

Contents

Preface	<i>XXI</i>
About the Editors	<i>XXV</i>
List of Contributors	<i>XXIX</i>

Part 1 Display Devices 1

1	TN, STN, and Guest–Host Liquid Crystal Display Devices	3
	<i>Peter Raynes</i>	
1.1	Introduction	3
1.2	Twisted Nematic Liquid Crystal Device	4
1.2.1	Twisted Nematic Construction and Operation	4
1.2.2	Domains	4
1.2.3	Optical Properties of the OFF State	5
1.2.4	Field-Induced Reorientation	6
1.2.5	Optical Properties of the ON State	7
1.2.6	Multiplexed Twisted Nematic Displays	9
1.3	Supertwisted Nematic Liquid Crystal Devices	10
1.3.1	Supertwisted Nematic LCD Construction and Operation	10
1.3.2	Optical Properties of the OFF State	11
1.3.3	Field-Induced Reorientation	13
1.3.4	Optical Properties of the ON State	14
1.4	Guest–Host Liquid Crystals	14
1.4.1	Introduction	14
1.4.2	Heilmeyer Single-Polarizer Display	14
1.4.3	Double-Layered Display	17
1.4.4	Quarter Wave Plate Display	17
1.4.5	White–Taylor Display	19
	Acknowledgments	20
	References	20

2	In-Plane Switching Display Devices 21
	<i>Hyunki Hong</i>
2.1	Introduction 21
2.2	LC Reorientation Under an Applied Electric Field 22
2.2.1	Basics of the IPS Mode 22
2.2.2	Analysis of IPS Based on the Simplified One-Dimensional Model 23
2.2.3	Actual LC Director Motion in the IPS Mode 28
2.3	Pixel Structure and Production Process 30
2.3.1	Layer Position of Common and Pixel Electrodes 30
2.3.2	High Aperture Structure 33
2.4	Performance 34
2.4.1	Wide Viewing Angle 34
2.4.2	Dynamic Performance 37
	Abbreviations 39
	References 39
3	Vertical alignment Liquid Crystal mode 41
	<i>Jang-Kun Song</i>
3.1	Introduction and Fundamentals of VA Mode 41
3.1.1	History of Vertical Alignment (VA) LCDs 41
3.1.2	LC Materials with Negative Dielectric Materials and Vertical Alignment Agents 43
3.1.3	Electrooptic Features of a Single-Domain VA Cell 45
3.2	Key Electrooptical Features of VA LCDs and Their Evaluation Tools 47
3.2.1	Transmittance Efficiencies 48
3.2.2	Tone-Rendering Distortion Index (TRDI) (or Gamma Curve Distortion Index: GDI) 49
3.3	Wide Viewing Technologies for VA Mode 52
3.3.1	Compensation Films 52
3.3.2	Four-Domain Technologies 55
3.3.2.1	Viewing Angle Properties of a Four-Domain VA Cell 55
3.3.2.2	ITO Slit Pattern and PVA (Patterned-Electrode Vertical Alignment) Mode 56
3.3.2.3	Protrusion and MVA (Multidomain Vertical Alignment) Mode 57
3.3.3	Eight-Domain Technology Using Pixel Division 58
3.3.3.1	Eight-Domain Pixel Structure and Off-Axis Image Quality 58
3.3.3.2	TT (Two TFT) Technology 61
3.3.3.3	CC (Capacitive-Coupling) Technology 62
3.3.3.4	CS (Charge-Sharing) Technology 63
3.3.3.5	SC (Swinging Common Signals) Technology 64
3.3.4	Other Methods to Improve the Off-Axis Image Quality 65
3.3.4.1	Temporal Division Technologies 65
3.3.4.2	Backlight Dimming and Off-Axis Image Quality 66
3.3.4.3	In-Plane VA Mode Using In-Plane Electrodes and Positive LCs 67

