

# Contents

<b>1</b>	<b>Synthesis of Perovskite Nanocrystals</b> . . . . .	<b>1</b>
	He Huang	
1.1	Introduction . . . . .	1
1.2	Early Works . . . . .	2
1.3	Precipitation Method . . . . .	3
1.4	Injection Method . . . . .	7
1.5	Methods Beyond Precipitation and Hot-Injection . . . . .	9
1.5.1	Sonication . . . . .	9
1.5.2	Solvothermal . . . . .	9
1.5.3	Microwave . . . . .	11
1.5.4	Balling Milling . . . . .	11
1.6	Summary and Outlook . . . . .	13
	References . . . . .	14
<b>2</b>	<b>Strongly Quantum Confined Metal Halide Perovskite Nanocrystals</b> . . . . .	<b>19</b>
	Daniel Rossi, David Parobek, and Dong Hee Son	
2.1	Introduction . . . . .	19
2.2	Synthesis of Quantum-Confined Perovskite Nanocrystals . . . . .	22
2.2.1	All-Inorganic Metal Halide Perovskites Quantum Dots . . . . .	23
2.2.2	Organic-Inorganic Hybrid Halide Perovskite Quantum Dots . . . . .	28
2.2.3	Synthesis of Quantum Confined Nanowires and Nanoplatelets of Perovskites . . . . .	29
2.3	Photophysical Properties of Quantum-Confined MHP NCs . . . . .	34
2.3.1	Size-Dependent Exciton Level Structure and Absorption Cross Section of MHP QDs . . . . .	35
2.3.2	Size-Dependent Exciton Dynamics in MHP QDs . . . . .	39

2.4	Applications and Future Outlook . . . . .	43
	References . . . . .	44
<b>3</b>	<b>All-Inorganic Perovskite Quantum Dots: Ligand Modification, Surface Treatment and Other Strategies for Enhanced Stability and Durability . . . . .</b>	<b>51</b>
	Zhigang Zang and Dongdong Yan	
3.1	Introduction . . . . .	51
3.2	Structure, Synthesis and Morphological Control of CsPbX <sub>3</sub> QDs . . . . .	53
3.2.1	Crystal Structure . . . . .	53
3.2.2	Synthetic Strategies . . . . .	55
3.2.3	Phase Transformation . . . . .	56
3.2.4	Degradation Mechanism of CsPbX <sub>3</sub> QDs . . . . .	56
3.3	Surface Ligand Modification . . . . .	60
3.3.1	Surface Engineering . . . . .	60
3.3.2	Categories of the Common Ligands . . . . .	63
3.3.3	Ligand Modification . . . . .	65
3.3.4	Ligand Exchange . . . . .	68
3.4	Post-Synthetic Ligand Treatments . . . . .	71
3.5	Coating Strategies . . . . .	75
3.5.1	Silica Coating for Stable CsPbX <sub>3</sub> QDs . . . . .	75
3.5.2	Other Materials Coating . . . . .	78
3.6	Compositional Engineering . . . . .	81
3.6.1	A-Site Doping . . . . .	84
3.6.2	B-Site Doping . . . . .	84
3.7	Polymer Encapsulation . . . . .	85
3.8	Application in Pc-LEDs . . . . .	89
3.9	Conclusion and Outlook . . . . .	90
	References . . . . .	95
<b>4</b>	<b>Perovskite Quantum Dots Based Light-Emitting Diodes . . . . .</b>	<b>107</b>
	Yun-Fei Li, Jing Feng, and Hong-Bo Sun	
4.1	Introduction . . . . .	108
4.2	Down-Converted Perovskite QLEDs . . . . .	108
4.2.1	Solid-State Lighting Sources . . . . .	109
4.2.2	Backlight Displays . . . . .	112
4.2.3	Stability and Lifetime . . . . .	114
4.3	Perovskite AM-QLEDs . . . . .	120
4.3.1	Evolution of Device Performance . . . . .	121
4.3.2	Stability and Lifetime . . . . .	127
4.3.3	Lead-Free Devices . . . . .	132
4.3.4	Flexible and Stretchable Devices . . . . .	133

