

Contents

1	Basics of Biosensors and Nanobiosensors	1
	<i>Pravin Bhattarai and Sadaf Hameed</i>	
1.1	Introduction	1
1.2	Biosensor and Its Working Principle	3
1.3	Characteristics of a Biosensor	4
1.3.1	Selectivity	4
1.3.2	Reproducibility	4
1.3.3	Stability	5
1.3.4	Sensitivity and Linearity	5
1.4	Biosensor Evolution: A Brief Outlook	6
1.5	Types of Biosensors	6
1.5.1	Electrochemical Biosensors (ECBs)	6
1.5.1.1	Potentiometric Biosensors	8
1.5.1.2	Voltammetric/Amperometric	8
1.5.1.3	Impedance (Electrical Impedance Spectroscopy, EIS)	8
1.5.1.4	Conductometric	9
1.5.2	Optical Biosensors	9
1.5.2.1	Surface Plasmon Resonance	10
1.5.2.2	Evanescence Wave Fluorescence Biosensors	10
1.5.3	Piezoelectric Biosensors	11
1.5.4	Electronic Biosensors: Based on Field-Effect Transistor	12
1.6	On the Basis of the Use of Biorecognition Elements: Catalytic Versus Affinity Biosensors	13
1.6.1	Enzymatic Biosensors	13
1.6.2	Immunosensors	13
1.6.3	DNA Aptamer Biosensors	14
1.6.4	Peptide-Based Biosensors	14
1.6.5	Whole-Cell Biosensors	14
1.7	Application of Biosensors	15
1.7.1	Biosensors in Microbiology	15
1.7.2	Biosensors for Environmental Monitoring Applications	16
1.7.3	Biosensors for Cancer Biomarker Identification	16
1.7.4	Biosensor in the Detection of Infectious Diseases	16

1.8	Conclusion	17
	Acknowledgment	17
	References	17
2	Transduction Process-Based Classification of Biosensors	23
	<i>Fang Yang, Yuanyuan Ma, Stefan G. Stanciu, and Aiguo Wu</i>	
2.1	Introduction	23
2.2	Electrochemical Biosensors	24
2.2.1	Potentiometric Biosensors	25
2.2.2	Impedimetric Biosensors	26
2.2.3	Conductometric Biosensors	28
2.3	Optical Biosensors	29
2.3.1	Biosensors Based on Surface Plasmon Resonance (SPR)	29
2.3.2	Raman and Fourier Transform Infrared Spectroscopy (FT-IR)	30
2.3.3	Biosensors Based on Fluorescence Effect	31
2.4	Mass-Based Biosensors	32
2.4.1	Piezoelectric Biosensors	32
2.4.2	Quartz Crystal Microbalance (QCM)	33
2.4.3	Surface Acoustic Wave (SAW)	34
2.5	Thermal Biosensors	35
2.5.1	Thermometric Sensors	35
2.5.2	Terahertz Effect	36
2.5.3	Thermal Radiation	37
2.6	Energy Biosensors	38
2.6.1	Adenosine Triphosphate	39
2.6.2	Fluorescence Resonance Energy	39
2.7	Conclusion	40
	Acknowledgments	40
	References	40
3	Novel Nanomaterials for Biosensor Development	45
	<i>Sadaf Hameed and Pravin Bhattarai</i>	
3.1	Introduction	45
3.2	Graphene and Its Composites	46
3.2.1	Graphene and Their Composite-Based Biosensors	48
3.2.1.1	Graphene and Their Composite-Based Electrochemical Biosensors	49
3.2.1.2	Graphene and Their Composite-Based Field-Effect Transistor Biosensors	50
3.3	Carbon Nanotubes and Their Hybrids	51
3.3.1	Biosensors Based on Carbon Nanotubes and Their Hybrids	53
3.4	Nitride-Based Biosensors	57
3.4.1	Biosensing Application of Nitride-Based Nanomaterials	58
3.5	Metal and Metal Oxide Nanoparticles for Biosensors	60
3.5.1	Fundamental Characteristics of Metal and Metal Oxide Nanostructure for the Development of a Biosensor	61