3.3.4.4	Wide Viewing Angle Using the Surface-Scattering Effect	68
3.4	Technologies for Improving Optical Transmittance	69
3.4.1	Design of Pixel Structure and Pattern Shape	69
3.4.2	Circular Polarizer and VA Mode	71
3.4.3	PSVA (Polymer-Stabilized VA) and Fish-Bone Electrodes	73
3.4.4	Photoalignment Technology in VA Mode	74
3.4.5	Summary of the Technologies for High Transmittance	75
3.5	Technologies for High Contrast Ratio in the VA Mode	76
3.5.1	High Contrast Ratio of VA Mode	76
3.5.2	High Contrast Design	77
3.6	Technologies for Fast Response Time in VA Mode	78
3.6.1	Response Time of VA Mode and Moving Picture Image Quality	78
3.6.2	Image-Processing Technologies for Improving the Moving Image Quality	79
3.6.3	Pretilt and Response Time in VA Mode	80
3.7	Technologies for Improving Color Accuracy in VA LCDs	80
3.8	Manufacturing Process for Large Size Panel	81
3.9	Conclusion	82
	Acknowledgments	82
	References	82
4	Bistable Nematic Liquid Crystal Displays	87
	<i>Cliff Jones</i>	
4.1	Introduction	87
4.2	Basics of Bistable Liquid Crystal Displays	88
4.2.1	Definition of Bistability	88
4.2.2	Creating Bistable States	90
4.3	Common Aspects of Bistable LCDs	93
4.3.1	Optical Contrast and Transmittance	93
4.3.2	Shock Stability	95
4.3.3	Low-Cost Manufacture	95
4.3.4	Passive Matrix Addressing	96
4.3.5	Active Matrix Addressing	100
4.3.6	Operating Voltage and Power	101
4.3.7	Electronic Drivers and DC Balance	102
4.3.8	Temperature Range and Operating Window	105
4.3.9	Ionic Effects and Reverse Latching	106
4.3.10	Gray scale	107
4.3.11	Color	110
4.4	Bulk Bistable Nematic LCD	110
4.4.1	The $0-2\pi$ Bistable Twisted Nematic	110
4.4.2	Weak Anchoring and the $0-\pi$ Bistable Twisted Nematic	115
4.4.3	Bend-Splay Bistable Nematic Modes	119
4.4.4	Bulk Azimuthal Bistability	121
4.5	Bistable Surfaces	122

4.5.1	Azimuthal Bistable Devices	123
4.5.1.1	Surface Alignment	123
4.5.1.2	Devices Using Azimuthal Bistable Surfaces	127
4.5.2	Zenithal Bistable Nematic Displays	130
4.5.2.1	Surface-Relief Structures	130
4.5.2.2	Flexoelectric Latching at Zenithal Bistable Surfaces	135
4.5.2.3	Zenithal Bistable Display	138
4.5.2.4	Postaligned Bistable Nematics	140
4.6	Conclusion	141
	References	142
5	Chiral Nematic Liquid Crystal Displays	147
	<i>David Coates</i>	
5.1	Introduction	147
5.2	Properties of the Chiral Nematic Phase	148
5.3	Optical Properties	150
5.3.1	The Planar Texture	150
5.3.2	The Focal Conic and Fingerprint Textures	153
5.3.3	The Homeotropic Texture	154
5.4	Bistability	154
5.5	Alignment	155
5.5.1	Surface Alignment	155
5.5.2	Polymer and Bulk Alignment	156
5.6	Electrical Switching Properties	156
5.6.1	Homeotropic to Planar and Focal Conic Textures	159
5.6.2	Focal Conic and Planar Texture to Homeotropic Texture	160
5.6.3	Planar to Focal Conic Texture	160
5.6.4	Focal Conic to Planar Texture	160
5.6.5	Negative Dielectric Anisotropy and Two-Frequency Liquid Crystals	161
5.7	Electrical Driving of Cholesteric Films	161
5.8	Cholesteric Displays	164
5.8.1	Surface-Stabilized Displays	165
5.8.1.1	Multiple-Layer Surface-Stabilized Displays	166
5.8.2	Polymer-Stabilized Displays	168
5.9	Cholesteric Displays on Flexible Substrates	169
5.10	Other Applications for Cholesteric Displays	170
	References	171
6	Smectic A Memory Displays (SAM Displays)	175
	<i>William A. Crossland, Anthony B. Davey, Daping P. Chu, and Terry V. Clapp</i>	
6.1	Introduction	175
6.2	Dynamic Scattering	176
6.3	Ionic Dopants for SAM Displays	182

