

Table of Contents

Preface	xv
Chapter 1. Chemical and Biological Recognition	1
Nicole JAFFREZIC-RENAULT	
1.1. Gas molecule recognition	1
1.1.1. Utilizing metallic oxides as semi-conductor materials for detecting gases	2
1.1.2. Molecular semiconductors.	4
1.1.3. Ionic conductor materials for detecting gas molecules	7
1.1.4. Selective sorption in polymer matrices	8
1.2. Ionic recognition	11
1.2.1. Inorganic materials for ionic recognition.	11
1.2.2. Organic materials for ionic recognition.	13
1.3. Biological recognition	16
1.3.1. Enzyme biosensors	16
1.3.2. Immunosensors.	17
1.3.3. Oestrogenic receptor biosensors	18
1.3.4. DNA and aptamer biosensors	19
1.3.5. Cellular biosensors	20
1.3.6. Immobilization methods for a bioreceptor	21
1.3.7. A biomimetic approach: molecularly imprinted polymers (MIPs)	23
1.4. Bibliography	24

Chapter 2. Adsorption Phenomena	27
René LALAUZE	
2.1. The surface of a solid	27
2.2. Examining the adsorption phenomenon	29
2.3. Forces intervening between a gas molecule and the solid's surface	31
2.3.1. Overview of van der Waals forces	31
2.3.2. Expression of potential between a molecule and a solid	32
2.3.3. Chemical forces between a gas environment and the surface of a solid	34
2.3.4. Distinction between physical and chemical adsorption.	34
2.4. Thermodynamic study of physical adsorption.	35
2.4.1. Different adsorption models	35
2.4.2. Hill's model	36
2.4.3. Hill and Everett's models	37
2.5. Physical adsorption isotherms.	38
2.5.1. General remarks	38
2.5.2. Adsorption isotherms in mobile mono-layers	39
2.5.3. Adsorption isotherms in localized mono-layers	39
2.6. Chemical adsorption isotherms	43
2.7. Bibliography	43
 Chapter 3. Microcantilever Transduction	 49
Isabelle DUFOUR	
3.1. Introduction	49
3.2. Sensitive layers	51
3.3. Static mode	52
3.3.1. Measurement principle.	53
3.3.2. Equations	53
3.3.3. Example of measurement	54
3.4. Dynamic mode	55
3.4.1. Actuation	56
3.4.2. Measurement of resonant frequency	56
3.4.3. Equation.	57
3.5. Example of measurement	60
3.6. Other uses for dynamic mode	63
3.6.1. Dynamic mode without a sensitive layer	64
3.6.2. Dynamic mode with in-plane vibrations.	66

3.7. Conclusion	67
3.8. Acknowledgments	67
3.9. Bibliography	67
Chapter 4. Piezoelectric Transduction (QCM).	71
Hubert PERROT	
4.1. General remarks and basic principles	71
4.1.1. Piezoelectric effect	71
4.1.2. Vibration modes	73
4.1.3. Different acoustic devices	74
4.1.4. Measuring methodology	76
4.2. Theoretical aspects of the quartz microbalance	79
4.2.1. Measures in vacuum or gas environments	79
4.2.2. Measurements in liquid environments	80
4.2.3. Electroacoustic modeling	83
4.3. Applications of quartz microbalances	85
4.3.1. Electrochemistry	85
4.3.2. Biosensors	86
4.4. Bibliography	89
Chapter 5. Metal Oxide Gas Sensors	93
Christophe PIJOLAT	
5.1. Introduction: gas detection and micro-sensors	93
5.2. Catalytic sensors	96
5.3. Potentiometric sensors	99
5.4. Semi-conductor sensors	104
5.4.1. Introduction	104
5.4.2. Basic principles	105
5.4.3. Semi-conductive properties of metal oxides and redox reactions	106
5.4.4. Electronic surface states, space charge and gas adsorption	108
5.4.5. Effect of grain size and the complexity of polycrystalline materials	110
5.4.6. Examples of industrial developments and applications	114
5.5. Future developments	120
5.6. Bibliography	123

