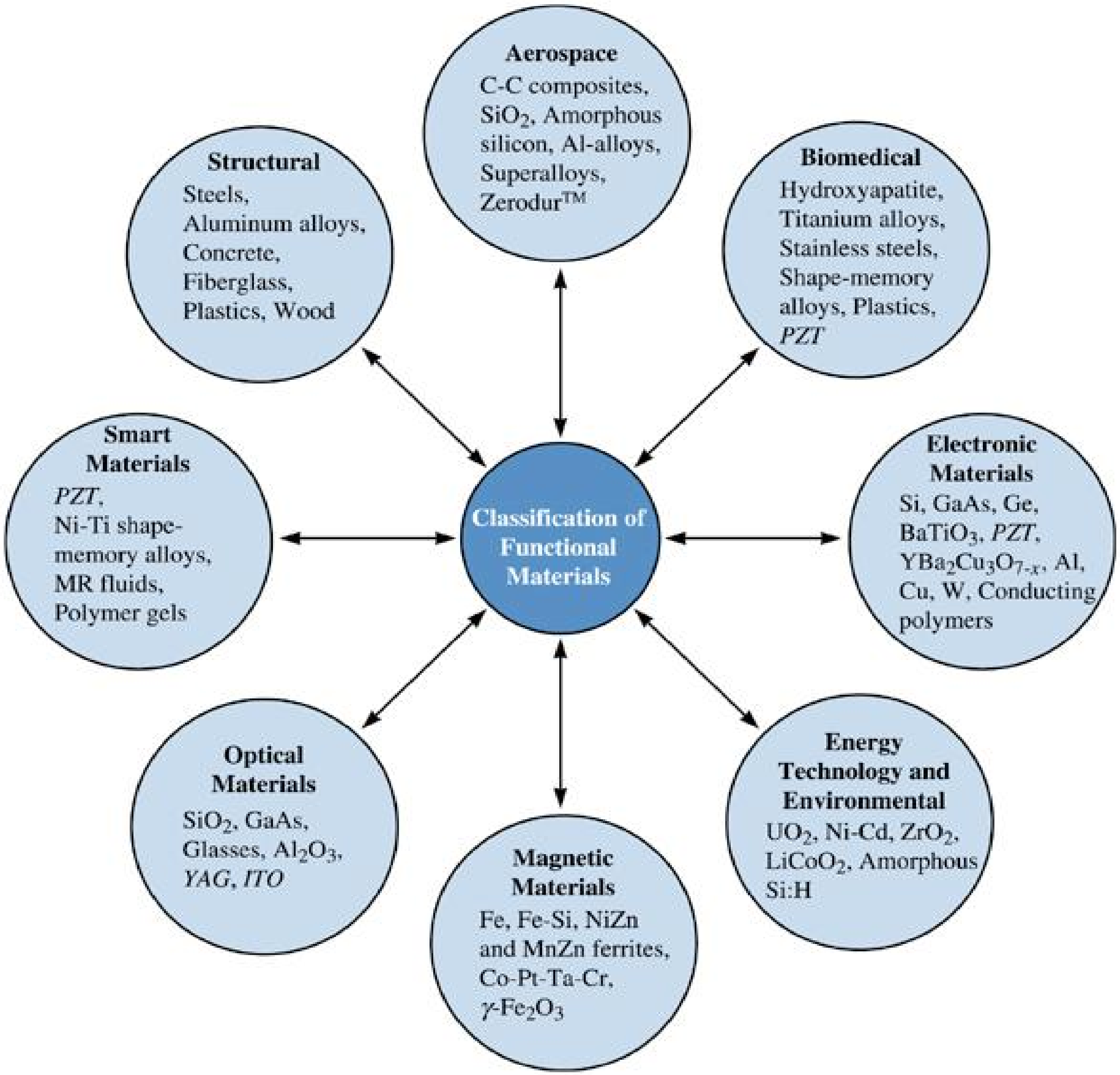
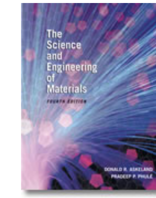


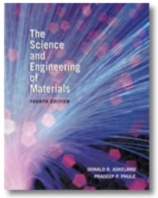
Figure 1.11 Functional classification of materials. Notice that metals, plastics, and ceramics occur in different categories. A limited number of examples in each category is provided