3.5.2	Performance of Nanostructured Metal and Metal Oxide-Based Biosensors	61
3.6	Conclusion	64
	Acknowledgment	64
	References	64
4	Biomarkers and Their Role in Detection of Biomolecules	73
	<i>Ayesha Taj, Abdul Rehman, and Sadia Z. Bajwa</i>	
4.1	Introduction	73
4.2	Types of Biomarkers	75
4.2.1	Predictive Biomarker	75
4.2.2	Prognosis Biomarker	75
4.2.3	Pharmacodynamic Biomarker	75
4.3	Cancer Biomarker	76
4.3.1	Role of Biomarkers in Cancer Medicine	77
4.3.2	Use of Biomarkers in Cancer Research	78
4.3.2.1	Risk Assessment	79
4.3.2.2	Screening	79
4.3.2.3	Diagnostic Test	79
4.3.2.4	Staging	80
4.3.2.5	Monitoring Tests	80
4.3.3	Types of Cancer Biomarkers	80
4.4	Cardiac Biomarkers	80
4.4.1	Measurement	81
4.4.2	Types of Cardiac Biomarkers	81
4.4.2.1	Troponin	81
4.4.2.2	Creatine Kinase (CK)	82
4.4.2.3	Myoglobin	82
4.4.2.4	Lactate Dehydrogenase (LDH)	82
4.4.2.5	C-Reactive Protein (CRP)	82
4.5	Biomarker of Aging	83
4.6	Alzheimer's Biomarker	83
4.7	HIV Biomarker	85
4.8	Conclusion	87
	Acknowledgment	88
	References	88
5	Detection of Cancer Cells by Using Biosensors	95
	<i>Nuzhat Jamil and Waheed S. Khan</i>	
5.1	Introduction	95
5.2	Early Stage Detection of Cancer and Its Importance	96
5.3	Biosensor – A Good Option for Detecting Cancers	96
5.4	Cancers Commonly Observed in Females	97
5.4.1	Breast Cancer Detection	97
5.4.1.1	Electrochemical DNA Biosensor Based on Immobilized ZnO Nanowires	97

- 5.4.1.2 Optical Biosensor of Breast Cancer Cells 98
- 5.4.1.3 Microfluidic Plasmonic Biosensor 100
- 5.4.1.4 QCM Biosensor for Sensitive and Selective Detection 100
- 5.4.2 Ovarian Cancer Detection 102
 - 5.4.2.1 ZnO–Au-Based Electrochemical Biosensor for Ovarian Cancer 102
 - 5.4.2.2 Magnetic Nanoparticle–Antibody Conjugates (MNP–ABS)-Based Assay 103
- 5.4.3 Cervical Cancer Detection 103
 - 5.4.3.1 Impedimetric Biosensor for Early Detection of Cervical Cancer 104
 - 5.4.3.2 Automated Cervical Cancer Detection Using Photonic Crystal-Based Biosensor 105
- 5.5 Cancers Commonly Observed in Males 106
 - 5.5.1 Lung Cancer Detection 106
 - 5.5.2 Gold Nanoparticle-Based Colorimetric Biosensor 106
- 5.6 Prostate Cancer Detection 107
 - 5.6.1 Novel Label-Free Electrochemical Immunosensor for Ultrasensitive Detection of Prostate-Specific Antigen Based on the Enhanced Catalytic Currents of Oxygen Reduction Catalyzed by Core–Shell Au@Pt Nanocrystals 107
 - 5.6.2 Electrochemical Biosensor to Simultaneously Detect VEGF and PSA for Early Prostate Cancer Diagnosis Based on Graphene Oxide/ssDNA/PLLA Nanoparticles 108
 - 5.6.3 Detection of Early Stage Prostate Cancer by Using a Simple Carbon Nanotube@Paper Biosensor 109
- 5.7 Oral Cancer 110
 - 5.7.1 Graphene Biosensor Based on Antigen Concentration in Saliva 110
- 5.8 Conclusions 111
 - Acknowledgments 112
 - References 112