Chapter 6. Molecular Material-based Conductimetric Gas Sensors	127
Marcel BOUVET	
6.1. Molecular semiconductors	127
6.2. Molecular material-based conductimetric devices	131
6.3. Oxidizing or electron providing compound sensors	134
6.4. Volatile organic compound (VOC) sensors	138
6.5. Bibliography	139
Chapter 7. Responses and Electrical Properties of Gas Microsensors	143
Khalifa AGUIR	
7.1. Introduction	143
7.2. Response of a gas sensor	145
7.3. Chemical microsensors	148
7.4. Modeling conductivity of the sensitive layer with WO_3 gas microsensors in the air in the presence of ozone	152
7.4.1. Model of a microsensor	152
7.4.2. Wolkenstein model	153
7.4.3. Modeling	154
7.4.4. Some results from the calculations developed above	160
7.5. Impedance spectroscopy on gas sensors	165
7.6. Selectivity in gas sensors	168
7.7. Electronic noise spectroscopy in gas microsensors	169
7.8. Conclusion	173
7.9. Bibliography	174
Chapter 8. Gas Microsensor Technology	175
Philippe MENINI	
8.1. Introduction	175
8.2. Metal oxide gas sensor technology	177
8.2.1. Overview of how gas sensors function	177
8.2.2. Existing structures	177
8.2.3. Different technological approaches	183
8.2.4. Technological improvements in the heating layer	189
8.2.5. Integrating the sensitive material	194
8.2.6. Summary	196

8.3. New generation of wireless gas sensors	198
8.3.1. Introduction	198
8.3.2. Detection principle	200
8.3.3. Design structure	201
8.3.4. Production	205
8.4. Conclusion	208
8.5. Bibliography	209
Chapter 9. Multisensors: Measurements and Behavior	
Models	211
Philippe BREUIL	
9.1. Introduction	211
9.2. Modeling the behavior of multisensors	212
9.2.1. General concepts	212
9.2.2. Performance of measurement systems	214
9.2.3. Modeling = calibration	215
9.2.4. Principles of behavior modeling: least squares	217
9.2.5. Single linear regression	218
9.2.6. Multiple linear regression	219
9.2.7. Influence of the model's complexity	220
9.2.8. Methods of factor analysis (PCR, PLS)	221
9.2.9. Neural networks, quantification	222
9.3. Performance of gas sensors, influence on prediction computation	223
9.3.1. 3S: sensitivity	223
9.3.2. 3S: stability	224
9.3.3. 3S: selectivity	225
9.3.4. Propagation of error in the model	228
9.3.5. Conclusion on the 3Ss	229
9.4. Example with four sensors	230
9.5. Bibliography	233
Chapter 10. Development of Microtechnologies for the Realization of Chemical, Biochemical and/or Biological Microsensors	235
Pierre TEMPLE-BOYER	
10.1. Introduction	235
10.2. Chemical sensors	237
10.2.1. Defining chemical sensors	237

10.2.2. The obstacles in developing chemical microsensors	238
10.2.3. Development solutions	240
10.3. Development of silicon and polymer microtechnologies applied to chemical sensors.	243
10.3.1. Technological platform based on chemically sensitive resistors	244
10.3.2. Technological platform based on microelectrodes	246
10.3.3. Technological platform based on field effect transistors	248
10.3.4. Technological platforms based on micro electromechanical systems	252
10.3.5. Technological platform based on surface acoustic wave microsensors	255
10.4. Conclusion	257
Chapter 11. Development of Micro-preconcentrators for the Detection of Gaseous Species at Trace Level.	261
Jean-Paul VIRICELLE	
11.1. Introduction	261
11.2. Preconcentration principle/preconcentration factors	262
11.3. Adsorption phenomena	264
11.3.1. Texture of materials: specific surface areas and porosity.	264
11.3.2. Adsorption isotherms	266
11.3.3. Physico-chemical adsorption-desorption models	268
11.3.4. Study on the adsorbent's affinity to gases	272
11.4. Adsorbing materials	276
11.4.1. Active carbons	277
11.4.2. Carbon nanotubes	277
11.4.3. Other adsorbents.	279
11.5. Development of preconcentrators	280
11.5.1. State-of-the-art microcomponents/materials	280
11.5.2. R&D example for a preconcentrator	284
11.5.3. Example of a commercial machine	288
11.6. Conclusion	288
11.7. Bibliography.	289

