

Contents

Foreword

v

Preface

vii

1. Functional Materials	1
1.1 Introduction to Ceramic Materials	1
1.2 Processing of Ceramics	2
1.2.1 Powder Processing	2
1.2.2 Shaping	2
1.3 Classification of Ceramic Materials	2
1.3.1 Classification Based on Composition	3
1.3.2 Classification Based on Applications	3
1.3.3 Classification Based on Functionality	4
1.4 Properties of Ceramic Materials	6
1.4.1 Mechanical Properties	6
1.4.2 Electrical Properties	6
1.4.3 Magnetic Properties	6
1.4.4 Chemical Properties	6
1.4.5 Thermal Properties	6
1.4.6 Optical Properties	6
1.4.7 Nuclear Properties	7
1.4.8 Biological Properties	7
1.4.9 Piezoelectric Property	7
1.5 Advanced Ceramic Materials	7
1.5.1 Alumina (Al_2O_3)	7
1.5.2 Carborundum or Silicon Carbide (SiC)	8
1.6 Superhard Ceramics	10
1.6.1 Tungsten Carbide	10
1.6.2 Boron Nitride	11
1.6.3 Transparent Ceramics	12
1.7 Composites	13
1.7.1 Matrix	13
1.7.2 Reinforcement	13
1.7.3 Classification	14
1.7.4 Properties of Composites	15
1.7.5 Applications	15
1.8 Advanced Composites	15
1.8.1 Polymer-nanoclay Composites	15
1.8.2 Synthesis of Polymer-nanoclay Composite	16

1.8.3	Advantages	16
1.8.4	Applications	16
1.8.5	Polymer-carbon Nanotube Composites	17
1.9	Alloys	18
1.9.1	Phase Mixture of Solid Solutions	18
1.9.2	Factors Affecting Alloying or Solubility of Metal with Each Other	19
1.9.3	Ferro Alloys	19
1.9.4	Copper Alloys	19
1.9.5	Aluminium Alloys	21
1.10	Glass	23
1.10.1	Introduction	23
1.10.2	Chemical Constitution of Ordinary Glass	23
1.10.3	Classification Based on Application	23
1.10.4	Manufacture of Glass Using Tank Furnace	24
1.10.5	Manufacture of Glass Using Pot Furnace	24
1.11	Lubricants	24
1.11.1	Some Properties of a Good Lubricant	25
1.11.2	Some Important Functions of a Good Lubricants	25
1.11.3	Classification	25
1.11.4	Solid Lubricants	26
1.11.5	Semi-solid Lubricants	26
1.11.6	Liquid Lubricants	27
1.11.7	Mechanism of Lubrication	28
1.11.8	Applications of Lubricants	28
1.12	Refractories	29
1.12.1	Properties	29
1.12.2	Measuring Pyrometric Cone Equivalent (PCE) Value	29
1.12.3	Classification of Refractories	29
1.12.4	Manufacture of Refractories	30
	<i>Conceptual Questions</i>	30
	<i>Descriptive Questions</i>	31
	<i>Multiple Choice Questions</i>	32

2. Commodity and Engineering Polymers

34

2.1	Introduction to Liquid Crystals	34
2.2	Structural Requirement for a Liquid Crystal	35
2.3	Examples of Polymeric Fragments Exhibiting Liquid Crystal Behaviour	35
2.4	Liquid Crystal Polymers	35
2.5	Structure–Activity Relationship	35
2.5.1	Rigid Main Chain	36
2.5.2	Semiflexible Main Chain	36
2.5.3	Role of Substituents	36
2.6	Phase Behavior	36
2.7	Classification of Liquid Crystals Based on Their Method of Synthesis	37

2.8	Applications of Liquid Crystals	40
2.9	Conducting Polymers	41
2.9.1	Mechanism of Conduction	41
2.9.2	The Role of Dopants	41
2.9.3	Applications of Polyaniline	43
2.10	High Performance Fibres	43
2.10.1	Fibres	44
2.11	Photonic Polymers	46
2.11.1	Polymethyl Methacrylate (PMMA)	46
2.12	Elastomers	48
2.12.1	Structural Activity	48
2.12.2	Natural Rubber or Raw Rubber	48
2.12.3	Synthetic Rubber	49
2.13	Inorganic Polymers	51
2.13.1	Polyphosphazines	51
2.14	Bioderadable Polymers	52
	Conceptual Questions	55
	Descriptive Questions	56
	Multiple Choice Questions	57
3.	Electronic Materials	59
3.1	Introduction	59
3.1.1	Energy Levels and Bands	61
3.2	Conduction in Semiconductors	61
3.2.1	Doping	62
3.2.2	Intrinsic Semiconductors	62
3.2.3	Extrinsic Semiconductor	62
3.3	Fermi Level in Intrinsic Semiconductor	63
3.3.1	Fermi Level in Extrinsic Semiconductor	63
3.4	E-K Diagrams	64
3.5	Band Gap Engineering	65
3.6	Applications of Semiconductors in Optoelectronic Devices	65
3.6.1	Light Emitting Diode (LED)	66
3.6.2	Solar Cell	67
3.6.3	Phototransistors	68
3.6.4	Photoconductors	69
3.6.5	Photodiodes	70
3.7	Safe Disposal of Electronic Materials	71
3.8	Bioimplants	72
3.8.1	Metal Bioimplants	73
3.8.2	Ceramic Bioimplants	77
3.8.3	Polymeric Bioimplants	78
3.8.4	Tissue Engineering	78
3.8.5	Biocompatibility	78