4.4	Summary and Outlook	133
	References	135
<b>5</b>	<b>Polarized Emission from Perovskite Nanocrystals</b>	<b>139</b>
	Qiang Jing and Kai Wang	
5.1	Polarized Emission Mechanism of PNCs	141
5.2	Linearly Polarized Luminescence of PNCs	143
5.2.1	Electrospinning Technique	143
5.2.2	Mechanical Stretching Technique	144
5.2.3	Template Assisted Growth Technique	147
5.2.4	Solution-Phase Growth Technique	148
5.2.5	Chemical Vapor Deposition Growth Technique	151
5.2.6	Other Techniques	151
5.3	Circularly Polarized Luminescence of PNCs	152
	References	154
<b>6</b>	<b>Characterization of Lead Halide Perovskites Using Synchrotron X-ray Techniques</b>	<b>157</b>
	Lijia Liu and Zhaohui Dong	
6.1	Introduction	157
6.2	Techniques and Applications	159
6.2.1	X-ray Absorption Spectroscopy	159
6.2.2	X-ray Excited Optical Luminescence (XEOL)	167
6.2.3	X-ray Diffraction (XRD)	170
6.3	Concluding Remarks	176
	References	176
<b>7</b>	<b>Perovskite Quantum Dot Photodetectors</b>	<b>181</b>
	Xiangxing Xu and Linwei Yu	
7.1	Introduction to Perovskite QDs and Photodetectors	181
7.1.1	Quantum Dots	181
7.1.2	Perovskite QDs: Structure and Synthesis	182
7.1.3	Types of Photodetectors	183
7.1.4	Photodetector Performance Metrics	183
7.2	QD Photodetectors	185
7.2.1	Fundamentals of QD Photodetectors	185
7.2.2	The History of QD Photodetectors	186
7.3	Perovskite QD Photodetectors	189
7.3.1	Category Methods	189
7.3.2	Band Types	189
7.3.3	Response Features	190
7.3.4	Mechanical Performance: Flexible or Not	192
7.3.5	Working Mechanisms	193
7.3.6	Device Structures	195

7.3.7	Detection Ranges of Wavelength . . . . .	197
7.3.8	Material-System Design . . . . .	205
7.4	Summary and Perspective . . . . .	207
	References . . . . .	208
<b>8</b>	<b>Perovskite Quantum Dots Based Luminescent Solar Concentrators</b> . . . . .	<b>219</b>
	Haiguang Zhao	
8.1	Introduction . . . . .	219
8.2	Single-Layer LSC . . . . .	222
8.2.1	LSC Based on Mixed-Halide Perovskite QDs . . . . .	222
8.2.2	LSC Based on Doped Perovskite QDs . . . . .	224
8.2.3	LSC Based on Zero-Dimensional Perovskite NCs . . . . .	229
8.2.4	LSC Based on Perovskite Nanoplatelets . . . . .	232
8.3	Tandem LSC Based on Perovskite QDs . . . . .	233
8.4	Bilayer LSCs Based on Perovskite QDs . . . . .	235
8.5	Conclusion and Future Directions . . . . .	237
	References . . . . .	238
<b>9</b>	<b>Perovskite Quantum Dots for Photovoltaic Applications</b> . . . . .	<b>243</b>
	Xu Chen, Siyuan Huang, Yue Tian, Tingming Jiang, and Yang (Michael) Yang	
9.1	Introduction to Perovskite Solar Cells . . . . .	243
9.2	Perovskite Quantum Dot Solar Cells with Enhanced Device Stabilities . . . . .	245
9.3	Quantum Dots Synthesis Methods . . . . .	246
9.4	Device Structure and Physics . . . . .	248
9.5	Conclusion . . . . .	251
	References . . . . .	252
<b>10</b>	<b>Perovskite Quantum Dots Based Phototransistors</b> . . . . .	<b>255</b>
	Xiang Liu, Yuan Tao, You Zhang, Zhi Tao, and Jianhua Chang	
10.1	Introduction . . . . .	255
10.2	Perovskite Based Phototransistors . . . . .	256
10.2.1	Overview of Perovskite Phototransistors . . . . .	256
10.2.2	Bulk Perovskite Semiconductor Phototransistors . . . . .	257
10.2.3	Careers' Transfer Inside of Bulk Perovskite Transistor . . . . .	258
10.2.4	Characterization of Perovskite Based Phototransistors . . . . .	258
10.3	Classification of QDs Based Phototransistors . . . . .	261
10.3.1	Phototransistors with QD's Hybrid Active Layer . . . . .	261
10.3.2	Phototransistors with QD's Hybrid Insulator . . . . .	262