6.4	Organic Smectic Phases and the First-Generation SAM Displays	186
6.4.1	Smectic A Phases	186
6.4.2	Electro-Optic Performance	186
6.5	SAMD Devices with Organosiloxane Smectic A Phases	190
6.5.1	Organosiloxane Smectic A Components	190
6.5.2	Electro-Optic Properties	193
6.5.3	Second-Generation Smectic A Formulations	194
6.5.4	Stability, Uniformity, and Lifetime in Organosiloxane Smectic A Scattering Devices	196
6.6	Other Proprietary Materials Systems for SAM Displays	199
6.7	Page-Oriented Electrical Addressing of Electronic Print Displays	200
6.8	Basic Display Contrast Modes of SAMDs	202
6.9	Plastic Devices	205
6.10	Prototype SAM Displays	206
	Acknowledgments	211
	References	211
7	Ferroelectric Liquid Crystal Displays and Devices	213
	<i>Sven Lagerwall</i>	
7.1	Introduction	213
7.2	The Canon FLC Technology	215
7.3	The LETI FLC	219
7.4	The Citizen FLC Technology	219
7.5	The Agfa MSP DIMAX Printing Station	220
7.6	The Sharp FLC	220
7.7	The Idemitsu Polymer FLC	223
7.8	Actively Addressed FLCs	225
7.8.1	Philips–Roche	225
7.8.2	The Toshiba Thresholdless Mode TV	228
7.9	FLC-on-Silicon Microdisplays	231
7.10	Outlook	233
	References	234
8	Designing Principles, Synthesis, and Properties of Smectic C Host Materials for Ferroelectric Liquid Crystals	237
	<i>Michael Hird</i>	
8.1	Introductory Aspects of Ferroelectric Liquid Crystals	237
8.2	Material Requirements for Ferroelectric Devices	238
8.3	The Development of Achiral Host Materials for Ferroelectric Mixtures	240
8.4	Ferroelectric Mixtures Based on Achiral Host Mixtures and Chiral Dopants	255
8.5	Concluding Remarks	259
	Acknowledgments	260
	References	260

9	Antiferroelectric Liquid Crystal Displays and Their Materials 263 <i>Yuichiro Yamada and Atsuo Fukuda</i>
9.1	Introduction 263
9.2	Phase Transitions between Anticlinic Antiferroelectric SmC_A^* and Synclinc Ferroelectric SmC^* 264
9.2.1	Electric-Field-Induced Transition 264
9.2.2	Temperature-Induced Transition and Subphase Emergence 265
9.3	Antiferroelectric Liquid Crystal Displays Driven by Simple Matrix (SM-AF-LCDs) 269
9.4	Thresholdless Antiferroelectric Liquid Crystal Displays Driven by TFT Active Matrix (TFT-TLAF-LCDs) 277
9.4.1	What Are Thresholdless Antiferroelectric Liquid Crystals (TLAF-LCs)? 277
9.4.2	Bulk State Crucial for TLAF Materials: Neither Simple Ferroelectric SmC^* Nor Antiferroelectric SmC_A^* 281
9.4.3	Interface Effects: Charge-Stabilized Ferroelectric Vertical Alignment or Surface-Stabilized Antiferroelectric Horizontal Alignment 287
9.5	Antiferroelectric Liquid Crystal Displays with Field Sequential Color Driven by Simple Matrix (FSC-SM-AF-LCD) 292
	References 298
10	Blue Phase and Isotropic Displays 303 <i>Khoa V. Le and Hideo Takezoe</i>
10.1	Introduction 303
10.2	Kerr Effect and Kerr Constant 303
10.3	Response Time 306
10.4	Viewing Angle and Contrast Ratio 308
10.5	Operating Voltage and Electrode Design 308
10.6	Hysteresis 309
10.7	Optically Transparent Nematic Liquid Crystals 312
10.8	Conclusions 313
	References 313
	Part 2 Non-Display Applications and Functions 315
11	Applications of Liquid Crystals in Telecommunications 317 <i>Timothy Wilkinson</i>
11.1	Introduction 317
11.2	Liquid Crystal Waveguide Structures 318
11.3	Variable Optical Attenuators 319
11.4	Optical Switching in Telecommunications 321
11.4.1	Shadow-Routed Crossbars 322
11.4.1.1	The $1-n$ Shadow Logic Switch 323
11.4.1.2	The $n \times n$ Crossbar Switch 324
11.4.1.3	The OCPM Optical Switch 325

