

Dedicated
to
My beloved
Parents & family...

DECLARATION BY THE CANDIDATE

I do hereby declare that the thesis entitled “*Development of stable perovskite based nanocomposites and their fluorometric sensing applications*” is the result of investigations carried out by me in the Department of Chemical Sciences, under the School of Sciences, Tezpur University, India. In keeping with the general practice of reporting scientific opinions, due acknowledgements have been made wherever the work described is based on the findings of other investigators. No part of this thesis has been submitted before for any degree or examination at this or any other university.

Date:

Place: Tezpur University



(Shahnaz Ahmed)



तेजपुरविश्वविद्यालय / **TEZPUR UNIVERSITY**
(संसद के अधिनियम द्वारा स्थापित केंद्रीय विश्वविद्यालय)
(A Central University established by an Act of Parliament)

CERTIFICATE FROM SUPERVISOR

This is to certify that the thesis entitled "*Development of stable perovskite based nanocomposites and their fluorometric sensing applications*" submitted to the School of Sciences, Tezpur University in partial fulfillment for the award of the degree of Doctor of Philosophy in Chemical Sciences is a record of research work carried out by **Ms. Shahnaz Ahmed** under my supervision and guidance. She has been duly registered (Registration No. TZ189846 of 2018), and the thesis presented is worthy of being considered for Ph.D. Degree.

All help received by her from various sources have been duly acknowledged. No part of this thesis has been submitted elsewhere for award of any other degree.

Date: 28-02-2024

(Prof. Swapan Kumar Dolui)

Place: Tezpur University

Supervisor



तेजपुरविश्वविद्यालय / **TEZPUR UNIVERSITY**
(संसद के अधिनियम द्वारा स्थापित केंद्रीय विश्वविद्यालय)
(A Central University established by an Act of Parliament)

CERTIFICATE FROM CO-SUPERVISOR

This is to certify that the thesis entitled “*Development of stable perovskite based nanocomposites and their fluorometric sensing applications*” submitted to the School of Sciences, Tezpur University in partial fulfillment for the award of the degree of Doctor of Philosophy in Chemical Sciences is a record of research work carried out by **Ms. Shahnaz Ahmed** under my supervision and guidance. She has been duly registered (Registration No. TZ189846 of 2018), and the thesis presented is worthy of being considered for Ph.D. Degree.

All help received by her from various sources have been duly acknowledged. No part of this thesis has been submitted elsewhere for award of any other degree.

Date:

(Prof. Dambarudhar Mohanta)

Place: Tezpur University

Co-Supervisor



तेजपुरविश्वविद्यालय / **TEZPUR UNIVERSITY**
(संसद के अधिनियम द्वारा स्थापित केंद्रीय विश्वविद्यालय)
(A Central University established by an Act of Parliament)

CERTIFICATE OF THE EXTERNAL EXAMINER AND ODEC

This is to certify that the thesis entitled "*Development of stable perovskite based nanocomposites and their fluorometric sensing applications*" submitted by **Ms. Shahnaz Ahmed** to the School of Sciences, Tezpur University in partial fulfillment of the award of the degree of Doctor of Philosophy in the Department of Chemical Sciences has been examined by us on _____ and found to be satisfactory.

The committee recommends for the award of the degree of Doctor of Philosophy.

Supervisor

Name:

Date:

Co-Supervisor

Name:

Date:

(External Examiner)

Name:

Date:

Acknowledgement

First and foremost, thanks to the almighty for showering his blessings throughout my research work, for giving me this life to accomplish this phase in my lifetime and to meet all the wonderful people acknowledged below.

I take this as an opportunity to name all those persons who to varying degrees have provided assistance, encouragement, and guidance throughout. I shall always remain indebted to all these people who have given their time, love and energy to complete this dissertation and finish my doctorate.

Words cannot express my sincere gratitude to my esteemed supervisor Prof. Swapan Kumar Dolui who generously provided guidance, inspiration and his expertise which help me grow and tackle the hurdles I faced during my PhD. His insightful nature, positive approach towards life, timely suggestions with kindness, and enthusiasm had a great deal of impact on my life.

