

Contents

Series Editor's Foreword	xi
About the authors	xiii
Preface	xv
Acknowledgements	xvii
1 Introduction	1
1.1 Flat panel displays	1
1.2 Emissive and nonemissive displays	3
1.3 Display specifications	3
1.3.1 Physical parameters	3
1.3.2 Brightness and color	5
1.3.3 Contrast ratio	5
1.3.4 Spatial and temporal characteristics	5
1.3.5 Efficiency and power consumption	6
1.3.6 Flexible displays	6
1.4 Applications of flat panel displays	6
1.4.1 Liquid crystal displays	7
1.4.2 Light-emitting diodes	7
1.4.3 Plasma display panels	8
1.4.4 Organic light-emitting devices	8
1.4.5 Field emission displays	9
References	9
2 Color science and engineering	11
2.1 Introduction	11
2.2 The eye	12
2.3 Colorimetry	15
2.3.1 Trichromatic space	15
2.3.2 CIE 1931 colorimetric observations	16
2.3.3 CIE 1976 uniform color system	19
2.3.4 Color saturation and color gamut	21
2.3.5 Light sources	22

2.3.5.1 Sunlight and blackbody radiators	22
2.3.5.2 Backlights of transmissive displays	23
2.3.5.3 Color rendering index	24
2.3.6 Photometry	25
2.4 Production and reproduction of colors	27
Homework problems	28
References	28
3 Thin-film transistors	31
3.1 Introduction	31
3.2 Basic concepts of crystallized semiconductor materials	31
3.2.1 Band structure of crystallized semiconductors	32
3.2.2 Intrinsic and extrinsic semiconductors	36
3.3 Disordered semiconductors	38
3.3.1 Amorphous silicon	39
3.3.2 Polycrystalline silicon	41
3.4 Thin-film transistor characteristics	43
3.5 Passive matrix and active matrix driving schemes	47
3.6 Non-silicon-based thin-film transistors	53
Homework problems	55
References	56
4 Liquid crystal displays	57
4.1 Introduction	57
4.2 Transmissive thin-film transistor liquid crystal displays	58
4.3 Liquid crystal materials	60
4.3.1 Phase transition temperatures	60
4.3.2 Eutectic mixtures	61
4.3.3 Dielectric constants	62
4.3.4 Elastic constants	65
4.3.5 Rotational viscosity	65
4.3.6 Optical properties	66
4.3.7 Refractive indices	67
4.3.7.1 Wavelength effect	67
4.3.7.2 Temperature effect	68
4.4 Liquid crystal alignment	70
4.5 Homogeneous cell	71
4.5.1 Phase retardation effect	72
4.5.2 Voltage-dependent transmittance	73
4.6 Twisted nematic	73
4.6.1 Optical transmittance	74
4.6.2 Viewing angle	75
4.6.3 Film-compensated TN cells	76
4.7 In-plane switching	78
4.7.1 Device structure	78
4.7.2 Voltage-dependent transmittance	79
4.7.3 Viewing angle	79
4.7.4 Phase compensation films	80
4.8 Fringe field switching	81

4.9	Vertical alignment	83
4.9.1	<i>Voltage-dependent transmittance</i>	83
4.9.2	<i>Response time</i>	83
4.9.3	<i>Overdrive and undershoot voltage method</i>	85
4.9.4	<i>Multidomain vertical alignment</i>	86
4.10	Optically compensated bend cell	88
4.10.1	<i>Voltage-dependent transmittance</i>	88
4.10.2	<i>Compensation films for OCB</i>	89
4.10.3	<i>No-bias bend cell</i>	91
4.11	Transflective liquid crystal displays	91
4.11.1	<i>Introduction</i>	91
4.11.2	<i>Dual cell gap transflective LCDs</i>	93
4.11.3	<i>Single cell gap transflective LCDs</i>	95
4.12	Future directions	101
	Homework problems	101
	References	103
5	Plasma display panels	109
5.1	Introduction	109
5.2	Physics of gas discharge	109
5.2.1	<i>I–V characteristics</i>	110
5.2.2	<i>Penning reaction and Paschen curve</i>	111
5.2.3	<i>Priming mechanism</i>	112
5.3	Plasma display panels	112
5.3.1	<i>DC PDP</i>	112
5.3.2	<i>AC PDP</i>	113
5.3.3	<i>Panel processes</i>	115
5.4	Front plate techniques	117
5.4.1	<i>Substrate</i>	118
5.4.2	<i>Sustain electrode</i>	118
5.4.3	<i>Dielectric</i>	119
5.4.4	<i>Protection layer</i>	119
5.5	Rear plate techniques	120
5.5.1	<i>Substrate</i>	121
5.5.2	<i>Address electrode</i>	121
5.5.3	<i>Dielectric</i>	121
5.5.4	<i>Barrier rib</i>	122
5.5.5	<i>Phosphor</i>	124
5.6	Assembly and aging techniques	126
5.6.1	<i>Sealing layer formation and panel alignment</i>	126
5.6.2	<i>Sealing, gas purging and display gas filling</i>	127
5.6.3	<i>Aging</i>	128
5.7	System techniques	128
5.7.1	<i>Cell operation mechanism</i>	129
5.7.2	<i>Driving</i>	130
5.7.3	<i>Energy saving</i>	130
5.7.4	<i>PDP issues</i>	132
	Homework problems	132
	References	132

