

## Contents

### Section 1 Miniaturized Devices in Analytical and Bioanalytical Sciences 1

#### 1 Miniaturized Capillary Electrophoresis for the Separation and Identification of Biomolecules 3

*Suresh K. Kailasa, Vaibhavkumar N. Mehta, and Jigneshkumar V. Rohit*

- 1.1 Introduction 3
- 1.2 Brief Summary of MCE 4
  - 1.2.1 Fabrication of Microfluidic Chips 4
  - 1.2.2 Designing Microfluidic Channels 5
  - 1.2.3 Electrophoretic Separation 6
  - 1.2.4 Detectors 6
    - 1.2.4.1 Capability of Microchip Electrophoresis for the Separation and Identification of Biomolecules 7
    - 1.2.4.2 Detection of Cancer Biomarkers 8
    - 1.2.4.3 Assays of Immune Disorders and Microbial Diseases by MCE 10
    - 1.2.4.4 Assays of Biomarkers by MCE 11
- 1.3 Summary 14
- Acknowledgments 14
- References 14

#### 2 Portable Nanomaterials Impregnated Paper-Based Sensors for Detection of Chemical Substances 21

*Khemchand Dewangan and Kamlesh Shrivastava*

- 2.1 Introduction 21
- 2.2 General Aspects of Nanomaterials 22
- 2.3 Synthesis of Nanomaterials 22
  - 2.3.1 Solvothermal/Hydrothermal Technique 23
  - 2.3.2 Reduction of Metal Salts 25
  - 2.3.3 Microemulsion Techniques 25
  - 2.3.4 Sol-Gel 25
  - 2.3.5 Polyol Processes 25

2.3.6	Coprecipitation	26
2.3.7	Thermal Decomposition of Metal–Organic Complex	26
2.3.8	Temperature-Programmed Reaction in the Presence of NH <sub>3</sub> Gas	26
2.3.9	Urea as Nitrogen Source	27
2.4	Characterization of Nanomaterials	27
2.5	Paper Substrate and Functional Materials	29
2.5.1	Uniqueness of Paper Substrate	29
2.5.2	Functional Materials and Fabrication Methods	29
2.6	Different Types of Detection Methods	30
2.6.1	Colorimetric	31
2.6.2	Electrochemical	32
2.6.3	Fluorescence	32
2.6.4	Surface-Enhanced Raman Scattering (SERS)	33
2.7	Applications of Nanomaterial-Based Paper Sensors	33
2.7.1	Environmental Aspects	33
2.7.2	Clinical Aspects	35
2.7.3	Food Safety Aspects	36
2.8	Conclusion and Future Prospects	36
	References	37
<b>3</b>	<b>Miniaturized Analytical Technology in Agriculture</b>	<b>49</b>
	<i>Vaibhavkumar N. Mehta, Vimalkumar S. Prajapati, and Jigneshkumar V. Rohit</i>	
3.1	Introduction	49
3.2	Miniaturized Analytical Techniques for the Fungal Detection in Plants	51
3.3	Miniaturized Analytical Techniques for the Virus Detection in Plants	53
3.4	Miniaturized Analytical Techniques for the Bacterial Detection in Plants	61
3.5	Conclusion and Future Perspectives	65
	References	66
<b>4</b>	<b>Solvent Extraction Coupled with Gas Chromatography for the Analysis of Polycyclic Aromatic Hydrocarbons in Riverine Sediment and Surface Water of Subarnarekha River and Its Tributary, India</b>	<b>71</b>
	<i>Balram Ambade, Shrikanta S. Sethi, Amit Kumar, and Tapan K. Sankar</i>	
4.1	Introduction	71
4.2	Materials and Methods	72
4.2.1	Description of Study Area	72
4.2.2	Sampling and Pretreatment	72
4.2.3	Extraction and Cleanup of PAHs from Samples	74
4.2.4	Analysis	74
4.2.5	Quality Assurance	74
4.3	Results and Discussion	75