An immense thank to my respected Co-supervisor, Prof. Dambarudhar Mohanta, for his invaluable suggestions and constant guidance throughout my PhD journey who has fantastically fill the void of my supervisor Prof. Swapan K Dolui after his retirement with his impactable support and guidance. I would like to thank for all his supportive efforts in my research problems.

I am grateful to the reviewers and referees who accessed my work during the publication of the manuscripts and provided valuable appreciation and suggestions which helped me tremendously. They being the greatest critics of my research, I learned the several aspects to consider, for further improving and consolidating the study.

I would like to convey my profound appreciation and respect to the members of my doctoral research committee, Prof. Ashim Jyoti Thakur and Prof. A.K Mukherjee, for their timely assistance and advise. I am thankful to the present Head of the Department Prof. Panchanan Puzari, along with the former Head of the Department Prof. Ruli Borah for providing access to all the available departmental facilities in my research work.

Major thanks to the Vice-Chancellor, Tezpur University for providing us with a suitable ambience to live in and all the requisite facilities to complete my research work.

My sincere thanks to all the non-teaching staff of the Department of Chemical Sciences, technical staffs of SAIC, Tezpur University and Department of Physics, Tezpur University for their help throughout this journey. I also want to acknowledge all the cleaning staff of the department for maintaining a healthy environment.

I would also like to offer my thanks to the Technical Staffs of CSIR-NEIST Jorhat, CIF-IIT Guwahati, IASST Guwahati, Material Analysis & Research Centre, Bengaluru for their analytical

supports. Special acknowledgement to Krishna Kamal Hazarika for helping me in characterization.

Heartfelt gratitude to my fellow lab mates Suman, Priyankamoni Ba, Asfi, Kankana, and Parveen. Thank you all for all the loving memories and help. My special acknowledgement to my seniors: Dr. Kiranjyoti Mohan, Dr. Anindita Bora, Dr. Junali Handique, Dr. Jayashree Nath, Dr. Simanta Doley for their love and support in my PhD journey. My warm thanks to the lab members from Mohanta Sir's Group: Ms. Kakoli Doloi, Ms. Bhupali Deka, Ms. Stuti Tamuli, Ms. Susmita Baruah, Mr. Bikash Kumar Das, Dr. Aftab Ansari, Mr. Ankush Medhi, Mr. Mahesh C. Dubey, and Anuj Kumar Maurya for their help and support in my research work.

I am thankful to my dearest friends Suman Lahkar, Dimpee Sarmah, Rahul Shankar Hazarika, Jharna Borah, Shyamali Kalita, Barsha Das, Dipika Konwar, Sudakhina Saikia for their love and motivation.

I gratefully acknowledge DST-INSPIRE Fellowship for providing financial assistance during my PhD tenure.

I am grateful to Mrs. Sutapa Dolui for her motherly care, motivation, and kindness.

Heartily thankful to all the members of Pobitora Madam Curie Women's Hostel for providing me a homely environment to stay in the campus.

I want to acknowledge the authorities of Tezpur University for granting me the permission to do my research-work.

Last but not the least, special shoutout for my parents and my sister for their continuous support, sacrifices, and understanding. Their support have been unconditional in all these years, cherished with me every great moment stood by me when I needed the most. Your prayer for me was what sustained me so far. I finish by thanking my hometown Lakhimpur where the source of my life energy resides, my family...

Thank You Everyone

Shahnaz Ahmed

ABBREVIATIONS AND SYMBOLS USED

%	Percentage
$(\text{CH}_3)_2\text{NH}_2^+$	Dimethylammonium
$\text{CH}(\text{NH}_2)_2^+$	Formamidineum
CH_3NH_3^+	Methylammonium
$\text{CH}_3\text{NH}_3\text{PbX}_3$	Methylammonium lead halide
°	Degree
°C	Degree centigrade
Å	Angstrom unit
μ	Octahedral factor
cm^{-1}	per centimetre
$\text{cm}^3 \text{g}^{-1}$	cubic centimetre per gram
μl	microliter
μM	micro molar
t	Tolerance factor
a.u.	Arbitrary unit
ACN	Acetonitrile
Al_2O_3	Aluminium oxide
Ala	Alanine
ASV	Anodic stripping voltammetric method
BDC	Benzene dicarboxylic acid
BET	Brunauer-Emmett-Teller
BJH	Barrett–Joyner–Halenda
BTC	Benzene-1,3,5-tricarboxylate
C	Concentration
$\text{Ca}(\text{NO}_3)_2$	Calcium Nitrate
CaTiO_3	Calcium titanate
CB	Conduction band
CBM	Conduction band maxima
CdS	Cadmium Sulfide
CDs	Carbon Dots