6 Biosensor Applications for Viral and Bacterial Disease

Diagnosis 117

Ayesha Shaheen, Rabia Arshad, Ayesha Taj, Usman Latif, and Sadia Z. Bajwa

- 6.1 Introduction 117
- 6.2 Dengue Fever Virus Detection 118
 - 6.2.1 Nanostructured Electrochemical Biosensor 118
 - 6.2.2 Plasmonic Biosensor for Early Detection of Dengue Virus 120
 - 6.2.3 Impedimetric Biosensor to Test Neat Serum for Dengue Virus 120
- 6.3 Zika Virus Detection 122
 - 6.3.1 Electrochemical Biosensors for Early Stage Zika Diagnostics 122
 - 6.3.2 Novel Graphene-Based Biosensor for Early Detection of Zika Virus 124
 - 6.3.3 Smartphone-Based Diagnostic Platform for Rapid Detection of Zika Virus 126
- 6.4 Yellow Fever 126
 - 6.4.1 Field-Effect Transistor Biosensor for Rapid Detection of Ebola Antigen 127

6.5	Hepatitis B	128
6.5.1	Carbon Nanotube-Based Biosensor for Detection of Hepatitis B	128
6.5.2	Gold Nanorod-Based Localized Surface Plasmon Resonance (SPR) Biosensor for Sensitive Detection of Hepatitis B Virus	129
6.5.3	Amplified Detection of Hepatitis B Virus Using an Electrochemical DNA Biosensor on a Nanoporous Gold Platform	129
6.6	Hepatitis C	130
6.6.1	Aggregation of Gold Nanoparticles: A Novel Nanoparticle Biosensor Approach for the Direct Quantification of Hepatitis C	131
6.6.2	Impedimetric Genosensor for Detection of Hepatitis C Virus (HCV1) DNA Using the Viral Probe on Methylene Blue-Doped Silica Nanoparticles	132
6.6.3	Ultrasensitive Aptasensor Based on a GQD Nanocomposite for Detection of Hepatitis C Virus Core Antigen	133
6.7	Typhoid Fever	134
6.7.1	Graphene Oxide–Chitosan Nanocomposite-Based Electrochemical DNA Biosensor for Detection of Typhoid	135
6.8	<i>Mycobacterium tuberculosis</i>	137
6.8.1	Gold Nanotube Array Electrode Platform-Based Electrochemical Biosensor for Detection of <i>Mycobacterium tuberculosis</i> DNA	138
6.8.2	Label-Free Biosensor Based on Localized Surface Plasmon Resonance for Diagnosis of Tuberculosis	138
6.9	Conclusions	139
	Acknowledgment	140
	References	140
7	Detection of HIV Virus Using Biosensor	149
	<i>Haq Nawaz, Muhammad Tahir, Shumaila Anwar, Muhammad Irfan Majeed, and Nosheen Rashid</i>	
7.1	Introduction	149
7.1.1	Structure and Genomic Specifications of HIV	150
7.1.2	Morphology	150
7.2	Electrochemical Based Biosensors for HIV Detection	155
7.2.1	DNA Electrochemical Biosensors for Detection of HIV	155
7.2.1.1	Detection of HIV DNA Sequence	155
7.2.2	Label-Free Electrochemical Biosensor for Detection of HIV	156
7.2.3	Ultrasensitive Biosensors for HIV Gene	157
7.2.4	Optical Biosensors for HIV Detection	158
7.2.5	Nanostructured Optical Photonic Crystal Biosensor for HIV	159
7.2.5.1	Virus Capture	160
7.2.6	Surface Plasmon Resonance-Based Biosensors	160
7.2.7	Sensitive Impedimetric DNA Biosensor for the Determination of the HIV-1 Gene	162
7.2.8	Improved Piezoelectric Biosensor for HIV Rapid Detection of HIV	163
7.2.8.1	Measurement Procedure	163
7.3	Conclusions	164
	Acknowledgments	165
	References	165