4.3.1	PAH Concentration in Water	75
4.3.1.1	PAHs Concentration in Subarnarekha Riverine Sediment	76
4.3.1.2	PAH Concentration in Kharkai Riverine Sediment	77
4.3.2	PAH Composition	78
4.3.3	Analysis for Sources of PAHs	79
4.3.3.1	Diagnostic Ratio	79
4.3.3.2	Principal Component Analysis	82
4.3.3.3	Potential Ecosystem Risk Assessment	83
4.4	Conclusions	85
	Acknowledgments	86
	References	86

## **5 Laboratory-on-a-Chip: A Multitasking Device** 91

*Mansi Mehta, Bhikhu More, Tanvi Tamakuwala, and Gaurav Shah*

5.1	Introduction	91
5.1.1	LOC in Multiplexing Microfabricated Devices	91
5.1.2	LOC in Integration	92
5.2	History	92
5.3	LOC Manufacturing Technologies	92
5.3.1	PDMS (Polydimethylsiloxane)	93
5.3.2	Thermopolymers	93
5.3.3	Glass	93
5.3.4	Silicon	93
5.3.5	Paper	93
5.4	Advantages of LOC Compared to Conventional Technologies	94
5.4.1	Low Cost	94
5.4.2	Easy Use	94
5.4.3	Reduction of Human Error	94
5.4.4	Less Sample Requirement	94
5.4.5	High Parallelization	94
5.4.6	Fast Response	94
5.4.7	Process Control and Sensitivity	95
5.4.8	Cost Effective	95
5.5	Limitations of LOC Compared to Conventional Technologies	95
5.5.1	Industrialization	95
5.5.2	Signal/Noise Ratio	95
5.5.3	Additional Requirements for Efficient Work	95
5.5.4	Ethics	95
5.6	Applications of LOC in Different Fields	95
5.6.1	LOC in Genomics	95
5.6.2	LOC in Post-Genome Era	96
5.6.3	LOC in Immunological Assay	96
5.6.4	Organ-on-a-Chip	98
5.6.5	LOC in Food Safety	98
5.6.6	LOC in Environmental Monitoring	99

- 5.6.7 LOC in Cancer Diagnosis 99
- 5.6.8 LOC in COVID-19 Detection 100
- 5.7 Present Challenges 101
- 5.8 Conclusion and Future Perspectives 102
- References 102
  
- 6 Microscopic Tools for Cell Imaging 105**  
*Parveen Parasar and Vivek K. Singh*
- 6.1 Introduction 105
- 6.2 Microscopy – History and Development 106
  - 6.2.1 Live-cell Imaging Microscopy 107
    - 6.2.2 Fluorescent Microscopy 107
      - 6.2.2.1 Principle 107
      - 6.2.2.2 Photobleaching 107
      - 6.2.2.3 Fluorescence Microscopy and Dynamics of Cellular Processes 108
      - 6.2.2.4 Confocal Microscopy of Living Cells: General Approach 109
      - 6.2.2.5 Minimizing Photodynamic Damage 109
      - 6.2.2.6 Improving Photon Efficiency 110
      - 6.2.2.7 Use of Antioxidants 110
    - 6.2.3 Fluorescence Imaging Modalities 110
      - 6.2.3.1 Light Sheet Fluorescence Microscopy (LSFM) 110
      - 6.2.4 Phase-contrast Microscopy 111
        - 6.2.4.1 Principle 111
      - 6.2.5 Quantitative Phase-contrast Microscopy 112
        - 6.2.5.1 Principle 112
    - 6.2.6 Holotomography (HT) or Optical Diffraction Tomography 113
      - 6.2.6.1 Principle 113
  - 6.3 Other Considerations 114
    - 6.3.1 Oil Immersion and Water Immersion Lenses 114
    - 6.3.2 Dry Lenses 114
    - 6.3.3 Photodamage of Cells 114
    - 6.3.4 Specimen Environment 115
    - 6.3.5 Improve S/N Ratio 115
  - 6.4 Conclusions 115
  - References 116

