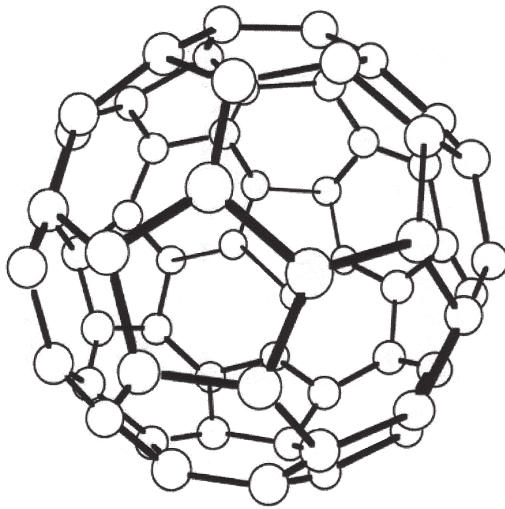


Elementary Materials Science

William F. Hosford



**The Materials
Information Society**

ASM International®
Materials Park, Ohio 44073-0002
www.asminternational.org

Copyright © 2013
by
ASM International®
All rights reserved

No part of this book may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the written permission of the copyright owner.

First printing, August 2013

Great care is taken in the compilation and production of this book, but it should be made clear that NO WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE GIVEN IN CONNECTION WITH THIS PUBLICATION. Although this information is believed to be accurate by ASM, ASM cannot guarantee that favorable results will be obtained from the use of this publication alone. This publication is intended for use by persons having technical skill, at their sole discretion and risk. Since the conditions of product or material use are outside of ASM's control, ASM assumes no liability or obligation in connection with any use of this information. No claim of any kind, whether as to products or information in this publication, and whether or not based on negligence, shall be greater in amount than the purchase price of this product or publication in respect of which damages are claimed. THE REMEDY HEREBY PROVIDED SHALL BE THE EXCLUSIVE AND SOLE REMEDY OF BUYER, AND IN NO EVENT SHALL EITHER PARTY BE LIABLE FOR SPECIAL, INDIRECT OR CONSEQUENTIAL DAMAGES WHETHER OR NOT CAUSED BY OR RESULTING FROM THE NEGLIGENCE OF SUCH PARTY. As with any material, evaluation of the material under end-use conditions prior to specification is essential. Therefore, specific testing under actual conditions is recommended.

Nothing contained in this book shall be construed as a grant of any right of manufacture, sale, use, or reproduction, in connection with any method, process, apparatus, product, composition, or system, whether or not covered by letters patent, copyright, or trademark, and nothing contained in this book shall be construed as a defense against any alleged infringement of letters patent, copyright, or trademark, or as a defense against liability for such infringement.

Comments, criticisms, and suggestions are invited, and should be forwarded to ASM International.

Prepared under the direction of the ASM International Technical Book Committee (2012–2013), Bradley J. Diak, Chair.

ASM International staff who worked on this project include Scott Henry, Senior Manager, Content Development and Publishing; Karen Marken, Senior Managing Editor; Amy Nolan, Content Developer; Sue Sellers, Editorial Assistant; Madrid Tramble, Manager of Production; and Diane Whitelaw, Production Coordinator.

Library of Congress Control Number: 2013931785

ISBN-13: 978-1-62708-002-6

ISBN-10: 0-62708-002-3

SAN: 204-7586

ASM International®
Materials Park, OH 44073-0002

www.asminternational.org

Printed in the United States of America

Contents

CHAPTER 1	
Chemistry Basics.	1
Elements	1
Fundamental Particles	2
Bonding	2
Crystal Structures	4
Amorphous (Noncrystalline) Materials	9
Exercises	10
CHAPTER 2	
Phase Relations	11
Phases	11
Solid Solutions	11
Phase Diagrams	12
Freezing	16
Segregation during Freezing	17
Metal Glasses	19
Exercises	21
CHAPTER 3	
Mechanical Behavior	23
Stress and Strain	23
Elasticity	23
Plastic Deformation	25
Ductility	28
Hardness	28
Creep	29
Fatigue	29
Fracture	30
Exercises	34