10.4	Perovskite QDs Encapsulated in Insulator Gel of Phototransistors	262
10.4.1	Fabrication Processes of the Hybrid Photo-Sensing Insulator	263
10.4.2	Photo-Charges' Inducing Mechanism of Phototransistors	263
10.4.3	Dynamic Analysis of the Phototransistors	265
10.5	Optimal Perovskite QDs Based Phototransistor and Evaluation of Figures of Merit	266
10.5.1	Optimal Heterostructures of the Perovskite Phototransistors	266
10.5.2	Photo-Charges' Transport Mechanism	268
10.5.3	Fabrication Compatibility of the Optimal Perovskite QDs' Phototransistors	269
10.5.4	Origins' Exploration of the Optimal Phototransistors' Performances	271
10.5.5	Verification and Characterization for Practical Detecting Application	273
10.6	Conclusions and Outlook	277
	References	277
<b>11</b>	<b>Perovskite Quantum Dots Based Lasing-Prospects and Challenges</b>	<b>279</b>
	Yue Wang and Siyang Xia	
11.1	Introduction	280
11.2	Photophysics of Perovskite Quantum Dots	281
11.2.1	Crystal and Electronic Band Structure	281
11.2.2	Optical Properties	285
11.2.3	Carrier Dynamics	285
11.2.4	Optical Gain in Pe-QDs	291
11.3	Perovskite Quantum Dots Lasers with Various Resonator Configurations	314
11.3.1	Random Lasers	314
11.3.2	Distributed Feedback Lasers	317
11.3.3	Whispering-Gallery-Mode Lasers	318
11.3.4	Vertical Cavity Surface Emitting Lasers	320
11.3.5	Multicolored Laser Arrays	320
11.3.6	Pe-QDs Lasers Based on Liquid Crystal Cavity	322
11.4	Issues and Challenges	325
11.4.1	Stability	325
11.4.2	Toxicity	326
11.4.3	Towards Electrically Pumped Lasing	326
11.5	Summary and Outlook	328
	References	329

<b>12 Electrospun Nanofibers Embedded with Perovskite Quantum Dots</b> .....	337
Manikandan Venkatesan, Loganathan Veeramuthu, Fang-Cheng Liang, Chia-Jung Cho, and Chi-Ching Kuo	
12.1 Introduction .....	337
12.2 Applications of PQD-Embedded Electrospun Nanofibers .....	339
12.2.1 Light Emitting Application .....	339
12.2.2 Sensing Application .....	342
12.2.3 Photodetector Application .....	343
12.3 Conclusion .....	344
References .....	344
<b>13 Strategies Towards Improving the Stability of All-Inorganic Perovskite Quantum Dots</b> .....	347
Kai Gu, Mu Yang, and Hongshang Peng	
13.1 Compositional Adjustment .....	348
13.1.1 A-Site Doping .....	348
13.1.2 B-site Doping .....	350
13.2 Surface Engineering .....	355
13.2.1 Surface Passivation .....	355
13.2.2 Surface Coating .....	357
13.2.3 Polymer Encapsulation .....	359
13.3 Conclusion and Perspective .....	364
References .....	367
<b>Index</b> .....	373