Contents

Preface *ix*

- 1 Introduction 1
- 1.1 Overview of Integrated Smart Micro-systems 1
- 1.1.1 The Progress of Portable Smart Micro-systems 2
- 1.1.2 Integrated Smart Micro-systems Toward Healthcare Monitoring 4

۱v

- 1.2 Three Core Units of Smart Micro-systems 5
- 1.2.1 Triboelectric Nanogenerator (Energy-Harvesting Unit) 5
- 1.2.2 Solid-State Supercapacitors (Energy-Storage Unit) 9
- 1.2.3 Strain Sensors (Functional Sensing Unit) 12
- 1.3 The Progress of the Integration of Smart Micro-systems 15
- 1.3.1 Self-Charging Power Unit 16
- 1.3.2 Self-Driven Monitor Patch 18
- 1.3.3 Self-Powered Sensing Platform 20
- 1.4 The Progress of Applications of Integrated Smart Micro-systems 22
- 1.4.1 Real-Time Health Monitoring 22
- 1.4.2 Multifunctional Human–Machine Interaction 24
- 1.4.3 Assisted Precision Therapy 26
- 1.5 Scope and Layout of the Book 28
- 1.5.1 Scope of the Book 29
- 1.5.2 Layout of the Book 31 Abbreviations 33 References 33

2 Core Units of Smart Micro-systems 39

- 2.1 Triboelectric Nanogenerators for Energy Harvesting 39
- 2.1.1 Single-electrode Triboelectric Nanogenerator 40
- 2.1.2 Freestanding Triboelectric Nanogenerator 44
- 2.2 Supercapacitors for Energy Storage 50
- 2.2.1 Wearable Supercapacitor 50
- 2.2.2 Planar Micro-supercapacitor 54
- 2.3 Piezoresistive Sensors for Function Sensing 61
- 2.3.1 Conductive Sponge-Based Piezoresistive Sensor 61

vi Contents

2.3.2 2.4	Porous Conductive Elastomer-Based Piezoresistive Sensor 67 Summary 72 Abbreviations 73 References 74
3	Sandwiched Self-charging Power Unit 77
3.1	Self-charging Power Unit 77
3.1.1	Working Principle 78
3.1.2	Theoretical Analysis 79
3.2	Enhancement of TENG Based on Surface Optimization 81
3.2.1	Formation Mechanism of Wrinkle Structure 81
3.2.2	Fabrication Process and Morphology Characterization 82
3.3	Flexible Paper Electrode–Based Supercapacitor 83
3.3.1	Percolation Theory 84
3.3.2	Flexible CNT–Paper Electrode 85
3.3.3	Fabrication Process and Morphology Characterization 87
3.4	Performance Characterization of SCPU 88
3.4.1	Evaluation of TENG 88
3.4.2	Evaluation of SC 92
3.4.3	Self-charging Performance 93
3.5	Applications of SCPU 94
3.5.1	Power Supply for Low-power Electronics 94

- 3.5.2 Smart Display of Electrochromic Device *95*
- 3.6 Summary 96 Abbreviations 97 References 98

4 All-in-one Self-driven Monitor Patch 101

- 4.1 Self-driven Monitor Patch 102
- 4.1.1 Working Principle 102
- 4.1.2 Theoretical Analysis 102
- 4.2 Fabrication Process of Self-driven Monitor Patch 104
- 4.2.1 "Solution-Evaporation" Method 105
- 4.2.2 Modulation of Parameters and Morphologies 106
- 4.2.3 Integrated Fabrication 108
- 4.3 Performance Characterization of Self-driven Monitor Patch 110
- 4.3.1 Evaluation of PRS 110
- 4.3.2 Evaluation of MSC 114
- 4.4 Applications of Self-driven Monitor Patch 118
- 4.4.1 Real-time Health Monitoring *118*
- 4.4.2 Personalized Human–Machine Interaction 118
- 4.4.3 Static Pressure Distribution and Dynamic Tactile Trajectory 120
- 4.5 Summary 123 Abbreviations 124
 - References 125

- 5 Fully Integrated Self-powered Sweat-Sensing Platform 127
- 5.1 Structural Design of Self-powered Sweat-Sensing Platform 128
- 5.2 Freestanding Triboelectric Nanogenerator 130
- 5.2.1 Working Principle and Structural Design *130*
- 5.2.2 Performance Characterization 133
- 5.3 Potentiometric Electrochemical Sensing Unit 135
- 5.3.1 Working Principle 136
- 5.3.2 Microfluidic Structural Design 138
- 5.3.3 Fabrication Process 139
- 5.3.4 Performance Characterization 141
- 5.3.4.1 Sensitivity 141
- 5.3.4.2 Selectivity 142
- 5.3.4.3 Cycling Repeatability 142
- 5.4 System-level Integrated Circuit Module 143
- 5.4.1 Schematic Diagram and Operation Flow Analysis 145
- 5.4.2 Performance Characterization 146
- 5.5 Applications of Fully Integrated Self-powered Sweat-Sensing Platform *149*
- 5.5.1 Validation of Flexible Sensing Unit 149
- 5.5.2 On-body Evaluation for Dynamic Sweat Analysis 151
- 5.6 Summary 155 Abbreviations 156 References 156

6 Multimodal Sensing Integrated Health-Monitoring System 159

- 6.1 Multimodal Sensing Platform 160
- 6.1.1 Structural Design 160
- 6.1.2 Fabrication and Morphology of All-Laser-Engraved Process 161
- 6.2 LEG-based Chemical Sensor for UA and Tyr Detection 165
- 6.2.1 Performance Characterization 165
- 6.2.2 Reliability and Selectivity 168
- 6.3 LEG-based Physical Sensor for Vital Signs Monitoring 171
- 6.3.1 Evaluation of LEG-based Temperature Sensor 171
- 6.3.2 Microfluidic Structural Design 173
- 6.4 System-Level Circuity Module 175
- 6.4.1 Design and Block Diagram 176
- 6.4.2 Signal Processing and Validation 179
- 6.5 On-body Evaluation of Integrated Health-Monitoring System 181
- 6.5.1 Sweat Analysis at Different Body Parts 181
- 6.5.2 Multimodal Real-Time Continuous In Situ Measurement 183
- 6.6 Health-Monitoring System for Non-invasive Gout Management 184
- 6.6.1 Purine-Rich Diets and Gout 185
- 6.6.2 Personalized Non-Invasive Gout Management 185

viii Contents

6.7 Summary 189 Abbreviations 190 References 190

7 **Progress and Perspectives** 193

- 7.1 The Progress of the Micro-systems *193*
- 7.2 Perspectives of the Micro-systems 195 Abbreviations 196 References 196

Index 199