Materials Science for Engineering Students

About the Cover

The front cover shows some of the 15,000 spun aluminum disks that constitute the façade of the Selfridges building in Birmingham UK. This is one example of the utilization of metals for their environmental stability and aesthetics. Other examples are the titanium-clad Guggenheim Museum in Bilbao, Spain, and the traditional copper claddings that acquire an attractive green patina through weathering. All three metals rely on the fact that chemical "attack" by the environment forms a dense film on the surface that protects it from further degradation. The use of copper has a very long history, but the use of aluminum required 20th century metallurgical technology, and titanium became widely available only recently.

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Traugott Fischer

Stevens Institute of Technology

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To my students.

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Preface

This book is based on the experience acquired by teaching a course on materials to the engineering students at Stevens Institute of Technology. It appeared to me that it is possible to improve on existing textbooks despite my great respect for quite a few of them. So I have attempted to innovate in subject matter and in the presentation.

Much innovation has occurred in engineering materials and in the way they are used. Light sources are evolving in the direction of reduced energy use and large-area mobile image displays; electric batteries are ubiquitous and will acquire even more importance with the spreading of hybrid vehicles; the quest for renewable and nonpolluting energy sources will undoubtedly stimulate progress in plastic solar cells; medical advances spur the increasing use of biomaterials; and nanomaterials stimulate thousands of start-up companies intent on capitalizing on their novel properties. These developments cannot be ignored by engineers and receive a succinct treatment in the book. Obviously the introduction of these new topics cannot be done by increasing the amount that must be learned. Therefore, the traditional structural materials, especially metallurgy, are treated in less detail than in most other books.

I endeavored to present the material the way we learn naturally: we first observe a fact or a phenomenon, and then we try to understand it. Having found the explanation, we generalize it by formulating an abstract theory and explore whether it has wider applications. This is generally known as "inductive presentation." Applying it in my lectures, I observed that it stimulates the students' curiosity and raises their interest. I have also introduced new concepts through concrete examples; once that is done, abstracting a general law becomes a pleasure of the mind.

Students often express difficulty in learning a subject because they do not see the use of it. I have read somewhere that we only learn efficiently when we feel the need to know. I have tried to follow this principle and present the "real engineering" topics first and the necessary science "just in time," as it is needed. Why, for example, would an engineer bother with crystal structure? Rather, where would the engineer need to know it? The answer is that only crystalline metals can be shaped by plastic deformation and this deformation is easier in certain structures than in others. So plastic deformation is presented first, and the crystal structure is introduced just as its need is apparent. This principle is followed throughout the book.

The breadth of the field is a real challenge for a course on Materials. Most Engineering curricula allocate one three-credit semester course, consisting of 42 hours of instruction to this subject. With this limited volume of information one can either cover a small area in depth or provide a "shallow" coverage of the entire field and teach a "survey course." I would not underestimate the merit of the latter approach; depth can also be acquired through the relationships between lightly touched separate concepts. The worst way of teaching this material would be to follow the book from its beginning, hope to be able to teach it all, but end where time runs out. I strongly recommend taking some time to plan what one wants to cover in the available time and to eliminate what one does not consider essential. I recommend a complete treatment of Chapter 1, which is the foundation on which the rest is built. For the remainder of the material, I would emphasize the fundamental concepts and drop the details wherever possible. Also, principles normally taught in other courses are included here but could be skipped; this is the case of Chapter 2, the section on crystallography of Chapter 3, the science of diffusion in Chapters 6 and 7, the introductory physics in Chapters 11, 13, and 14, and possibly the electrochemistry of Chapter 15. Many instructors may also choose to ignore the last three chapters. A more detailed list of suggestions can be found in the Web site for instructors at www.textbooks.elsevier.com. The Web site also contains the solutions of all the problems and other resources, such as Powerpoint slides of the figures and hyperlinks to some useful web sites. Solutions to most of the numerical problems are printed at the end of the book.

This book owes much to my students who taught me how to teach; by their interest, their enthusiasm, by their difficulties, and by their occasional boredom, they taught me what motivates us to learn, what works and what does not work in teaching. I am indebted to my colleague Professor Milton Ohring at the Stevens Institute of Technology. He was kind enough to give me the Word document of his entire book *Engineering Materials Science* to use as I wish. Although the style of this book is quite different from his, I have taken many of the figures from his book and reproduced some of its sections word for word. I also owe thanks to Professor Bernard Gallois for inspiring the "just in time science" concept and for much advice. I am indebted to Professor Hong Liang of Texas A&M University and her students who have read the different chapters of the book and given me constructive criticism.

I wish to express my gratitude to Dr. Marwan Al-Haik, Dept. of Mechanical Engineering, University of New Mexico, Dr. James Falender, Dept. of Chemistry, Central Michigan University, Dr. Gregg M. Janowski, Dept. of Materials Science and Engineering, University of Alabama at Birmingham, and Dr. Robert G. Kelly, Professor of Materials Science & Engineering, University of Virginia. Professor Glenn McNutt, College of Engineering, Embry-Riddle Aeronautical University, Dr. Lew Reynolds, Dept. of Materials Science and Engineering, North Carolina State University, Professor Mark L. Weaver, Dept. of Metallurgical Materials Engineering, University of Alabama, and Professor Henry Du of Stevens Institute of Technology, who have carefully read the manuscript, have saved me from errors and omissions and have made valuable suggestions. My thanks also to the editors at Elsevier, to Joel Stein who gave me much early encouragement and advice, to Steve Merken, Acquisitions Editor, who helped and guided me during the preparation of the manuscript, and to Jeff Freeland, Senior Project Manager, who produced this book. And, of course, my gratitude goes to my wife whose patience and support were essential for this endeavor.

Traugott Fischer