Section 1.4
Classification of Materials-Based on Structure



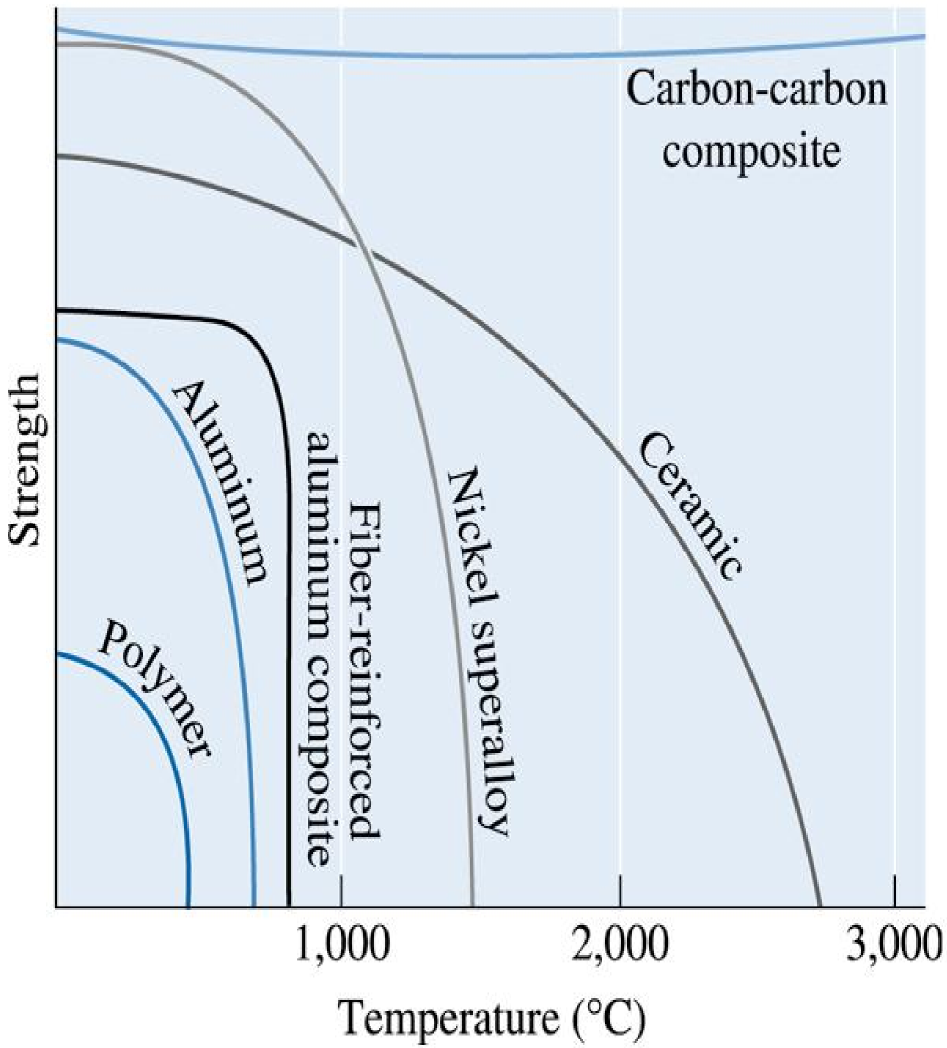
- **Crystalline** material is a material comprised of one or many crystals. In each crystal, atoms or ions show a long-range periodic arrangement.
- **Single crystal** is a crystalline material that is made of only one crystal (there are no grain boundaries).
- **Grains** are the crystals in a polycrystalline material.
- **Polycrystalline material** is a material comprised of many crystals (as opposed to a single-crystal material that has only one crystal).
- **Grain boundaries** are regions between grains of a polycrystalline material.

Section 1.5
Environmental and Other Effects



Effects of following factors must be accounted for in design to ensure that components do not fail unexpectedly:

- Temperature
- Corrosion
- Fatigue
- Strain Rate



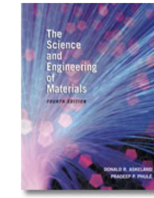


Figure 1.12 Increasing temperature normally reduces the strength of a material. Polymers are suitable only at low temperatures. Some composites, special alloys, and ceramics, have excellent properties at high temperatures