6	Light-emitting diodes	137
6.1	Introduction	137
6.2	Material systems	140
6.2.1	<i>AlGaAs and AlGaInP material systems for red and yellow LEDs</i>	142
6.2.2	<i>GaN-based systems for green, blue and UV LEDs</i>	143
6.2.3	<i>White LEDs</i>	145
6.3	Diode characteristics	147
6.3.1	<i>The p-layer and n-layer</i>	148
6.3.2	<i>Depletion region</i>	149
6.3.3	<i>J–V characteristics</i>	152
6.3.4	<i>Heterojunction structures</i>	153
6.3.5	<i>Quantum well, quantum wire and quantum dot structures</i>	154
6.4	Light-emitting characteristics	155
6.4.1	<i>Recombination model</i>	156
6.4.2	<i>L–J characteristics</i>	157
6.4.3	<i>Spectral characteristics</i>	158
6.5	Device fabrication	161
6.5.1	<i>Epitaxy</i>	161
6.5.2	<i>Process flow and device structure design</i>	164
6.5.3	<i>Extraction efficiency improvement</i>	165
6.5.4	<i>Package</i>	167
6.6	Applications	168
6.6.1	<i>Traffic signals, electronic signage and huge displays</i>	169
6.6.2	<i>LCD backlight</i>	169
6.6.3	<i>General lighting</i>	172
	Homework problems	173
	References	174
7	Organic light-emitting devices	177
7.1	Introduction	177
7.2	Energy states in organic materials	178
7.3	Photophysical processes	179
7.3.1	<i>Franck–Condon principle</i>	180
7.3.2	<i>Fluorescence and phosphorescence</i>	182
7.3.3	<i>Jablonski diagram</i>	183
7.3.4	<i>Intermolecular processes</i>	184
7.3.4.1	<i>Energy transfer process</i>	184
7.3.4.2	<i>Excimer and exciplex formation</i>	185
7.3.4.3	<i>Quenching process</i>	187
7.3.5	<i>Quantum yield calculation</i>	187
7.4	Carrier injection, transport and recombination	189
7.4.1	<i>Richardson–Schottky thermionic emission</i>	190
7.4.2	<i>SCLC, TCLC and PF mobility</i>	192
7.4.3	<i>Charge recombination</i>	193
7.4.4	<i>Electromagnetic wave radiation</i>	193
7.5	Structure, fabrication and characterization	195
7.5.1	<i>Device structure</i>	196
7.5.1.1	<i>Two-layer OLED</i>	197
7.5.1.2	<i>Dopant in the matrix as the EML</i>	198

7.5.1.3 HIL, EIL and p-i-n structure	200
7.5.1.4 Top-emission and transparent OLEDs	203
7.5.2 Polymer OLEDs	204
7.5.3 Device fabrication	205
7.5.3.1 Thin-film formation	206
7.5.3.2 Encapsulation and passivation	209
7.5.3.3 Device structures for AM driving	210
7.5.4 Electrical and optical characteristics	211
7.5.5 Degradation mechanisms	213
7.6 Improvement of internal quantum efficiency	218
7.6.1 Phosphorescent OLEDs	218
7.6.2 Tandem structure	220
7.6.3 White OLEDs	222
7.7 Improvement of extraction efficiency	224
Homework problems	225
References	226
8 Field emission displays	233
8.1 Introduction	233
8.2 Physics of field emission	233
8.2.1 Work function and field enhancement	233
8.2.2 Vacuum mechanism	236
8.3 FED structure and display mechanism	237
8.4 Emitter	238
8.4.1 Spindt emitter	239
8.4.2 CNT emitter	240
8.4.3 Surface conduction emitter	243
8.5 Panel process	244
8.6 Field emission array plate techniques	247
8.7 Phosphor plate techniques	248
8.8 Assembly and aging techniques	249
8.8.1 Spacer	251
8.8.2 Sealing layer formation and panel alignment	251
8.8.3 Sealing	252
8.8.4 Evacuation and sealing off	252
8.8.5 Aging	253
8.9 System techniques	253
Homework problems	254
References	254
Index	259