

Contents

Preface	ix
1 Introduction	1
1.1 What is Optical Characterization?	1
1.2 Infrared, Raman, and Photoluminescence Spectroscopy	3
2 Optical Theory for Semiconductor Characterization	7
2.1 Electromagnetic Waves in Free Space	7
2.2 Electromagnetic Waves in Semiconductors	9
2.3 Quantities for Semiconductor Spectroscopy	12
3 Optical Physics of Semiconductors	17
3.1 Physics of Semiconductors	17
3.2 Optical Response of Semiconductors	26
4 Measurement Methods	45
4.1 Introduction	45
4.2 Fourier Transform Infrared Spectroscopy	45
4.3 Photoluminescence Spectroscopy	50
4.4 Raman Scattering Spectroscopy	54
4.5 Sample Considerations	58
5 Case Studies: Photoluminescence Characterization	61
5.1 General Introduction to Case Studies	61
5.2 Introduction to Photoluminescence Case Studies	61
5.3 Band Emission	62
5.4 Impurity Emission	74
5.5 Two-dimensional Mapping	89
5.6 Interfaces and Microstructures	92
6 Case Studies: Raman Characterization	105
6.1 Introduction	105
6.2 Phonons and Lattice Properties	106
6.3 Free Carriers: Electronic Properties	130
6.4 Impurities	135
6.5 Surfaces, Interfaces and Microstructures	148
7 Case Studies: Infrared Characterization	159
7.1 Introduction	159
7.2 Band Gap Absorption	159
7.3 Phonons and Lattice Properties	161
7.4 Impurities	163
7.5 Free Carriers: Electronic Properties	180
7.6 Layered Systems	188

8	Summary and Future Trends	201
8.1	Comparison and Selection Among the Methods	201
8.2	The Future of Optical Characterization	202
	References	207
	Index	217

ix	Preface	
1	Introduction	1
1	1.1 What is Optical Characterization?	1
3	1.2 Infrared, Raman, and Photoluminescence Spectroscopy	3
7	2 Optical Theory for Semiconductor Characterization	7
7	2.1 Electromagnetic Waves in Free Space	7
9	2.2 Electromagnetic Waves in Semiconductors	9
12	2.3 Quantities for Semiconductor Spectroscopy	12
17	3 Optical Physics of Semiconductors	17
17	3.1 Physics of Semiconductors	17
26	3.2 Optical Response of Semiconductors	26
42	4 Measurement Methods	42
42	4.1 Introduction	42
42	4.2 Fourier Transform Infrared Spectroscopy	42
50	4.3 Photoluminescence Spectroscopy	50
54	4.4 Raman Scattering Spectroscopy	54
58	4.5 Sample Considerations	58
61	5 Case Studies: Photoluminescence Characterization	61
61	5.1 General Introduction to Case Studies	61
61	5.2 Introduction to Photoluminescence Case Studies	61
62	5.3 Band Emission	62
74	5.4 Impurity Emission	74
89	5.5 Two-dimensional Mapping	89
92	5.6 Interfaces and Microstructures	92
102	6 Case Studies: Raman Characterization	102
102	6.1 Introduction	102
106	6.2 Phonons and Lattice Properties	106
130	6.3 Free Carriers: Electronic Properties	130
132	6.4 Impurities	132
148	6.5 Surfaces, Interfaces and Microstructures	148
159	7 Case Studies: Infrared Characterization	159
159	7.1 Introduction	159
159	7.2 Band Gap Absorption	159
161	7.3 Phonons and Lattice Properties	161
163	7.4 Impurities	163
180	7.5 Free Carriers: Electronic Properties	180
188	7.6 Layered Systems	188