- 11.4.1.4 The ATM Switch 326
- 11.5 Holographic Interconnects 328
- 11.5.1 The 1– n Holographic Switch 328
- 11.5.2 The Polarization-Insensitive 1–16 Holographic Switch Experiment 331
- 11.5.3 The n – n Holographic Switch 332
- 11.5.4 Wavelength-Tuneable Filters and Laser 333
- 11.5.4.1 The Digitally Tuneable Wavelength Filter 333
- 11.5.4.2 Digitally Tuneable Fiber Laser 336
- 11.5.4.3 Fabry Perot-Based Wavelength Filters 338
- 11.6 Adaptive Optics 339
- References 343

- 12 Adaptive Optics and Lenses 345**
Gordon D. Love
- 12.1 Introduction 345
- 12.1.1 Adaptive Optics for Wavefront Correction 345
- 12.1.2 Adaptive Optics for Wavefront Control 346
- 12.2 Phase Modulation with Liquid Crystals 348
- 12.2.1 Phase Modulation with Nematic Liquid Crystals 348
- 12.2.2 Phase Modulation with Ferroelectric Liquid Crystals 351
- 12.3 Conventional Liquid Crystal Adaptive Optics 354
- 12.4 Diffractive Adaptive Optics 354
- 12.4.1 Aberration Generators 356
- 12.4.2 Optical Phase Conjugation 357
- 12.4.3 Generating Optical Traps and Complex Optical Beams 359
- 12.5 Adaptive Liquid Crystal Lenses 360
- 12.5.1 Pixelated Lens 361
- 12.5.2 Curved Cell Gap Lens 361
- 12.5.3 Hole-Patterned Lens 362
- 12.5.4 Fresnel/Diffraction Liquid Crystal Lens 363
- 12.5.5 Modal Liquid Crystal Lens 363
- 12.5.6 Hidden Layer LC Lens 366
- 12.5.7 Switchable Birefringent Liquid Crystal Lens 366
- References 368

- 13 Photonic Micro- and Nanostructures, Metamaterials 373**
Heinz-Siegfried Kitzerow
- 13.1 Introduction 373
- 13.2 Basic Principles 374
- 13.2.1 Photonic Crystals 374
- 13.2.2 Photonic Crystal Fibers 384
- 13.2.2.1 General Properties 384
- 13.2.3 Microresonators 391
- 13.2.4 Metamaterials 397