8	Use of Biosensors for Mycotoxins Analysis in Food Stuff	171
	<i>Muhammad Rizwan Younis, Chen Wang, Muhammad Adnan Younis, and Xing-Hua Xia</i>	
8.1	Introduction	171
8.2	Types of Mycotoxins	173
8.2.1	Aflatoxins	173
8.2.2	Ochratoxins	174
8.2.3	Citrinin	174
8.2.4	Patulin	174
8.2.5	<i>Fusarium</i>	175
8.3	Biosensors for Aflatoxin Detection	175
8.3.1	DNA-Based Biosensor for Aflatoxins	176
8.3.2	Electrochemical Detection Systems	179
8.3.3	Carbon Nanotube (CNT)-Based Aflatoxin Biosensor	180
8.3.4	QCM Biosensor for Aflatoxin	182
8.4	Biosensors for Ochratoxins	185
8.4.1	Horseradish Peroxidase-Screen-Printed Biosensor for the Determination of Ochratoxin	185
8.4.2	Aptamer–DNAzyme Hairpin Biosensor for Ochratoxin	186
8.4.3	Development of QCM-D Biosensor for Ochratoxin A	189
8.5	Biosensors for Citrinin Determination	192
8.5.1	Molecular Imprinted Surface Plasmon Resonance (SPR) Biosensor	192
8.6	Biosensors for Patulin Determination	194
8.6.1	Cerium Oxide ISFET-Based Immune Biosensor	194
8.6.2	Conductometric Enzyme Biosensor for Patulin Determination	196
8.7	Biosensors for <i>Fusarium</i> Determination	196
8.7.1	Rapid Biosensor for the Detection of Mycotoxin in Wheat (MYCOHUNT)	198
8.8	Conclusions	198
	Acknowledgment	199
	References	199
9	Development of Biosensors for Drug Detection	
	Applications	203
	<i>Razium Ali Soomro</i>	
9.1	Introduction	203
9.2	What Is the Need of Biosensors for Drug Detection?	205
9.3	Biosensors for the Detection of Antibiotics	206
9.3.1	Electrochemical Biosensor for Antibiotics	207
9.3.2	Voltammetric Biosensor for Antibiotics	207
9.3.3	Photoelectrochemical Biosensors for Antibiotics	209
9.3.4	Amperometric Biosensor for Antibiotics	211
9.4	Biosensors for the Detection of Therapeutic Drugs	212
9.5	Biosensors for Neurotransmitter	214
9.6	Conclusion and Perspective	219
	Acknowledgment	219
	References	220

10	Detecting the Presence of Illicit Drugs Using Biosensors	223
	<i>Muhammad Irfan Majeed, Haq Nawaz, and Falaq Naz Arshad</i>	
10.1	Introduction	223
10.1.1	Classification of Illicit Drugs	224
10.1.2	Drug's Effect on Brain and Body	225
10.1.3	Signs of Illicit Drug Addiction	225
10.1.4	Biosensors for Illicit Drugs	226
10.1.5	Nanomaterials for Biosensors	227
10.1.6	Molecular Receptors for the Nanobiosensors	229
10.2	Cocaine Detection	230
10.2.1	Quantum Dot-Based Optical Biosensors for Cocaine Detection	230
10.2.2	Nanopore Biosensor for Rapid and Highly Sensitive Cocaine Detection	231
10.2.3	Colorimetric Cocaine Aptasensors	232
10.2.4	Electrochemical Based Cocaine Aptasensors	234
10.3	Methamphetamine Detection	234
10.3.1	Nonaggregated Au@Ag Core–Shell Nanoparticle Based Colorimetric Biosensor for Methamphetamine Detection	235
10.4	Chlorpromazine Detection	237
10.4.1	DNA Intercalation-Based Amperometric Biosensor for Chlorpromazine Detection	238
10.5	Codeine Detection	239
10.6	Morphine Detection	241
10.7	Alcohol Detection	242
10.8	Conclusion	244
	Acknowledgments	245
	References	245
11	Biosensors for Determination of Pesticides and Their Residues	255
	<i>Asma Rehman, Lutfur Rahman, Bushra Tehseen, and Hafiza F. Khalid</i>	
11.1	Introduction	255
11.2	Types of Pesticides and Their Benefits	256
11.2.1	Insecticides	256
11.2.2	Herbicides	257
11.2.3	Fungicides	257
11.2.4	Benefits of Pesticides	258
11.2.5	Beneficiaries of Pesticides	258
11.2.6	Controlling Agricultural Pests and Vectors of Plant Disease	259
11.2.7	Benefits of Pesticides to Prevent Organisms that Harm Other Activities or Damage Structures	260
11.3	Detrimental Effects: Health and Environmental Effects	261
11.3.1	Impact of Pesticides on Human Health: Topical or Systemic	262
11.3.2	Short-Term Effects of Pesticides	262
11.3.3	Long-Term Effects of Pesticides	263
11.3.4	Effects of Pesticides on Pregnant Women	263
11.3.5	Pesticides and Children	263
11.3.6	Effects of Pesticides on the Environment	264