CHAPTER 4	
Electrical Behavior	37
Conduction	37
Metallic Conduction	37
Ionic Conduction	40
Energy Bands	40
Intrinsic Semiconduction	41
Extrinsic Semiconduction	42
III-V Compound Semiconductors	44
<i>p-n</i> Rectifiers	45
Light Emitting Diodes	46
Transistors	46
Polar Compounds	47
Piezoelectric Behavior	47
Thermal Conductivity	49
Exercise	49
CHAPTER 5	
Magnetic Behavior	51
Ferromagnetism	51
Magnetostatic Circuits	52
Domain Boundaries	54
Soft versus Hard Magnetic Materials	54
Soft Magnetic Materials	55
Hard Magnetic Materials	56
Exercise	57
CHAPTER 6	
Nonferrous Metals	59
Cold Work	60
Annealing	60
Copper	63
Aluminum	63
Magnesium	65
Titanium	65
Zinc	66
Lead and Tin	66
Exercises	67
CHAPTER 7	
Iron and Steel	69
Steels	69
Hardening	71
Tempering	74
Low-Carbon Steels	76

Stainless Steels	76
Cast Irons.	77
Exercises	78
CHAPTER 8	
Ceramics	81
Crystalline Ceramics	81
Glasses	82
Pottery	88
Hydration Reactions	91
Carbon	93
Exercise	98
CHAPTER 9	
Polymers.	99
Thermoplastics	100
Thermosetting Polymers	100
Degree of Polymerization and Molecular Weight	103
Branching	103
Cross-linking and Stereoisomerism	104
Copolymers.	105
Molecular Configuration	105
Glass Transition	106
Additives	106
Degradation	107
Properties and Uses of Polymers	109
Stretching of a Thermoplastic	112
Exercises	113
CHAPTER 10	
Composites	115
Fiber-Reinforced Composites	115
Volume Fraction of Fibers	117
Fiber Length	118
Particulate Composites.	120
Lamellar Composites.	120
Exercise	120
CHAPTER 11	
Wood	121
Structure of Wood	121
Dimensional Changes with Moisture.	122
Anisotropy of Properties	124
Plywood	125
Paper and Cardboard	125
Exercises	126

CHAPTER 12	
Corrosion	129
Corrosion in Water Solutions	129
Passivation	132
Corrosion Control	134
Stress Corrosion	135
Rust	136
Direct Oxidation	136
Exercise	138
CHAPTER 13	
Forming and Shaping	139
Liquid to Solid Processing	139
Bulk Forming of Solid Metals	140
Hot Working versus Cold Working	140
Sheet Forming	141
Polymer Processing	142
Powder Processing	144
Modern Manufacturing Techniques	146
CHAPTER 14	
Recycling	149
Metals	149
Plastics	150
Rubber	151
Glass and Paper	151
APPENDIX I	
Greek Alphabet	153
APPENDIX II	
SI Unit System	155
APPENDIX III	
Conversions and Constants	157
APPENDIX IV	
Properties of Elements	159
APPENDIX V	
Properties of Materials.	161
APPENDIX VI	
Unit Abbreviations.	163
Index	165

Preface

This textbook, which covers the subject of materials science with very few equations, is designed for high school students who are interested in materials science. It is assumed they already have had a course in chemistry. A prior course in physics is not necessary, and the use of mathematics is limited to algebra. This text also will be useful to nontechnical professionals in the materials industry.

The book first introduces materials science through the discussion of the elements, bonding, crystal structures, and amorphous (noncrystalline) materials; then presents the properties of phase relations, mechanical behavior, electrical behavior, and magnetic behavior. There is one chapter each devoted to the following materials: nonferrous metals, ferrous metals, ceramics, polymers, composites, and wood. To round out this important basic volume on a growing interdisciplinary scientific field are chapters on corrosion, forming and shaping, and recycling. There are 14 chapters. Chapters 3 to 7, and 9 will likely require more time to cover than chapters 1, 2, 8, 10, and 12. Chapters 11, 13, and 14 can be covered in less time than the others. Chapters end with a Note of Interest and Exercises—all pertaining to the chapters' topics of discussion. The Notes of Interest engage readers with fascinating bits of information about notable people, events, and developments; the Exercises allow students to explore the world of materials in a pragmatic, hands-on manner.