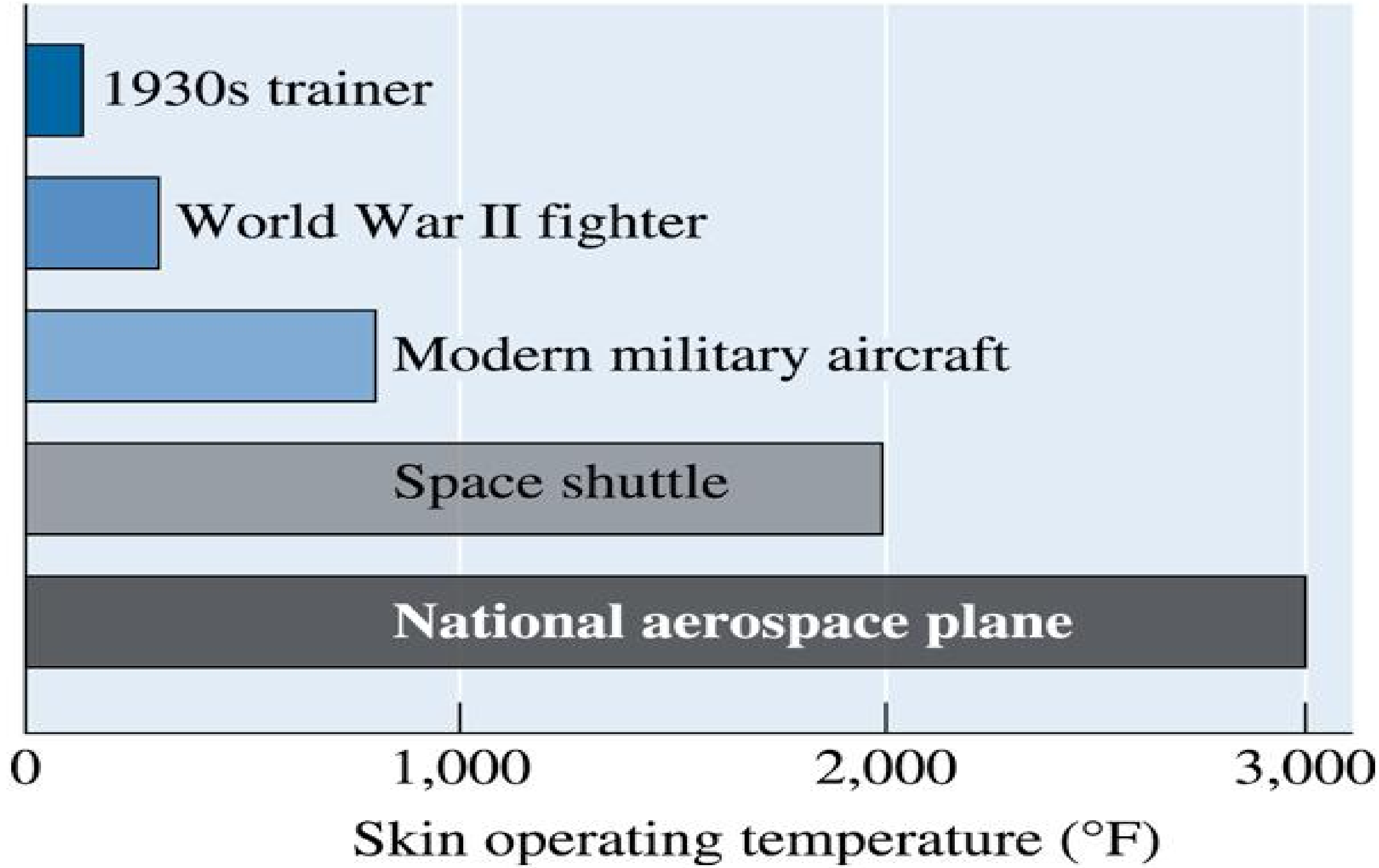
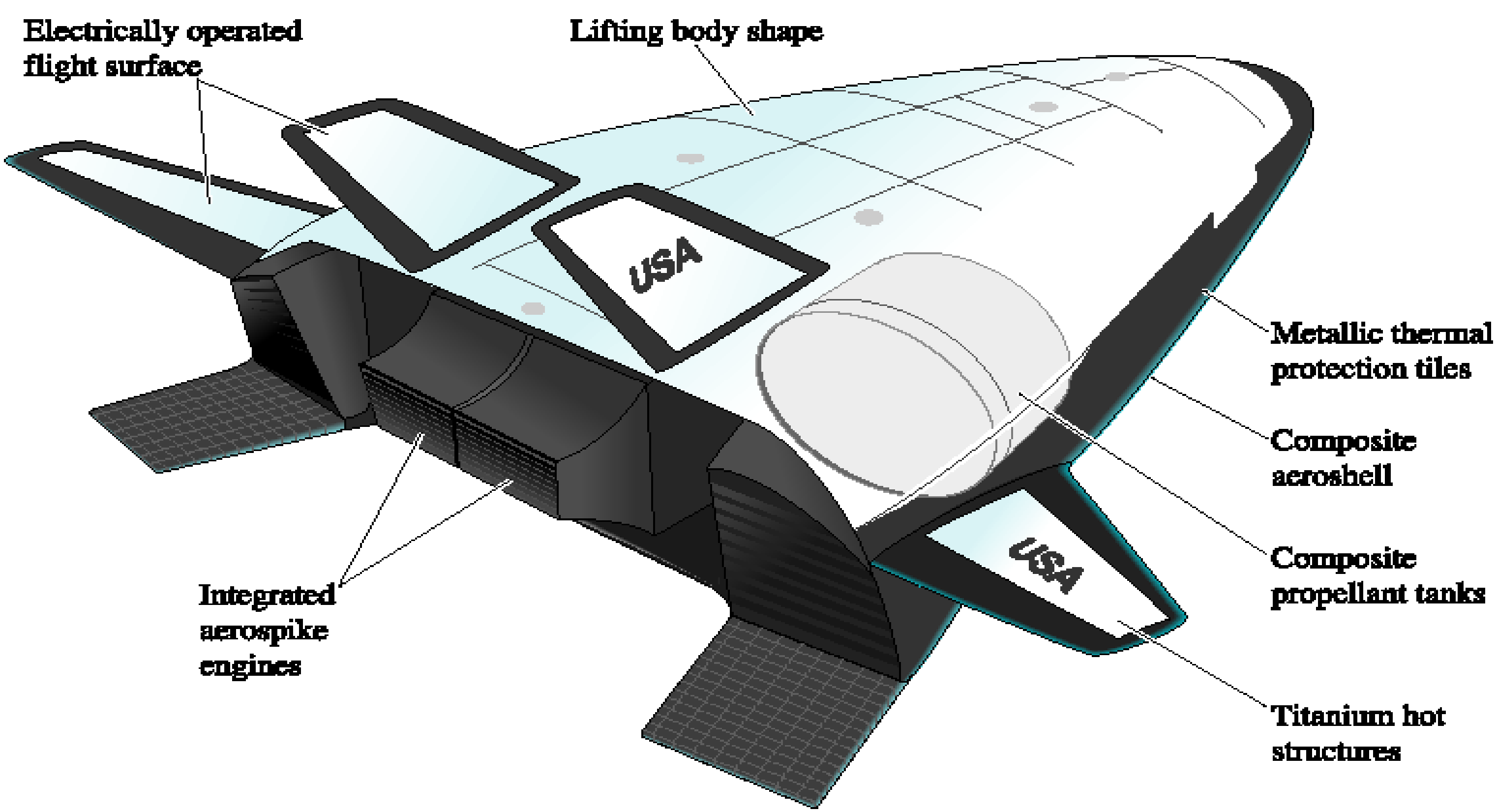