CdSe	Cadmium selenide
CdTe	Cadmium telluride
CPB	Cesium lead bromide
CR	Chemiresistance
Cr(NO ₃) ₃	Chromium Nitrate
Cs	Cesium
CsPbX ₃	Cesium lead halide
CsSnX ₃	Cesium tin halide
CsX	Cesium halide
CTAB	Cetyl Trimethyl Ammonium Bromide
Cys	Cysteine
DCM	Dichloromethane
DEA	Diethyl Amine
DEF	N, N- Diethylformamide
DFT	Density Functional Theory
DMF	N, N - Dimethylformamide
DMSO	Dimethyl sulfoxide
DNA	Dinitroaniline
ECL	Electrochemiluminescence
EDA	Ethylene diamine
EDX	Energy dispersive X-ray
EQE	External Quantum Efficiency
ETM	Electron transport material
EuCl ₃	Europium (III) chloride
eV	Electron volt
FESE	Field emission scanning electron microscopy
FIR	Fluorescence intensity ratio
FL	Fluorescence
FRET	Forster Resonance energy Transfer
FTIR	Fourier transform infrared
FTO	Fluorine-doped tin oxide
FWHM	Full width half maxima

g	Gram
g/mol	Gram per mole
Glu	Glutamic acid
Gly	Glycine
h	Hour
HI	Hot Injection
HIMDC	4,5- Imidazole dicarboxylic acid
HmIM	Methyl Imidazole
HPLC	High performance liquid chromatography
HRTEM	High resolution Transmission electron Microscopy
HTM	Hole transport material
IFE	Inner Filter Effect
InP	Indium phosphide
K	Kelvin
K_{sv}	Stern Volmer Constant
$LaAlO_3$	Lanthanum aluminate
LARP	Ligand assisted reprecipitation
LC-MS	Liquid-chromatography-mass spectrometry
LED	Light Emitting Diode
LHP	Lead Halide Perovskites
LOD	Limit of detection
LUMO	Lowest unoccupied molecular orbital
m^2g^{-1}	meter square per gram
MA	Methyl Amine
$MAPbX_3$	Methyl ammonium lead halide
MHP	Metal Halide perovskites
min	Minutes
mL	millilitre
mmol	milli mole
MOF	Metal Organic Framework
N/A	Not applicable
NA	Nitroaniline

NAC	Nitro Aromatic Compounds
NC	Nano crystal
Ni(NO ₃) ₂	Nickel Nitrate
nM	nano molar
nm	Nano meter
NMP	N-Methyl Pyrrolidone
ns	nano second
OA	Oleic acid
OAm	Octylamine
OAm	Oleyl amine
ODE	Octadecene
PbS	Lead (II) sulfide
PbSe	Lead (II) selenide
PCE	Photoconversion efficiency
PDMS	Polydimethylsiloxane
PEC	Photo-electrochemistry
PeNCs	Perovskite nanocrystals
PeQDs	Perovskite quantum dots
PL	Photoluminescence
PLE	Photoluminescence emission
PLQY	Photo luminescence quantum yield
PMMA	Polymethyl methacrylate
p-NP	p-nitrophenol
ppb	Part per billion
P-Phe	Phenylene diamine
ppm	Parts per million
PS	Polystyrene
PTFE	Polytetrafluoroethylene Membrane
PV	Photovoltaic
PVDF	Polyvinylidene Fluoride
PXRD	Powder X-Ray diffraction
QDs	Quantum dots

