

Table of Contents

CERTIFICATE	i
DECLARATION BY THE CANDIDATE	iii
COPYRIGHT TRANSFER CERTIFICATE	v
Acknowledgments	vii
Table of Contents	xi
List of Figures	xvii
List of Tables	xxiii
List of Abbreviations	xxv
Preface	xxix
Chapter 1: Introduction	35
1.1 Introduction	35
1.2 All-Inorganic Halide Perovskite.....	36
1.2.1 Crystal Structure and Division of All-Inorganic Halide Perovskite	37
1.2.2 Optical Properties of All-Inorganic Halide Perovskite (CsPbX ₃)	40
1.2.3 Issues with All-Inorganic Halide Perovskites.....	43
1.2.4 Lanthanide Doping in All-Inorganic Halide Perovskites	46
1.2.5 Applications of Lanthanide Doped All-Inorganic Halide Perovskite.....	46
1.2.5.1 In photovoltaic:	47
1.2.5.2 In color and white LEDs.....	47
1.2.5.3 In NIR-LED and NIR camera:	47
1.2.5.4 In optical thermometry:	48
1.2.5.5 In optical encryption and decryption:	48
1.3 Lanthanide Ions as Unique Luminescence Centers.....	49
1.3.1 Spectroscopy of Eu ²⁺ / Eu ³⁺ -ion	51

1.3.2 Spectroscopy of Tb ³⁺ -ion.....	53
1.3.3 Upconversion Mechanism in Er ³⁺ / Yb ³⁺ -ions Pair	54
1.4 Metal Organic Frameworks.....	57
1.4.1 Lanthanide Metal Organic Frameworks	58
1.4.2 Inorganic Halide Perovskite Encapsulated with Metal Organic Framework	59
1.5 Scandate Oxide Perovskite	61
1.5.1 Stability and Application of Scandate Oxide Perovskite.....	63
1.5.2 Lanthanide Doped Scandate Oxide Perovskite.....	62
1.6 Objectives and Motivation	63
Chapter 2: Materials, Synthesis Techniques, Characterization Techniques, and Software used	67
2.1 Overview	67
2.2 Materials	67
2.3 Synthesis Techniques	68
2.3.1 Hot-Injection Method	69
2.3.2 Solution-Processed Hydrothermal Method.....	71
2.3.3 Self-Propagated Gel-Combustion Method	73
2.4 Characterization Techniques	74
2.4.1 X-ray diffraction (XRD)	74
2.4.2 Scanning Electron Microscopy (SEM)	75
2.4.3 High Resolution-Transmission Electron Microscopy (HR-TEM)	77
2.4.4 Brunauer-Emmett-Teller (BET) analysis.....	79
2.4.5 X-Ray Photoelectron Spectroscopy (XPS)	80
2.4.6 Ultra Violet (UV) –Visible-near Infrared (NIR) Spectroscopy	82
2.4.7 Fourier Transform - Infrared (FT-IR) Spectroscopy	84
2.4.8 Photoluminescence (PL) Spectroscopy	86
2.4.9 Time resolved photoluminescence spectroscopy (TRPL)	88
2.5 Software used for the analysis of obtained data	90

2.5.1 FullProf Suite for the XRD analysis	90
2.5.2 ImageJ software for TEM/SEM Image Analysis.....	91
2.5.3 Color Calculator v7.77 for Luminescence Spectrum Analysis	91
2.5.3 OriginPro 9.0 for Graph Plotting.....	92
Chapter 3: Lanthanide Doping in CsPbBr₃ Nanocrystals: Extending the Emission in the Blue Region.....	93
3.1 Introduction	93
3.2 Synthesis of CsPbBr ₃ and Eu-doped CsPbBr ₃ Nanocrystals	94
3.2.1 Synthesis of CsPbBr ₃ NCs	95
3.2.2 Synthesis of Eu-doped CsPbBr ₃ NCs	95
3.3 Results and discussion.....	96
3.3.1 Crystal structure and morphology analysis.....	96
3.3.2 UV-visible absorption spectroscopy.....	101
3.3.3 Fourier transform infrared (FT-IR) study	102
3.3.4 X-ray photoelectron spectroscopy (XPS) analysis	104
3.3.5 Photoluminescence (PL) study	106
3.3.6 Time-resolved photoluminescence (TRPL) study.....	111
3.3.7 Commission International de l' Eclairage (CIE) chromaticity study.....	114
3.4 Conclusions	116
Chapter 4: Color Tunable Emission in a Hybrid of CsPbBr₃ with Europium Metal-Organic Framework for Anti-Counterfeiting Application	119
4.1 Introduction	119
4.2 Materials Synthesis.....	120
4.2.1 Synthesis of Eu-MOF	120
4.2.2 Synthesis of PbBr ₂ @Eu-MOF.....	121
4.2.3 Synthesis of CsPbBr ₃ @Eu-MOF.....	121
4.3 Results and Discussion.....	121
4.3.1 Structural and Morphology Analysis.....	121

4.3.2 UV-visible NIR Absorption Analysis.....	125
4.3.3 Fourier Transform Infrared (FT-IR) Study.....	127
4.3.4 Photoluminescence (PL) Study.....	128
4.3.5 Commission International de l' Eclairage (CIE) Chromaticity study.....	132
4.3.6 Optical Anti-Counterfeiting Application.....	134
4.4 Conclusions	139
Chapter 5: Multifunctional Self-Assembled Hybrid of CsPbCl_{1.5}Br_{1.5} with Terbium/Europium Metal-Organic Framework	141
5.1 Introduction	141
5.2 Synthesis Procedure	142
5.2.1 Synthesis of Tb/Eu-MOF.....	142
5.2.2 Synthesis of CsPbCl _{1.5} Br _{1.5} @ Tb/Eu-MOF.....	143
5.3 Results and Discussions	144
5.3.1 Structure, Phase, Morphology, and Porosity analysis	144
5.3.2 UV-visible-NIR absorption analysis.....	149
5.3.3 Fourier Transform-Infrared (FT-IR) analysis	150
5.3.4 Photoluminescence (PL) study	151
5.4 Multifunctional Applications	159
5.4.1 White light emitting diode (WLED) application.....	159
5.4.2 Optical anti-counterfeiting application	162
5.5 Conclusions	165
Chapter 6: Realization of Upconversion Emission in Gd_{1-x-y}Yb_xEr_yScO₃ Perovskite Nanocrystals for Optical Temperature Sensing Application.....	167
6.1 Introduction	167
6.2 Materials synthesis	168
6.2.1 Synthesis of GdScO ₃ nanocrystals.....	168
6.2.2 Synthesis of Yb ³⁺ , Er ³⁺ : GdScO ₃ nanocrystal.....	168
6.3 Results and discussion.....	169

6.3.1 Structure and morphology	169
6.3.2 UV-visible NIR absorption analysis	174
6.3.3 Fourier Transform-Infrared (FT-IR) analysis	175
6.3.4 Photoluminescence (PL) excitation and emission study	177
6.3.5 Photons Upconversion (UC) study	180
6.3.6 Commission International de l' Eclairage (CIE) Chromaticity study	183
6.4 Temperature-dependent UC and optical temperature sensing.....	184
6.5 Conclusions	190
Chapter 7: Conclusions and Future Perspective.....	191
7.1 Conclusion of the Present Investigation	191
7.2 Outlook for Future Work.....	196
References	197
List of Publications	221
Conference/Workshop.....	223