

G. Blasse, B. C. Grabmaier

Luminescent Materials

With 171 Figures and 31 Tables

Springer-Verlag

Berlin Heidelberg New York

London Paris Tokyo

Hong Kong Barcelona Budapest

Table of Contents

Chapter 1 A General Introduction to Luminescent Materials

Chapter 2 How Does a Luminescent Material Absorb Its Excitation Energy?

2.1	General Considerations	10
2.2	The Influence of the Host Lattice	16
2.3	The Energy Level Diagrams of Individual Ions	20
2.3.1	The Transition Metal Ions (d^n)	20
2.3.2	The Transition Metal Ions with d^0 Configuration	25
2.3.3	The Rare Earth Ions ($4f^n$)	25
2.3.4	The Rare Earth Ions ($4f-5d$ and Charge-Transfer Transitions) ...	27
2.3.5	Ions with s^2 Configuration	28
2.3.6	Ions with d^{10} Configuration	29
2.3.7	Other Charge-Transfer Transitions	30
2.3.8	Color Centers	30
2.4	Host Lattice Absorption	30
	References	31

Chapter 3 Radiative Return to the Ground State: Emission

3.1	Introduction	33
3.2	General Discussion of Emission from a Luminescent Center	33
3.3	Some Special Classes of Luminescent Centers	38
3.3.1	Exciton Emission from Alkali Halides	38
3.3.2	Rare Earth Ions (Line Emission)	40
3.3.3	Rare Earth Ions (Band Emission)	45
3.3.4	Transition Metal Ions	50
3.3.5	d^0 Complex Ions	52
3.3.6	d^{10} Ions	53
3.3.7	s^2 Ions	55
3.3.8	The U^{6+} ion	59
3.3.9	Semiconductors	60
3.3.10	Cross-Luminescence	64
3.4	Afterglow	65
3.5	Thermoluminescence	66
3.6	Stimulated emission	67
	References	70

Chapter 4 Nonradiative Transitions

4.1	Introduction	71
4.2	Nonradiative Transitions in an Isolated Luminescent Centre	72
4.2.1	The Weak-Coupling Case	74
4.2.2	The Intermediate- and Strong-Coupling Cases	77
4.3	Efficiency	84
4.4	Maximum Efficiency for High Energy Excitation [13]	85
4.5	Photoionization and Electron-Transfer Quenching	86
4.6	Nonradiative Transitions in Semiconductors	88
	References	89

Chapter 5 Energy Transfer

5.1	Introduction	91
5.2	Energy Transfer Between Unlike Luminescent Centers	91
5.3	Energy Transfer Between Identical Luminescent Centers	95
5.3.1	Weak-Coupling Scheme Ions	95
5.3.2	Intermediate- and strong-coupling scheme ions	103
5.4	Energy Transfer in Semiconductors	106
	References	106

Chapter 6 Lamp Phosphors

6.1	Introduction	108
6.2	Luminescent Lighting [1-3]	108
6.3	The Preparation of Lamp Phosphors	111
6.4	Photoluminescent Materials	112
6.4.1	Lamp Phosphors for Lighting	112
6.4.2	Phosphors for Other Lamp Applications	126
6.4.3	Phosphors for High-Pressure Mercury Vapour Lamps	127
6.4.4	Phosphors with Two-Photon Emission	130
6.5	Outlook	130
	References	133

Chapter 7 Cathode-Ray Phosphors

7.1	Cathode-Ray Tubes: Principles and Display	134
7.2	Preparation of Cathode-Ray Phosphors	136
7.3	Cathode-Ray Phosphors	137
7.3.1	Some General Remarks	137
7.3.2	Phosphors for Black-and-White Television	138
7.3.3	Phosphors for Color Television	138
7.3.4	Phosphors for Projection Television	141
7.3.5	Other Cathode-Ray Phosphors	143
7.4	Outlook	145
	References	145

Chapter 8 X-Ray Phosphors and Scintillators (Integrating Techniques)

8.1	Introduction	146
8.1.1	X-Ray Absorption	146
8.1.2	The Conventional Intensifying Screen	148
8.1.3	The Photostimulable Storage Phosphor Screen	149
8.1.4	Computed Tomography	153
8.2	Preparation of X-ray Phosphors	156
8.2.1	Powder Screens	156
8.2.2	Ceramic Plates	157
8.2.3	Single Crystals	159
8.3	Materials	159
8.3.1	X-Ray Phosphors for Conventional Intensifying Screens	159
8.3.2	X-Ray Phosphors for Photostimulable Storage Screens	162
8.3.3	X-Ray Phosphors for Computed Tomography	165
8.4	Outlook	168
	References	169

Chapter 9 X-Ray Phosphors and Scintillators (Counting Techniques)

9.1	Introduction	170
9.2	The Interaction of Ionizing Radiation with Condensed Matter	170
9.3	Applications of Scintillator Crystals	172
9.4	Material Preparation (Crystal Growth)	178
9.5	Scintillator Materials	182
9.5.1	Alkali Halides	182
9.5.2	Tungstates	183
9.5.3	$\text{Bi}_4\text{Ge}_3\text{O}_{12}$ (BGO)	183
9.5.4	$\text{Gd}_2\text{SiO}_5 : \text{Ce}^{3+}$ and $\text{Lu}_2\text{SiO}_5 : \text{Ce}^{3+}$	184
9.5.5	CeF_3	186
9.5.6	Other Ce^{3+} Scintillators and Related Materials	188
9.5.7	BaF_2 (Cross Luminescence; Particle Discrimination)	188
9.5.8	Other Materials with Cross Luminescence	190
9.6	Outlook	191
	References	193

Chapter 10 Other Applications

10.1	Upconversion: Processes and Materials	195
10.1.1	Upconversion Processes	195
10.1.2	Upconversion Materials	197
10.2	The Luminescent Ion as a Probe	203
10.3	Luminescence Immuno-Assay	206
10.3.1	Principle	206
10.3.2	Materials	208

10.4	Electroluminescence.....	210
10.4.1	Introduction.....	210
10.4.2	Light-Emitting Diodes and Semiconductor Lasers	210
10.4.3	High-Field Electroluminescence.....	212
10.5	Amplifiers and Lasers with Optical Fibers	214
10.6	Luminescence of Very Small Particles	216
	References	218
Appendix 1.	The Luminescence Literature	221
Appendix 2.	From Wavelength to Wavenumber and Some Other Conversions .	223
Appendix 3.	Luminescence, Fluorescence, Phosphoresence.....	224
Appendix 4..	Plotting Emission Spectra	225
Subject Index		227