Chapter 12. Microfluidics: Manipulation of Nanovolume Samples	293
Louis RENAUD	
12.1. Introduction.	293
12.2. The physics of microfluidic flows: simplified Navier–Stokes equations	295
12.3. Hydrodynamic flow: concept of microfluidic resistance	297
12.4. Electro-osmotic flow	301
12.5. Drop microfluidics: two-phase flows.	306
12.6. Conclusion	309
12.7. Bibliography	310
Chapter 13. Electrochemical Biosensors	313
Chantal GONDRAN	
13.1. Defining biosensors.	313
13.2. Principle behind biosensors.	313
13.3. Characteristics	314
13.3.1. Accuracy	314
13.3.2. Repeatability	314
13.3.3. Reproducibility	315
13.3.4. Limit of detection	315
13.3.5. Sensitivity	316
13.3.6. Selectivity	316
13.3.7. Response time.	317
13.4. Enzymatic biosensors	317
13.4.1. Amperometric enzyme biosensors	318
13.4.2. Potentiometric enzymatic biosensors	324
13.4.3. Conductimetric enzymatic biosensors.	326
13.5. Affinity sensors	330
13.5.1. Use of blocking electrodes (non-faradic)	330
13.5.2. Use of faradic electrodes (electrochemical probes)	331
13.6. Conclusion	333
Chapter 14. Fiber-optic Biosensors	335
Neso SOJIC	
14.1. Introduction.	335
14.2. Biomolecules and recognition	337

14.3. Fiber-optics	338
14.3.1. Individual fiber-optics	338
14.3.2. Fiber-optic bundles	339
14.3.3. Optical configurations	340
14.4. Fiber-optic sensor applications	341
14.4.1. Enzymatic biosensors.	342
14.4.2. Immunosensors	344
14.4.3. DNA sensors	347
14.5. Conclusion	349
14.6. Bibliography.	350
Chapter 15. <i>In Vivo</i> Analyses with Electrochemical Microsensors	353
Stéphane ARBAULT	
15.1. Introduction	353
15.1.1. Microelectrodes in electrochemical analysis of living systems	353
15.1.2. Principles of the electrochemical analysis of living systems	355
15.1.3. Chemical species detected <i>in vivo</i> and <i>ex vivo</i>	357
15.1.4. Experimental assemblies for <i>in vivo</i> and <i>ex vivo</i> detection.	358
15.2. <i>In vivo</i> electrochemical detection of neurotransmitters	359
15.2.1. Methods for <i>in vivo</i> electrochemical detection of neurotransmitters	361
15.2.2. <i>Ex vivo</i> and <i>in vivo</i> detection in rat brains	363
15.2.3. <i>Ex vivo</i> detection of neurotransmitter release in a single cell	366
15.3. Conclusion	370
15.4. Bibliography.	370
Chapter 16. Microbial Biosensors for Environmental Applications	373
Gérald THOUAND and Marie José DURAND	
16.1. Pollution and environment	373
16.2. Introduction to biosensors	376
16.2.1. Definition, principles, classification	376
16.2.2. Application fields, interest, drawbacks.	380
16.2.3. Markets, patents and legislation	381

16.3. Microorganisms	382
16.3.1. Diversity of microorganisms used in microbial biosensors	382
16.3.2. Characteristics of prokaryotes: <i>Escherichia coli</i>	385
16.3.3. Eukaryotes	387
16.4. Microbial biosensors	387
16.4.1. Brief history	387
16.4.2. Summary of the state of the art	389
16.4.3. Immobilization	392
16.4.4. Performance	395
16.5. Examples of microbial biosensors in environmental applications	397
16.5.1. BOD principle	397
16.5.2. Principle of BOD biosensors	397
16.5.3. Principle of alternative analysis methods	399
16.5.4. Example of three metal detecting bacterial biosensors	401
16.6. Bibliography	406
Chapter 17. Biofuel Cells	409
Serge COSNIER	
17.1. Presentation and risks	409
17.2. Principle and characterization of biofuel cells	412
17.2.1. Performance characteristics of biofuel cells	414
17.3. Principle and characterization of a biofuel cell.	416
17.3.1. Biofuel cells based on mediated electron transfer	416
17.3.2. Biofuel cells based on direct electron transfer	417
17.3.3. Hybrid biofuel cells	418
17.3.4. Bio-inspired and biomimetic fuel cells	418
17.4. Biofuel cell examples	419
17.5. Bibliography	422
List of Authors	425
Index	427