## **Section 2 Functionalized Nanomaterial for Miniaturized Devices 121**

- 7 Ionic Liquid–Assisted Single-Drop Microextraction: A Miniaturized Sample Preparation Tool for Various Analytes 123**  
*Janardhan R. Koduru and Lakshmi P. Lingamdinne*
- 7.1 Introduction 123
- 7.2 Ionic Liquids 124

- 7.2.1 Background 124
- 7.2.2 Chemistry and Functionality of Ionic Liquids 124
- 7.2.3 Classification of ILs 125
- 7.2.4 Various Applications of Ionic Liquids (ILs) 128
- 7.3 Ionic Liquid-Assisted SDME for Analytes 129
- 7.3.1 Factors Influencing Ionic-Liquid-Assisted SDME 129
- 7.3.1.1 Vapor Pressure and Thermal Stability of ILs 129
- 7.3.1.2 The ILs are Liquids in a Broad Range 131
- 7.3.1.3 Viscosity and Surface Tension of ILs 131
- 7.3.2 ILs in SDME Coupled with Various Analytical Detectors for Analysis of Various Analytes 131
- 7.3.2.1 Analysis of Organic/Bioorganic Molecules 132
- 7.3.2.2 Inorganic Analysis 134
- 7.4 Conclusion and Future Prospects 141
- References 142

## **8 Functionalized 2D Nanomaterials for Miniaturized Analytical Devices 153**

*Thang P. Nguyen*

- 8.1 Introduction 153
- 8.2 2D Nanomaterials 154
- 8.2.1 Graphene 154
- 8.2.1.1 Synthesis of Graphene 154
- 8.2.1.2 Characteristics and Applications of Graphene 156
- 8.2.2 Transition Metal Oxides 156
- 8.2.2.1 Synthesis Method 157
- 8.2.2.2 Characteristics and Applications of TMOs 157
- 8.2.3 Transition Metal Chalcogenides 159
- 8.2.3.1 Preparation of TMCs 159
- 8.2.3.2 Characteristics and Applications of TMCs 162
- 8.2.4 MXenes 163
- 8.2.4.1 MXene Preparation 163
- 8.2.4.2 Characteristics and Applications of MXenes 163
- 8.2.5 2D Metal–Organic Frameworks 164
- 8.2.5.1 Synthesis of 2D MOFs 165
- 8.2.5.2 Characteristics and Applications of MOFs 166
- 8.3 Functionalization Methodologies 167
- 8.3.1 Inorganic Doping Method 167
- 8.3.2 Functionalized Organic Functional Groups 168
- 8.4 Outlook 169
- References 171

## **9 Functionalized Materials for Miniaturized Analytical Devices 181**

*Hani Nasser Abdelhamid*

- 9.1 Introduction 181

9.2	Miniaturized Devices	182
9.3	Miniaturized Devices for Analysis	183
9.3.1	Optical Devices	183
9.3.2	Electrochemical Methods	184
9.3.3	Magnetic Relaxation Switches (MRSw) Assays	184
9.3.4	Microfluidic Technology	185
9.3.5	Mass Spectrometry	186
9.4	Applications of Nanomaterials in Miniaturized Separation Techniques	187
9.5	Advantages, Disadvantages, and Challenges	187
9.6	Conclusions	188
	Acknowledgments	189
	References	189
<b>10</b>	<b>Microvolume UV–Visible Spectrometry for Assaying of Pesticides</b>	<b>197</b>
	<i>Jigneshkumar V. Rohit and Vaibhavkumar N. Mehta</i>	
10.1	Introduction	197
10.2	Ag NP–Based Microvolume UV–Visible Spectrometry for Analysis of Pesticides	198
10.2.1	Analysis of Fungicides	199
10.2.2	Analysis of Herbicides	202
10.2.3	Analysis of Insecticides	202
10.2.4	Analysis of Other Pesticides	204
10.3	Au NP–based Microvolume UV–Visible Spectrometry for Analysis of Pesticides	205
10.3.1	Analysis of Fungicides	205
10.3.2	Analysis of Herbicides	205
10.3.3	Analysis of Insecticides	209
10.4	Summary	212
	References	212
<b>11</b>	<b>Miniaturized Liquid Extractions in MALDI–MS Analysis</b>	<b>219</b>
	<i>Nazim Hasan and Shadma Tasneem</i>	
11.1	Introduction	219
11.2	MALDI/SALDI–TOF–MS Instrumentation and Ionization Expected Mechanism Before Miniaturization of Liquid Extraction by Nanoparticles	221
11.2.1	MALDI–TOF–MS Techniques	221
11.2.2	Miniaturization-Based NPs in SALDI/MALDI–TOF–MS Application	224
11.3	Miniaturization of Metal Nanoparticles as Affinity Probe for SDME Via MALDI–TOF–MS	225
11.3.1	Affinity Probe of Functionalized Au and Ag Nanoparticles as SDME	225

