



Contents

1 The Structure of Materials 1

Chapter Goals 1

- 1.1 The Origin of Engineering Materials 2
- 1.2 The Periodic Table 6
- 1.3 Forming Engineering Materials from the Elements 7
- 1.4 The Solid State 9
- 1.5 The Nature of Metals 11
- 1.6 The Nature of Ceramics 14
- 1.7 The Nature of Polymers 15
- 1.8 The Nature of Composites 15

Summary 17

Important Terms 18

Questions 18

To Dig Deeper 19

2 Properties and Selection 21

Chapter Goals 21

- 2.1 The Property Spectrum 21

- 2.2 Chemical Properties 24
- 2.3 Physical Properties 26
- 2.4 Mechanical Properties 29
- 2.5 Dimensional Properties 43
- 2.6 Property Information 51

Summary 52

Important Terms 53

Questions 53

References for Property Data 54

To Dig Deeper 54

3 Principles of Polymeric Materials 55

Chapter Goals 55

- 3.1 Polymerization Reactions 56
- 3.2 Basic Types of Polymers 60
- 3.3 Strengthening Mechanisms 63
- 3.4 Polymer Fabrication Techniques 70

Summary 76

Important Terms 77

Questions 77

To Dig Deeper 78

4 Polymer Chemistry 79

Chapter Goals 79

- 4.1 Thermoplastic Commodity Plastics 81
- 4.2 Thermoplastic Engineering Plastics 88
- 4.3 Thermosetting Polymers 103
- 4.4 Elastomers 108
- 4.5 Selection of Elastomers 114

Summary 116

Important Terms 117

Questions 118

To Dig Deeper 118

5					
Polymer Composites	119				
<i>Chapter Goals</i>	119				
5.1 Reinforcement Types	119				
5.2 Matrix Materials	122				
5.3 Reinforcements	128				
5.4 Polymer Fabrication Techniques	134				
5.5 Application of Polymer Composites	137				
<i>Summary</i>	142				
<i>Important Terms</i>	143				
<i>Questions</i>	143				
<i>To Dig Deeper</i>	144				
6					
Engineering Plastics, Polymeric Coatings, and Adhesives	145				
<i>Chapter Goals</i>	145				
6.1 Selection of Plastics: Methodology	145				
6.2 Plastics for Structural Components	149				
6.3 Plastics for Friction and Wear	159				
6.4 Plastics for Corrosion Control	168				
6.5 Plastics for Electrical Applications	172				
6.6 Polymer Coatings	174				
6.7 Adhesives	181				
6.8 Recycling of Plastics	186				
<i>Summary</i>	188				
<i>Important Terms</i>	188				
<i>Questions</i>	189				
<i>To Dig Deeper</i>	190				
7					
Ceramics, Cermets, Glass, and Carbon Products	191				
<i>Chapter Goals</i>	191				
7.1 The Nature of Ceramics	191				
7.2 How Ceramics Are Made	192				
7.3 Morphology of Ceramics	197				
7.4 Properties of Ceramics	201				
7.5 Glasses	205				
7.6 Carbon Products	208				
7.7 Cemented Carbides	211				
7.8 Ceramics for Structural Applications	215				
7.9 Ceramics for Wear Applications	221				
7.10 Ceramics for Environmental Resistance	222				
7.11 Electrical Properties of Ceramics	223				
7.12 Magnetic Properties of Ceramics	225				
<i>Summary</i>	227				
<i>Important Terms</i>	228				
<i>Questions</i>	228				
<i>To Dig Deeper</i>	229				
8					
Steel Products	231				
<i>Chapter Goals</i>	231				
8.1 Iron Ore Benefication	232				
8.2 Making of Steel	233				
8.3 Converting Steel into Shapes	241				
8.4 Steel Terminology	247				
8.5 Steel Specifications	249				
<i>Summary</i>	250				
<i>Important Terms</i>	251				
<i>Questions</i>	252				
<i>To Dig Deeper</i>	252				
9					
Heat Treatment of Steels	253				
<i>Chapter Goals</i>	253				
9.1 Equilibrium Diagrams	253				
9.2 Morphology of Steel	257				
9.3 Reasons for Heat Treating	260				

