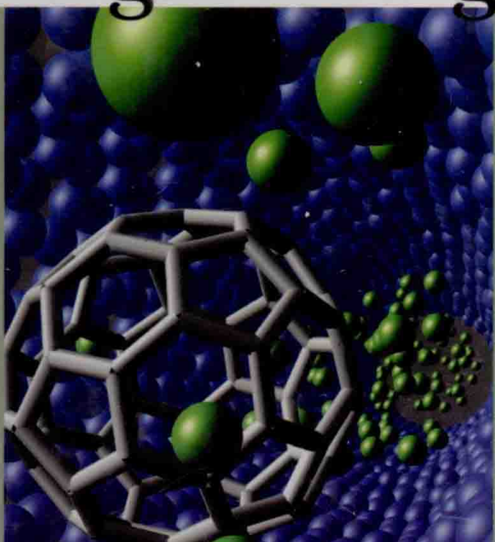
William F. Smith

FOUNDATIONS of Materials Science and Engineering

Third Edition



Foundations of Materials Science and Engineering

Third Edition

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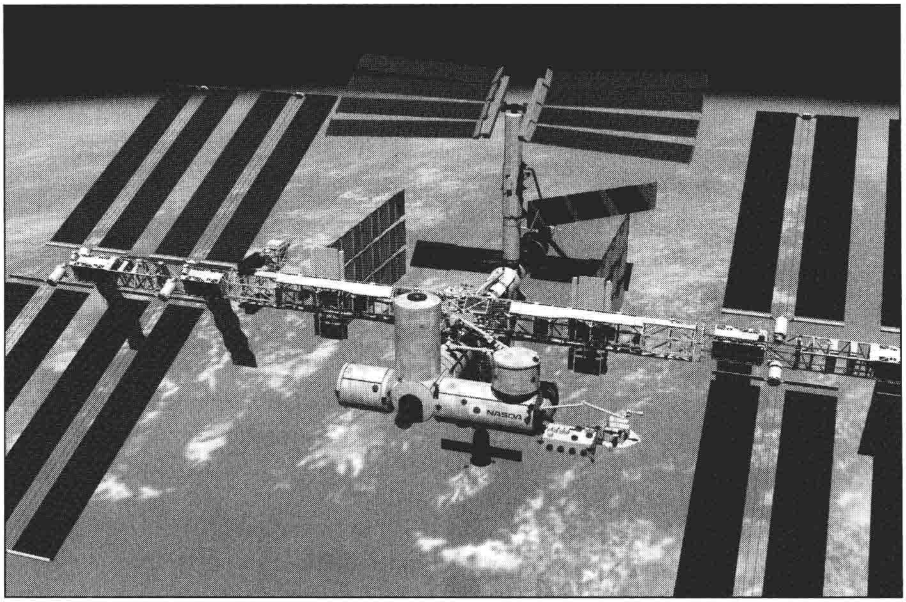
CHAPTER 1

Introduction to Materials Science and Engineering

The International Space Station (ISS) is the engineering marvel of the twenty-first century. Sixteen countries, led by the United States, have contributed to the design and construction of the space station. The ISS, moving at a speed of 27,000 km/h through space, will serve as a large research laboratory dedicated to various areas of science including materials science under microgravity conditions.[1]

[1] www.firstscience.com/site/articles/constructing.asp



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The construction of the space station required proper design and selection of materials for an environment that is far different that ours on earth. The design challenges in selecting materials for the structure are numerous. The materials must be lightweight to minimize payload weight during liftoff. The outer shell must protect against the impact of tiny meteoroids and man made debris. The internal air pressure of roughly 15 psi is constantly stressing the modules. The modules must also withstand the massive stresses at launch. These and other constraints push the limits of material selection in the design of complex systems. Such systems require selection from all five major categories of materials. ■

1.1 MATERIALS AND ENGINEERING

Definition: Materials may be defined as substances of which something is composed or made.