13.2.4.1	Fundamentals of Optical Metamaterials	397
13.3	Developing Applications and Perspectives	403
13.3.1	Tunable Light Sources	404
13.3.2	Optical Modulators, Filters, Switches, and Waveguide Components	404
13.3.3	Sensors Based on Liquid Crystal Micro- and Nanostructures	407
13.3.4	Opportunities of Plasmonic Structures and Metamaterials	408
	Acknowledgments	411
	References	411
14	Lasing in Cholesteric Liquid Crystals	427
	<i>Antonio Munoz-Flores, Peter Palffy-Muhoray, and Bahman Taheri</i>	
14.1	Introduction	427
14.2	Optics of Cholesteric Liquid Crystals	427
14.2.1	Optics of Cholesteric Liquid Crystals	428
14.2.2	Dye-Doped Systems	430
14.3	Lasing Background	431
14.3.1	Conventional Systems	431
14.3.2	Fabry–Perot Cavity	432
14.3.3	Distributed Feedback Lasers	433
14.3.4	Lasing Conditions	434
14.4	Lasing in CLC	435
14.4.1	Historical Notes	435
14.4.2	Material Aspect	437
14.4.2.1	Host CLC Materials	437
14.4.2.2	Active Dopants	438
14.4.3	Optical Properties	439
14.4.4	Applications	443
14.4.5	CW Lasing in CLC	446
14.5	Prospects	447
	References	449
15	Recent Advances in Nematic Liquid Crystal Nonlinear Optics	453
	<i>Nelson V. Tabiryan and Iam-Choon Khoo</i>	
15.1	Introduction	453
15.2	Basics Optical Physics of Nematic Liquid Crystals	454
15.3	Laser-Induced Modulation of Order Parameter	456
15.3.1	Photoisomerization	456
15.3.2	Photosensitivity for Pulsed and/or Continuous-Wave Light Beams	457
15.4	Laser-Induced Director Axis Reorientation Effects	462
15.4.1	Reorientation with Laser-Induced Space Charge Field: Photorefractivity	462
15.4.2	Dye-Mediated Torque	463
15.4.3	Reorientation due to Photoisomerization of Azobenzene LCs	464

15.4.4	Photoinduced Surface Alignment of LC – Command Surfaces	464
15.5	Nonlinear Optical Phenomena	466
15.5.1	Phototuning of CLCs	466
15.5.2	Photoinduced Critical Opalescence and Isotropic Domain Formation	466
15.5.3	All-Optical Switching	468
15.5.4	Spatial Solitons in Azobenzene Liquid Crystals	469
15.6	Concluding Remarks	470
	Acknowledgments	471
	References	471
16	Holography and Information Storage	475
	<i>Timothy Wilkinson</i>	
16.1	Introduction	475
16.2	Theory of Holographic Systems	475
16.2.1	Diffraction through an Aperture	476
16.2.2	Effects of Hologram Pixellation	479
16.2.3	Hologram Apodization	482
16.3	Calculating Holograms	483
16.4	Liquid Crystal Modulation Effects for Holography	486
16.4.1	Nematic Liquid Crystals	486
16.4.2	Ferroelectric Liquid Crystals	488
16.4.2.1	Binary Intensity Modulation	490
16.4.2.2	Binary Phase Modulation	491
16.4.3	Polarization-Insensitive Holographic Replay	492
16.5	Holographic Projection	494
16.5.1	Noise in Holographic Projection	497
16.5.2	One-Step Phase Retrieval	499
16.5.3	Commercial Holographic Projection	501
16.5.4	3D Holographic Projection	501
16.6	Optical Storage	505
16.6.1	Single-Layer Optically Addressed Devices	505
16.6.2	Two-Layer Optically Addressed Devices	509
	References	513
17	Thermography Using Liquid Crystals	517
	<i>Helen F. Gleeson</i>	
17.1	Introduction	517
17.2	Device Structures	520
17.3	Engineering and Aerodynamic Research	522
17.4	Medical Thermography	525
17.5	Thermal Mapping and Nondestructive Testing	527
17.6	Radiation Detection	529
	References	530