11.3.2	Nanoparticles and Ionic Liquid (NP-IL) Hybrid Probes as SDME	227
11.4	Miniaturization of Nanoprobes for LLME Via MALDI-TOF-MS	228
11.4.1	Miniaturized Nanoparticles as LLME Enrichment Probes for Biomolecules	228
11.4.2	Miniaturized Nanoparticle-Based LLME Affinity Probes for Bacterial Proteins	229
11.5	Miniaturization of Nanomaterial Affinity Probes for Biomolecules Liquid Extraction	233
11.5.1	Metal Nanoparticle-Based Miniaturization Liquid Extraction Probes	234
11.5.2	Semiconductor Quantum Dots (QDs)-Based Miniaturization Liquid Extraction Probes in MALDI-TOF Analysis	239
11.5.3	Metal-Oxide Nanomaterial-Based Miniaturization Liquid Microextraction for MALDI-TOF-MS	241
11.5.3.1	Phosphopeptides Enrichment by Liquid Microextraction Analysis by MALDI-TOF-MS	241
11.5.3.2	Miniaturization of Metal-Oxide Nanoparticles for Bacterial Proteins Liquid Microextraction Analysis by MALDI-TOF-MS	243
11.5.3.3	Miniaturization Nanoarray-Based Biochips for Biomolecule Analysis by MALDI-MS	247
11.6	Conclusion	250
	References	250
<b>12</b>	<b>Mechanisms and Applications of Nanopriming: New Vista for Seed Germination</b>	<b>261</b>
	<i>Karen P. Pachchigar, Darshan T. Dharajiya, Sumeet N. Jani, Jaykishan N. Songara, and Gourav S. Dave</i>	
12.1	Introduction to Agriculture and Green Nanotechnology	261
12.2	Nanopriming for Better Crop Germination	263
12.3	Anticipated Mechanisms Underlying Nanopriming: Plant Physiology and Molecular-Level Interactions	264
12.3.1	Imbibition and Vigorous Seedling Growth	265
12.3.2	Osmotic Adjustment and Membrane Dynamics	266
12.3.3	Antioxidant and ROS Signaling	267
12.3.4	Hormonal Crosstalk and Metabolic Flux	268
12.4	Current Status of Nanopriming	269
12.5	Conclusion	273
	References	273
<b>13</b>	<b>Nanotechnology for Environmental Pollution Detection and Remedies</b>	<b>279</b>
	<i>Nishant Srivastava and Gourav Mishra</i>	
13.1	Introduction	279
13.2	Nanotechnology for Environmental Monitoring and Diagnosis	280
13.2.1	Nanosensors for Water Contamination	280

13.2.2	Nanosensors for Air Pollution	282
13.2.3	Nanosensors for Soil Contamination	283
13.2.4	Nanobiosensors	284
13.3	Nanotechnology for Environmental Remediation	285
13.3.1	Photocatalysis Or Advanced Oxidation Process for Environmental Remediation	286
13.3.2	Nanocomposites and Nanodevices for Environmental Remediation	288
13.4	Conclusion	289
	References	289

<b>Index</b>	295
--------------	-----