Humankind, materials, and engineering have evolved over the passage of time and are continuing to do so. All of us live in a world of dynamic change, and materials are no exception. The advancement of civilization has historically depended on the improvement of materials to work with. Prehistoric humans were restricted to naturally accessible materials such as stone, wood, bones, and fur. Over time, they moved from the materials Stone Age into the newer Copper (Bronze) and Iron Ages. Note that this advance did not take place uniformly everywhere—we shall see that this is true in nature even down to the microscopic scale. Even today we are restricted to the materials we can obtain from the earth's crust and atmosphere (Table 1.1). As water-containing and air-breathing humans, we depend on the earth's large iron core for its gravitational attraction and will continue to do so as long as we are on this planet. In a sense, we are still in the Iron Age of materials, and we will continue to depend on iron for our existence and on our sun for our required energy.

The production and processing of materials into finished goods constitutes a large part of our present economy. Engineers design most manufactured products and the processing systems required for their production. Since products require materials, engineers should be knowledgeable about the internal structure and properties of materials so that they can choose the most suitable ones for each application and develop the best processing methods.

Research and development engineers create new materials or modify the properties of existing ones. Design engineers use existing, modified, or new materials to design and create new products and systems. Sometimes design engineers have a problem in their design that requires a new material to be created by research scientists and engineers. For example, engineers designing a High-Speed Civil Transport (HSCT) (Fig. 1.1) will have to develop new high-temperature materials that will withstand temperatures as high as 1800°C (3250°F) so that airspeeds as high as Mach 12 to 25 can be attained.[2] Research is currently underway to develop new ceramic-matrix composites, refractory intermetallic

[2]Mach 1 equals the speed of sound in air.

Table 1.1 The most common elements in planet earth's crust and atmosphere by weight percentage and volume

Element	Weight Percentage of the Earth's Crust
Oxygen (O)	46.60
Silicon (Si)	27.72
Aluminum (Al)	8.13
Iron (Fe)	5.00
Calcium (Ca)	3.63
Sodium (Na)	2.83
Potassium (K)	2.70
Magnesium (Mg)	2.09
Total	98.70
Gas	**Percent of dry air by volume**
Nitrogen (N_2)	78.08
Oxygen (O_2)	20.95
Argon (A)	0.93
Carbon dioxide (CO_2)	0.03

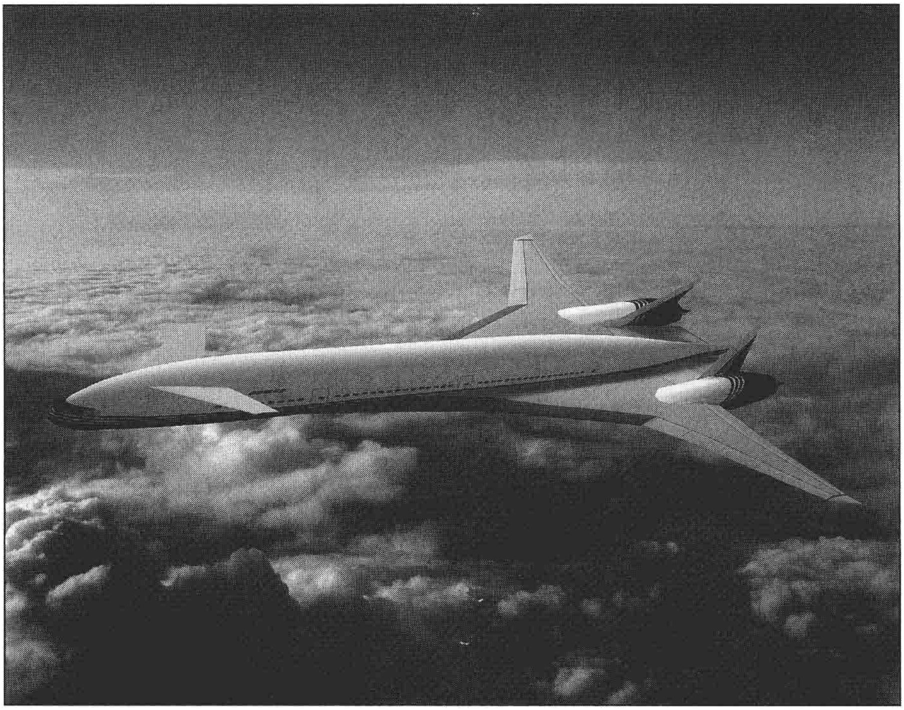

Figure 1.1
High-speed civil transport (HSCT) image shows the Hyper-X at Mach 7 with engine operating. Rings indicate surface flow speeds.
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