- 11.3.7 Safe Use of Pesticides 264
- 11.4 AuNP/MPS/Au Electrode Sensing Layer-Based Electrochemical Biosensor for Pesticide Monitoring 265
- 11.5 Citrate-Stabilized AuNP-Based Optical Biosensor for Rapid Pesticide Residue Detection of Terbutylazine and Dimethoate 266
- 11.6 Piezoelectric Biosensor for Rapid Detection of Pesticide Residue 267
- 11.7 Amperometric Acetylcholinesterase Biosensor Based on Gold Nanorods for Detection of Organophosphate Pesticides 272
- 11.8 Conclusions 275
- Acknowledgment 275
- References 275

- 12 Detection of Avian Influenza Virus 289**
Waheed S. Khan, and Muhammad Zubair Iqbal
- 12.1 Introduction 289
- 12.2 Surface-Enhanced Raman Spectroscopy (SERS)-Based Nanosensor 290
- 12.2.1 Design of Magnetic Immunoassay Based on SERS Strategy 291
- 12.3 Carbon Nanotube-Based Chemiresistive Biosensors for Label-Free Detection of DNA Sequences 292
- 12.4 Influenza Virus Detection Using Electrochemical Biosensors 297
- 12.5 Aptamer-Based Biosensors 303
- 12.6 Conclusions 304
- Acknowledgments 305
- References 306

- 13 Biosensors for Swine Influenza Viruses 311**
Madiha Saeed and Aiguo Wu
- 13.1 Introduction 311
- 13.2 Diagnostic Methods for Swine Influenza Virus and Their Limitations 312
- 13.3 Nanomaterial-Based Sensors 313
- 13.3.1 Applications of Carbon-Based Nanomaterials 313
- 13.3.2 Gold Nanoparticle-Based Biosensing 315
- 13.3.3 Gold Nanoparticle-Based Localized Surface Plasmon Resonance Sensors 315
- 13.3.4 Magnetic Nanoparticle-Based Biosensing 319
- 13.3.5 Others 321
- 13.4 Conclusion 321
- Acknowledgments 322
- References 322

- 14 Biosensors for Detection of Marine Toxins 329**
Khizra Bano, Waheed S. Khan, Chuanbao Cao, Rao F.H. Khan, and Thomas J. Webster
- 14.1 Introduction 329
- 14.2 Algal Blooms and Marine Toxins 330

14.3	Classification of Marine Toxins, also Known as Biotoxins	330
14.4	Harmful Effect of Marine Toxins on Human Health	335
14.5	Biosensing of Marine Toxins	337
14.5.1	SPR-Based Biosensors for Marine Toxins with Special Reference to Saxitoxin Sensing	338
14.5.2	Detection of Marine Biotoxin in Shellfish	344
14.5.3	Smartphone-Based Portable Detection System for Marine Toxins	345
14.5.4	Superparamagnetic Nanobead-Based Immunochromatographic Assay for Detection of Toxic Marine Algae	347
14.5.5	Gold Nanorod Aggregation-Based Optical Biosensor for Rapid Endotoxin Detection	349
14.6	Conclusion	350
	Acknowledgments	351
	References	351
15	Smartphone-Based Biosensors	357
	<i>Muhammad Rizwan Younis, Chen Wang, Muhammad Adnan Younis, and Xing-Hua Xia</i>	
15.1	Introduction	357
15.2	Smartphone-Based Devices and Their Applications	360
15.3	Rapid GMR Biosensor Platform with Smartphone Interface	363
15.4	Smartphone-Based Electrochemical Biosensor for Portable Detection of Clenbuterol	367
15.5	Biosensing of Metal Ions by a Novel 3D-Printable Smartphone	369
15.6	Ambient Light-Based Optical Biosensing Platform with Smartphone-Embedded Illumination Sensor	372
15.7	Smartphone Optical Biosensor Point-of-Care Diagnostics	374
15.8	Monitoring of Cardiovascular Diseases at the Point of Care by Smartphone	377
15.9	Smartphone-Based Sensing System Using ZnO- and Graphene-Modified Electrodes for VOCs Detection	379
15.10	Use of Smartphone Technology in Cardiology	381
15.11	Smartphone-Based Enzymatic Biosensor for Oral Fluid L-Lactate Detection	383
15.12	Conclusions	385
	Acknowledgments	385
	References	385
	Index	389