- 3.9 Biosensors 79
- 3.10 Classification of Biosensors 80
 - 3.10.1 Optical Biosensors 80
 - 3.10.2 Resonant Biosensor 80
 - 3.10.3 Electrochemical Biosensors 80
 - 3.10.4. Mass-based Biosensors 81
 - 3.10.5 Enzymatic Biosensors 81
 - 3.10.6 Thermal-detection Biosensors 81
 - 3.10.7 Ion-sensitive Biosensors 81
- 3.11 Glucose Biosensors 81
 - 3.11.1 Enzymatic Glucose Biosensors 81
- 3.12 Cholesterol Biosensors 82
- 3.13 DNA Biosensors 84
 - 3.13.1 Electrochemical DNA Biosensors 85
 - Conceptual Questions* 86
 - Descriptive Questions* 87
 - Multiple Choice Questions* 87

4. Characterization of Materials

90–115

- 4.1 Introduction 90
- 4.2 Electron Microscope 90
- 4.3 Transmission Electron Microscope (TEM) 92
 - 4.3.1 Principle 92
 - 4.3.2 Construction 92
 - 4.3.3 Advantages 93
 - 4.3.4 Disadvantages 93
 - 4.3.5 Applications 93
- 4.4 Scanning Electron Microscope (SEM) 93
 - 4.4.1 Principle 93
 - 4.4.2 Construction 93
 - 4.4.3 Advantages 93
 - 4.4.4 Disadvantages 94
 - 4.4.5 Applications 94
- 4.5 Scanning Probe Microscopy 94
- 4.6 Scanning Tunneling Microscope (STM) 95
 - 4.6.1 Principle 95
 - 4.6.2 Construction 95
 - 4.6.3 Advantages 95
 - 4.6.4 Disadvantages 95
 - 4.6.5 Applications 96
- 4.7 Atomic Force Microscopy (AFM) 96
 - 4.7.1 Principle 96
 - 4.7.2 Construction 96
 - 4.7.3 Applications 97

4.8	X-ray Methods	97
4.8.1	X-ray Photoemission Spectroscopy (XPS)	97
4.8.2	Analysis of the Spectrum	99
4.9	X-ray Powder Diffraction (XRD)	100
4.9.1	Principle	101
4.9.2	Lattice Planes	101
4.9.3	Analysis of Diffractogram	104
4.9.4	Calculation of Unit Cell Parameters from Diffraction Peak Positions	107
4.9.5	Debye-Scherrer Equation to Calculate the Particle Size	107
4.10	Thermal Analysis	108
4.11	Thermogravimetric Analysis (TGA)	108
4.11.1	Instrumentation	108
4.11.2	Factors Affecting TGA	109
4.11.3	Application of TGA	110
4.12	Differential Thermal Analysis (DTA)	110
4.12.1	Principle	110
4.12.2	Procedure	110
4.12.3	Factors Affecting DTA	110
	<i>Conceptual Questions</i>	112
	<i>Descriptive Questions</i>	113
	<i>Multiple Choice Questions</i>	113

5. Nanotechnology

116

5.1	Introduction	116
5.2	Synthesis	118
5.2.1	Top-down	118
5.2.2	Bottom-up	121
5.3	Biosynthesis of Nanoparticles	127
5.4	Quantum Dots	128
5.4.1	Properties	129
5.4.2	Synthesis of Quantum Dots	129
5.4.3	Toxicity of Quantum Dots	131
5.4.4	Eco-friendly Quantum Dots	132
5.4.5	Nanoscale Materials	132
5.5	Applications of Nanomaterials in Drug Delivery Mechanism	138
5.6	Applications of Nanomaterials in Photovoltaics	140
5.7	Applications of Nanomaterials in Sensors	140
	<i>Conceptual Questions</i>	141
	<i>Descriptive Questions</i>	142
	<i>Multiple Choice Questions</i>	142