- 18 Photoresponsive and Photoalignable Materials 539**
Takahiro Seki, Nobuhiro Kawatsuki, and Mizuho Kondo
- 18.1 Introduction 539
 - 18.2 Surface-Mediated Photoalignment 540
 - 18.2.1 Thermotropic Liquid Crystals 540
 - 18.2.2 Lyotropic LCs 541
 - 18.3 Photoalignment of Liquid Crystalline Polymers in Confined States 543
 - 18.3.1 Surface Grafting 543
 - 18.3.2 Block Copolymers 545
 - 18.4 Photoinduced Mass Migrations in Liquid Crystalline Systems 547
 - 18.4.1 Features of Liquid Crystalline Polymer Materials 547
 - 18.4.2 Hierarchical Structure Formation 548
 - 18.4.3 Extension to Inorganic Systems 549
 - 18.5 Photoalignment of Liquid Crystalline Polymer Films and Its Applications 550
 - 18.5.1 Photoalignment of LCP Film 551
 - 18.5.1.1 LCPs Comprising Cinnamate Derivatives 551
 - 18.5.1.2 LCPs Comprising Cinnamic Acid 557
 - 18.5.1.3 LCPs Containing Benzoate Derivatives 557
 - 18.5.2 Polarization-Preserved Photosensitization 559
 - 18.5.3 Application of Reoriented LCP Films 561
 - 18.5.3.1 Birefringent Films and the LC Alignment Layer 561
 - 18.5.3.2 Polarizers 563
 - 18.5.4 Applications to Optical Devices 564
 - 18.6 Photoresponsive Liquid Crystal (LC) Materials for Macro-Actuators 566
 - 18.6.1 Macroscopic Deformation of Crosslinked LC Polymers 567
 - 18.6.2 Deformation by Light 569
 - 18.6.3 Photomobile Fiber 573
 - References 574
- 19 Liquid Crystal Dyes 581**
Stephen J. Cowling
- 19.1 Introduction 581
 - 19.2 Dichroic Dyes 583
 - 19.3 Chromophores 584
 - 19.4 Azo Dyes 584
 - 19.5 Benzoquinone and Naphthoquinone Dyes 590
 - 19.6 Anthraquinone Dyes 595
 - 19.7 Perylene Dyes 603
 - 19.8 Azulene Dyes 606
 - 19.9 Indigo Dyes 608
 - 19.10 Tetrazine Dyes 609
 - 19.11 Order Parameter and Dichroic Ratio 610

19.12	Dye Solubility	614
19.13	Stability of the Dye	615
19.14	Other Types of Dyes	618
19.14.1	Chromonic	618
19.14.2	Laser Dyes, Fluorescent, and Liquid Crystals	620
19.15	Conclusion	622
	References	622
20	Discotic Liquid Crystals as Organic Semiconductors	627
	<i>Wojciech Pisula and Klaus Müllen</i>	
20.1	Introduction	627
20.2	Methods for Charge-Carrier Measurements	630
20.2.1	Pulsed Radiolysis Microwave Conductivity	630
20.2.2	Time-of-Flight	632
20.2.3	Space-Charge-Limited Current	632
20.2.4	Field-Effect Transistor	633
20.3	Chemical Design	633
20.3.1	Phase Behavior and Supramolecular Organization	633
20.3.2	Control over the Thermal Properties	635
20.3.3	One-Dimensional Transport of Charge Carriers	636
20.4	Processing and Charge-Carrier Transport in Thin Films	643
20.4.1	Homeotropic Alignment and Charge-Carrier Measurements	644
20.4.2	Photovoltaic Cells	650
20.4.3	Field-Effect Transistors	655
20.5	Conclusions	663
	References	663
21	Liquid Crystal Semiconductors: Oligothiophene and Related Materials	675
	<i>Masahiro Funahashi, Takuma Yasuda, and Takashi Kato</i>	
21.1	Introduction	675
21.2	Low-Molecular-Weight Liquid-Crystalline Oligothiophenes	676
21.2.1	Symmetrically Substituted 2,2':5',2''-Terthiophene and 2,2':5',2'':5'',2'''-Quaterthiophene Derivatives	676
21.2.2	Asymmetrically Substituted 2,2':5',2''-Terthiophene and 2,2':5',2'':5'',2'''-Quaterthiophene Derivatives	678
21.2.3	5-Phenyl-2,2':5',2''-Terthiophene Derivatives and 2,2':5',2'':5'',2'''-Quaterthiophene	680
21.2.4	Oligothiophene Derivatives Bearing an Oligoethylene Oxide Spacer	682
21.2.5	Related Liquid Crystal Compounds Including Thiophene Rings	682
21.3	Liquid-Crystalline Polythiophenes	687
21.3.1	Main-Chain Type Liquid-Crystalline Polythiophenes	687
21.3.2	Side-Chain Type Liquid-Crystalline Polythiophenes and Related Polymers	688