Figure 1.13 Skin operating temperatures for aircraft have increased with the development of improved materials. (After M. Steinberg, Scientific American, October, 1986.)



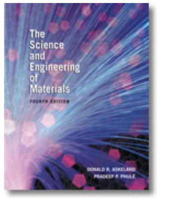
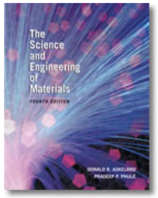


Figure 1-14 Schematic of a X-33 plane prototype. Notice the use of different materials for different parts. This type of vehicle will test several components for the Venturestar (From ''A Simpler Ride into Space,'' by T.K. Mattingly, October, 1997, Scientific American, p. 125. Copyright © 1997 Slim Films.)



Section 1.6
Materials Design and Selection

- Density is mass per unit volume of a material, usually expressed in units of g/cm^3 or lb/in.^{3}
- Strength-to-weight ratio is the strength of a material divided by its density; materials with a high strength-to-weight ratio are strong but lightweight.

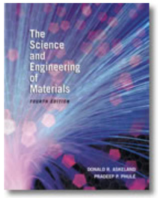


TABLE 1-2 ■ ***Strength-to-weight ratios of various materials***

Material	Strength (lb/in.^{2})	Density (lb/in.^{3})	Strength-to-weight ratio (in.)
Polyethylene	1,000	0.030	0.03×10^6
Pure aluminum	6,500	0.098	0.07×10^6
Al_2O_3	30,000	0.114	0.26×10^6
Epoxy	15,000	0.050	0.30×10^6
Heat-treated alloy steel	240,000	0.280	0.86×10^6
Heat-treated aluminum alloy	86,000	0.098	0.88×10^6
Carbon-carbon composite	60,000	0.065	0.92×10^6
Heat-treated titanium alloy	170,000	0.160	1.06×10^6
Kevlar-epoxy composite	65,000	0.050	1.30×10^6
Carbon-epoxy composite	80,000	0.050	1.60×10^6