INTRODUCTION

The study of materials and their properties and applications is an important part of modern science and technology. As may be expected for such a wide-ranging subject, the study of materials is a multidisciplinary effort, encompassing segments of physics, chemistry, and essentially all branches of engineering, including aerospace, chemical, civil, electrical, and mechanical. In addition, the relatively new discipline of materials science and engineering focuses directly on the study of the properties and applications of materials.

Materials can be classified as being either natural or artificial, the latter corresponding to materials, not found in nature, that are prepared by humans. Important natural materials have included organic materials such as wood, ivory, bone, fiber, and rubber, along with inorganic materials such as minerals and ceramics (stone, flint, mica, quartz, clay, and diamond) and metals such as copper and gold. Different eras of civilization have been given names corresponding to the materials from which tools were made: for example, the Stone Age, the Chalcolithic (Copper–Stone) Age, the Bronze Age, and the Iron Age. Recently, the dominant technological materials have been manufactured, such as steels as structural materials and the semiconductor Si for electronics.

Although the use of solid materials extends to prehistory, the systematic study and development of materials have begun much more recently, within the last 100 years. Development of the periodic table of the elements in the nineteenth century and the resulting grouping of elements with similar properties played a crucial role in setting the stage for the development of materials with desired properties. The discovery that x-rays could be used to probe the internal structure of solids early in the twentieth century also played a key role in accelerating the study of materials.

The study of materials as presented in the textbook, *The Physics and Chemistry of Materials*, begins with in-depth discussions of the structure of materials in Chapters 1 to 4 and of the fundamental principles determining the physical properties of materials in Chapters 5 to 10. Following these discussions of structure and properties, which apply to all materials, eight essentially distinct classes of materials are discussed in Chapters 11 to 18, with emphasis placed on their special properties and applications. The surfaces of materials, interfaces between materials, and materials in the form of thin films and multilayers are then discussed in Chapters 19 and 20. A discussion of the synthesis and processing (S&P) of materials follows in Chapter 21, with emphasis both on general issues and also on the S&P of specific materials.

In addition to the text material, supplementary material for all the chapters is found here, our home page at the Wiley Web site. This material includes a wide range of additional discussions of the properties and applications of materials. Also, experimental techniques used for the characterization of a wide range of materials properties are discussed in Chapter W22. The following topics are reviewed briefly in the appendices appearing at the Web site: thermodynamics, statistical mechanics, and quantum mechanics.

The eight classes of materials discussed in this book include semiconductors, metals and alloys, ceramics, polymers, dielectrics and ferroelectrics, superconductors, magnetic materials, and optical materials. Our discussions of these materials are meant to provide an introduction and solid grounding in the specific properties and applications of each class. Although each class of materials is often considered to be a separate specialty and the basis for a distinct area of technology, there are, in fact, many areas of overlap between the classes, such as magneto-optical materials, ceramic superconductors, metallic and ceramic permanent magnet materials, semiconductor lasers, dilute magnetic semiconductors, polymeric conductors, and so on.

There have been many materials success stories over the years, including the high-T_c superconductors, a-Si:H in photovoltaic solar cells, Teflon and other polymers, optical fibers, laser crystals, magnetic disk materials, superalloys, composite materials, and superlattices consisting of alternating layers of materials such as semiconductors or metals. These materials, most of which have found successful applications, are described throughout.

Our understanding of the structure of materials at the atomic level is well developed and, as a result, our understanding of the influence of atomic-level microstructure on the macroscopic properties of materials continues to improve. Between the microscopic and macroscopic levels, however, there exists an important additional level of structure at an intermediate length scale, often determined by defects such as grain boundaries, dislocations, inclusions, voids, and precipitates. Many of the critical properties of materials are determined by phenomena such as diffusion and interactions between defects that occur on this intermediate structural level, sometimes referred to as the mesoscopic level. Our understanding of phenomena occurring on this level in the heterogeneous (e.g., polycrystalline, amorphous, and composite) materials that are used in modern technology remains incomplete. Many of the properties of materials that are critical for their applications (e.g., mechanical properties) are determined by phenomena occurring on this level of microstructure.

Useful materials are becoming more complex. Examples include the high-T_c copper oxide–based ceramic superconductors, rare earth–based permanent magnets, bundles of carbon nanotubes, and even semiconductors such as Si–Ge alloys employed in strained layers and superlattices. Recent and continuing advances in the design and manipulation of materials atom by atom to create artificial structures are revolutionary steps in the development of materials for specific applications. This area of nanotechnology is an important focus of this book.

As we enter the twenty-first century and the world population and the depletion of resources both continue to increase, it is clear that the availability of optimum materials will play an important role in maintaining our quality of life. It is hoped that textbooks such as this one will serve to focus the attention of new students, as well as existing researchers, scientists, and engineers, toward the goals of developing and perfecting new materials and new applications for existing materials.