- 21.4 **Supramolecular Organization of Liquid-Crystalline Oligothiophenes** 691
- 21.5 **Electronic Functions and Devices** 694
 - 21.5.1 Electroluminescence 695
 - 21.5.2 Transistors 696
 - 21.5.3 Electrochromism 702
 - 21.5.4 Photovoltaic Devices 703
 - References 705

- 22 Redox-Active (Electrochromic) Liquid Crystals** 709
Kyosuke Isoda, Takuma Yasuda, Masahiro Funahashi, and Takashi Kato
- 22.1 TCNQ Derivatives 710
- 22.2 Viologen Derivatives 711
- 22.3 Truxene Derivatives 712
- 22.4 Oligothiophene Derivatives 715
- 22.5 Fullerene Derivatives 717
- 22.6 Rotaxane Derivatives 720
- 22.7 Metallomesogens 721
- References 723

- 23 Liquid Crystals as Ion Conductors** 727
Masafumi Yoshio and Takashi Kato
- 23.1 Introduction 727
- 23.2 Polyether-Based Liquid Crystals 727
- 23.3 Ionic Liquid Crystals 735
- 23.4 Self-Assembly of Ionic Liquids and Liquid Crystals 740
- 23.5 Carbonate-Based Liquid Crystals 745
- 23.6 Summary 746
- References 746

- 24 Electromechanical Effects** 751
Antal Jákli and Nándor Éber
- 24.1 Piezoelectricity 751
- 24.2 Electrostriction 757
- 24.3 Flexoelectricity 758
- 24.4 Electrophoresis 761
- 24.5 Electrohydrodynamic Convection (EHC) 764
- References 767

- 25 Mechanical Adaptivity in Photoresponsive Liquid Crystal Elastomers, Polymer Networks, and Composites** 773
Timothy White
- 25.1 Introduction 773
- 25.2 The Mechanics of Light-to-Work Transduction 775
- 25.3 Photomechanical Effects in Liquid Crystal Elastomers 780

- 25.3.1 Photochemical Systems 780
- 25.3.2 Photothermal Systems 781
- 25.4 Photomechanical Effects in Glassy, Liquid Crystal Polymer Networks 782
- 25.5 Application Outlook 787
 - 25.5.1 Haptic Displays 787
 - 25.5.2 Microfluidics and Flow Control 789
 - 25.5.3 Optics and Photonics 790
 - 25.5.4 Energy Harvesting 790
 - 25.5.5 Wireless Actuators and Mechanical Systems 791
 - 25.5.6 Shape Memory Polymers 792
- 25.6 Summary 793
 - Acknowledgments 793
 - References 794

- 26 Applications of Bent-Core Mesogens 799**
Wilder Iglesias and Antal Jákli
 - 26.1 Introduction 799
 - 26.2 Electro-Optical Applications 802
 - 26.2.1 SmCP_A Light Shutters, Reflectors, and Bistable Devices 804
 - 26.2.1.1 Tilt Separation Mode (TSM-LCD) 804
 - 26.2.1.2 Chiral Separation Mode (CSM-LCD) 805
 - 26.2.1.3 Bistable States 806
 - 26.2.1.4 Optical Storage Devices 806
 - 26.3 Tunable Birefringence 806
 - 26.3.1 Switching Biaxiality 808
 - 26.3.2 Blue Phases 811
 - 26.4 Other Applications 812
 - 26.4.1 Nonlinear Optics 812
 - 26.4.2 Optical Wave Guiding of BCLC Fibers 813
 - 26.4.3 Electromechanical Effects 813
 - References 814

 - 27 Applications of Mineral Liquid Crystals 819**
Patrick Davidson
 - 27.1 Introduction 819
 - 27.2 Hybrid and Composite Materials 820
 - 27.3 Mesoporous Materials 824
 - 27.4 Mineral Liquid Crystals as Matrices for Functional Organic Molecules 826
 - 27.5 Determination of the Conformation of Biomolecules 827
 - 27.6 Aligned Nanoparticle Coatings and Fibers 829
 - 27.7 Conclusion and Perspectives 834
 - References 835