QE	Quenching efficiency
Rb	Rubidium
rGO	Reduced graphene oxide
RhB	Rhodamine Blue
RSD	Relative Standard Deviation
SEM	Scanning electron microscopy
Ser	Serine
SiO ₂	Silicon dioxide
TAS	Transient Absorption Spectroscopy
TBAP ₆	Tributylammonium hexafluorophosphate
TEA	Triethylamine
TEM	Transmission electron Microscopy
TEM	Transmission electron microscopy
TGA	Thermogravimetric analysis
THF	Tetra hydro furan
TiO ₂	Titanium dioxide
TMB	1,3,5-trimethylbenzene
TNT	Trinitrotoluene
TOPO	Tri-octyl phosphine
TRPL	Time resolved photoluminescence spectroscopy
UV	Ultraviolet
VB	Valence band
VBM	Valence band maxima
VOC	Volatile organic compound
wt%	weight percentage
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction
ZIF-8	Zeolitic Imidazolate Framework
Zn(NO ₃) ₂	Zinc Nitrate
Zn-HIMDC	Zinc (II) imidazole-4,5-dicarboxylate
ZrCl ₄	Zirconium (IV) chloride

Figure No.	Figure Caption	Page No.
1.1	Structure of CaTiO_3 perovskite mineral.	1-3
1.2	Classification of perovskite materials according to their composition & stoichiometry.	1-5
1.3	Crystal structure of ABX_3 type perovskite material.	1-6
1.4	Tunable emission colors of CsPbX_3 colloidal NCs dispersion under UV lamp (a), Corresponding emission spectra (b), absorption spectra (c) and CIE chromaticity diagram (black dots represent the emission from CsPbX_3 PeNCs) (d) with various halide composition of CsPbX_3 NCs.	1-8
1.5	Schematic of band structure of defect intolerant semiconductor NCs and defect tolerant lead halide perovskite NCs.	1-9
1.6	Schematic representation of size dependent band gap and blue shifted emission of CsPbX_3 PeNCs.	1-10
1.7	Schematic diagram of different synthetic approach of perovskite nanocrystals, (a) LARP method, (b) Hot injection method, (c) Emulsion synthesis, (d) Microwave synthesis.	1-11
1.8	Different stabilization methods of halide perovskite materials.	1-14
1.9	Schematic representations of different synthetic methods of perovskite/MOF heterostructures.	1-17
1.10	Device structure of a LED (a), CIE color coordinates of white LED of CsPbBr_3 PeNCs (b).	1-19
1.11	Device architecture of two types of perovskites solar cells.	1-20
1.12	Diagram showing the different electrical sensing methods using MHPs.	1-22
1.13	Metal halide perovskites as optical sensor and its different optical sensing steps.	1-23
2.1	FTIR spectra of Zn-HIMDC MOF, $\text{PbBr}_2@$ MOF, $\text{CsPbBr}_3@$ MOF and CsPbBr_3 PeQDs.	2-7
2.2	P-XRD pattern of CsPbBr_3 , Zn-HIMDC MOF and PeQD@MOF composites (a), enlarged view of XRD pattern of $\text{CsPbBr}_3@$ MOF (b).	2-8