9.4	Heat-Treating Cycles	264	
9.5	Specification	273	
	<i>Summary</i>	274	
	<i>Important Terms</i>	274	
	<i>Questions</i>	275	
	<i>To Dig Deeper</i>	276	
10	Surface and Selective Hardening	277	
	<i>Chapter Goals</i>	277	
10.1	Mechanisms	278	
10.2	Processes	280	
10.3	Cost of Heat Treating	294	
10.4	Selection and Process Specification	295	
	<i>Summary</i>	297	
	<i>Important Terms</i>	298	
	<i>Questions</i>	298	
	<i>To Dig Deeper</i>	299	
11	Carbon and Alloy Steels	301	
	<i>Chapter Goals</i>	301	
11.1	Alloy Designation	302	
11.2	Carbon Steels	306	
11.3	Alloy Steels	317	
11.4	Selection of Alloy Steels	320	
11.5	High-Strength Sheet Steels	328	
11.6	High-Strength, Low-Alloy Steels	329	
11.7	Special Steels	331	
11.8	Selection and Specification	333	
	<i>Summary</i>	336	
	<i>Important Terms</i>	337	
	<i>Questions</i>	337	
	<i>To Dig Deeper</i>	338	
12	Tool Steels	339	
	<i>Chapter Goals</i>	339	
12.1	Identification and Classification	339	
12.2	Tool Steel Metallurgy	341	
12.3	Chemical Composition of Tool Steels	348	
12.4	Steel Properties	354	
12.5	Tool Steel Selection	361	
12.6	Specification of Tool Steels	373	
12.7	Tool Steel Defects	375	
	<i>Summary</i>	378	
	<i>Important Terms</i>	379	
	<i>Questions</i>	379	
	<i>To Dig Deeper</i>	380	
13	Corrosion	381	
	<i>Chapter Goals</i>	381	
13.1	The Nature of Corrosion	381	
13.2	Factors Affecting Corrosion	384	
13.3	Types of Corrosion	389	
13.4	Determination of Corrosion Characteristics	400	
13.5	Corrosion Control	404	
	<i>Summary</i>	410	
	<i>Important Terms</i>	412	
	<i>Questions</i>	413	
	<i>To Dig Deeper</i>	413	
14	Stainless Steels	415	
	<i>Chapter Goals</i>	415	
14.1	Metallurgy of Stainless Steels	416	
14.2	Alloy Identification	424	
14.3	Physical Properties	427	

14.4	Mechanical Properties	430	16.7	Fabrication	503
14.5	Fabrication	433	16.8	Wear Resistance	507
14.6	Corrosion Characteristics	439	16.9	Corrosion	510
14.7	Alloy Selection	444	16.10	Alloy Selection	512
	<i>Summary</i>	447		<i>Summary</i>	514
	<i>Important Terms</i>	448		<i>Important Terms</i>	514
	<i>Questions</i>	449		<i>Questions</i>	514
	<i>To Dig Deeper</i>	449		<i>To Dig Deeper</i>	515
15			17		
Castings and Powder Metallurgy		451	Aluminum and Its Alloys		517
	<i>Chapter Goals</i>	451		<i>Chapter Goals</i>	517
15.1	Casting Processes	451	17.1	General Characteristics	518
15.2	Casting Design	458	17.2	Alloy Designation	520
15.3	Gray Iron	460	17.3	Aluminum Products	521
15.4	Malleable Iron	469	17.4	Metallurgical Characteristics	522
15.5	Ductile Iron	471	17.5	Heat Treatment	524
15.6	White Alloy Irons	473	17.6	Surface Treatments	526
15.7	Steel Castings	474	17.7	Corrosion	529
15.8	Casting Selection	476	17.8	Alloy Selection	531
15.9	Powder Metallurgy	479		<i>Summary</i>	536
15.10	Process Selection	486		<i>Important Terms</i>	538
	<i>Summary</i>	489		<i>Questions</i>	538
	<i>Important Terms</i>	489		<i>To Dig Deeper</i>	538
	<i>Questions</i>	489	18		
	<i>To Dig Deeper</i>	490	Nickel, Zinc, Titanium, Magnesium, and Refractory Metals		541
16				<i>Chapter Goals</i>	541
Copper and Its Alloys		491	18.1	Nickel	541
	<i>Chapter Goals</i>	491	18.2	Zinc	547
16.1	Extraction of Copper from Ore	491	18.3	Titanium	552
16.2	Alloy Designation System	492	18.4	Magnesium	556
16.3	Copper Products	493	18.5	Refractory Metals	559
16.4	Metallurgy	497		<i>Summary</i>	563
16.5	Properties	500		<i>Important Terms</i>	564
16.6	Heat Treatment	503			

Questions 564
To Dig Deeper 565

19**Surface Engineering 567**

Chapter Goals 567

- 19.1 Electroplating 568
19.2 Other Metallic Platings 573
19.3 Conversion Coatings 574
19.4 Thin Film Coatings 576
19.5 Hardfacing 579
19.6 Thermal Spraying 580
19.7 High-Energy Processes 581
19.8 Diffusion Processes 582
19.9 Selective Hardening 582
19.10 Special Surface Treatments 583
19.11 Organic Coatings 583
19.12 Process Selection 584
19.13 Specifications 590
Summary 593
Important Terms 593
Questions 593
To Dig Deeper 594

20**The Selection Process 595**

Chapter Goals 595

- 20.1 The Design Process 595

- 20.2 Selection Factors 596
20.3 A Materials Repertoire 607
20.4 Materials for Typical Machine
Components 611
Summary 613
Important Terms 614
Questions 615
To Dig Deeper 616

21**Failure Prevention 617**

Chapter Goals 617

- 21.1 Preventing Wear Failures 618
21.2 Preventing Corrosion Failures 621
21.3 Preventing Mechanical Failures 625
21.4 Flaw Detection 631
Summary 636
Important Terms 637
Questions 637
To Dig Deeper 637