- 28 Magnetic Properties of Organic Radical Liquid Crystals and Metallomesogens 837**
Rui Tamura, Yoshiaki Uchida, and Katsuaki Suzuki
- 28.1 Introduction 837
- 28.2 Magnetic Anisotropy ($\Delta\chi$) of LC Compounds 840
- 28.3 Diamagnetic LCs 841
- 28.4 Magnetic Metallomesogens 841
- 28.4.1 Magnetic Anisotropy 841
- 28.4.2 Magnetic Interactions 844
- 28.4.3 Ferroelectricity 844
- 28.4.4 Spin Crossover 845
- 28.4.5 Single-Molecule Magnet 846
- 28.4.6 Luminescence 847
- 28.5 All-Organic Radical LCs 848
- 28.5.1 First-Generation of Rod-Like All-Organic Radical LCs 848
- 28.5.2 Second-Generation of Rod-Like All-Organic Radical LCs 850
- 28.5.2.1 Magnetic Properties 851
- 28.5.2.2 Ferroelectricity 858
- 28.5.3 Discotic All-Organic Radical LCs 859
- 28.6 Conclusions 861
- Acknowledgments 862
- References 862
-
- 29 Molecular Machines Based on Liquid Crystal 865**
Nobuyuki Tamaoki
- 29.1 Introduction 865
- 29.2 Liquid Crystalline Elastomer 866
- 29.3 Visualization of Unidirectional Motion of Liquid Crystalline Molecular Rotor Driven by the Flow of Water Molecules 869
- 29.4 Transformation of Structural Change in Molecule to Rotation of Microscale Object 870
- 29.5 Some Other Motion of the Macroscopic Objects Affected by the Liquid Crystal Media 874
- 29.6 Conclusion 876
- References 877
-
- 30 Liquid-Crystalline Polymers for Biomechanical Applications 879**
John W. Goodby, Andrew D. Wilson, Isabel M. Saez, and Stephen J. Cowling
- 30.1 Polymeric Biomaterials 879
- 30.2 Bioresorbable Polymers 880
- 30.3 Bioresorbable Polymers in Orthopedics 880
- 30.4 Current Bioresorbable Materials 882
- 30.4.1 Polyglycolic Acid (PGA) and Polylactic Acid (PLA) 882
- 30.5 Liquid-Crystalline Bioresorbable Materials 884

30.5.1	Bioresorbable Liquid-Crystalline Polymers	885
30.5.2	Development of Bioresorbable Liquid-Crystalline Polymers	885
30.5.3	Toward Bioresorbable Main-Chain Liquid-Crystalline Polymer Esters	892
30.5.4	Toward Practical Osteoconductive, Bioresorbable Polymers	898
	References	907
31	Biosensors and Liquid Crystals	909
	<i>Thomas Cronin</i>	
31.1	Surface-Bound Analytes	911
31.1.1	Oblique Gold Substrates	911
31.1.2	Detection of Gaseous Analytes	913
31.1.3	Detection of DNA	913
31.1.4	Substrates Without a Gold Layer	913
31.2	Investigations into the System Parameters Important for Analyte Detection	914
31.2.1	Quantification of Analyte Binding	918
31.2.2	Modeling the Effects of Surface-Bound Analytes on LC Alignment	919
31.3	LC–Aqueous Interfaces	920
31.3.1	LC Films Supported by Copper and Gold Grids	921
31.3.2	DNA Detection at LC–Aqueous Interfaces	923
31.3.3	Modeling of the Effect of Analytes Bound at the LC–Aqueous Interface on LC Alignment	923
31.4	Detection of Analytes in the Liquid Crystal Bulk	923
31.5	Nonoptical Detection	924
31.6	Wearable Sensors	925
31.7	Summary	925
	References	926
	Index	931