2.3	EDX spectra of pristine MOF (a), CsPbBr ₃ (b), CsPbBr ₃ @MOF (c).	2-9
2.4	EDX Elemental mapping images of elements C, O, Zn, N of the MOF and Cs, Pb, Br, Zn of CsPbBr ₃ @MOF.	2-9
2.5	XPS full survey spectra of CsPbBr ₃ @MOF composite (a), XPS spectrum of Cs 3 <i>d</i> (b), Pb 4 <i>f</i> (c), Br 3 <i>d</i> (d), C 1 <i>s</i> (e), N 1 <i>s</i> (f).	2-10
2.6	XPS fine spectra of Zn 2 <i>P</i> (a), O 1 <i>s</i> (b).	2-11
2.7	SEM images of pristine MOF (a), CsPbBr ₃ @MOF (b) with the inset shows corresponding size distribution histogram, and CsPbBr ₃ (c).	2-12
2.8	TEM images of CsPbBr ₃ @MOF composite (a, b), pristine Zn-HIMDC MOF (C) and CsPbBr _{3-x} Cl _x @MOF (d)	2-13
2.9	BET isotherm of Zn-HIMDC MOF and CsPbBr ₃ @MOF composite (a), TGA plot of MOF and CsPbBr ₃ @MOF composite (b).	2-14
2.10	Photoluminescence spectrum of free linker (black) and the MOF (blue) (a), emission and absorption spectrum of CsPbBr ₃ @MOF composite (b).	2-15
2.11	Comparison of PL and abs. spectra of CsPbBr ₃ QD (LARP) and CsPbBr ₃ @MOF (a), abs. and PL spectrum of CsPbBr _{3-x} Cl _x @MOF composite (b), (c).	2-16
2.12	TRPL decay dynamics of CsPbBr ₃ @MOF (black) and CsPbBr ₃ QD (red) (a), CsPbBr _{3-x} Cl _x @MOF (b).	2-18
2.13	Overlapping of abs. spectra of CsPbBr ₃ @MOF and emission spectra of MOF (a), TRPL decays for MOF and CsPbBr ₃ @MOF in the blue region (b).	2-18
2.14	PL responses of CsPbBr ₃ @MOF with temperature (a), variation in intensity of CsPbBr ₃ @MOF and bare CsPbBr ₃ as a function of temperature (b).	2-19
2.15	Storage test and UV Photo-stability test of CsPbBr ₃ @MOF composite (a, b), inset: Intensity vs. time plot, PL spectrum of mixture of CsPbBr ₃ @MOF and CsPbBr _{3-x} Cl _x @MOF dispersion (c).	2-20
2.16	Comparison of PL intensity of CsPbBr ₃ @MOF composite and bare CsPbBr ₃ PeQD in a polar solvent (a), PL peak shifting of bare CsPbBr ₃ PeQD in a polar solvent (b).	2-21

2.17	Emission of CsPbBr ₃ @MOF composite dispersed in different solvents.	2-22
2.18	PL response with different excitation wavelength (a), Excitation spectra of CsPbBr ₃ @MOF composite at 519 nm emission wavelength (b)	2-23
2.19	Emission spectra of CsPbBr ₃ @MOF with the increasing concentration of Cu ²⁺ metal ion (a), Stern-Volmer calibration plot (b), a plot of PL intensity variation of the QD probe with an incubation time of 2h (c), Excitation spectrum at 519 nm emission with various concentration of copper ion (d)	2-24
2.20	PL response of pristine MOF with various concentration of Cu ²⁺ ion, inset: Stern – Volmer calibration plot of MOF for Cu ²⁺ ion.	2-25
2.21	Quenching efficiency of various metal ions (a), PL quenching of the probe when Cu ²⁺ was mixed with another metal ion (b).	2-27
2.22	UV–vis absorption spectra of Cu ²⁺ (black), excitation (Red), and emission spectra (blue) of CsPbBr ₃ @MOF.	2-28
2.23	EDX spectrum of CsPbBr ₃ @MOF after Cu sensing (a), XPS full survey spectra of CsPbBr ₃ @MOF sensing probe with or without Cu ²⁺ ion (b), High resolution XPS spectrum of Cu 2p (c), TRPL decay curve of CsPbBr ₃ @MOF with various concentrations of Cu ²⁺ ion (d).	2-29
2.24	FTIR (a) PXRD (b) of Zn-HIMDC MOF before and after addition of Cu ²⁺ .	2-30
3.1	ZIF-8 MOF formation and the coordination of Zn metal ion with the linker.	3-3
3.2	FTIR spectra ZIF-8 and CsPbBr ₃ @ZIF-8 (a), and P-XRD diffraction pattern of ZIF-8, CsPbBr ₃ , and CsPbBr ₃ @ZIF-8.	3-7
3.3	EDX spectra of ZIF-8 MOF (a), CPB@ZIF-8 (b), EDX elemental mapping of Cs, Pb, Br, Zn elements of CPB@ZIF-8 (c).	3-8
3.4	XPS full survey spectrum (a), C1s and N1s high resolution XPS spectra (b, c) of CPB@ZIF-8.	3-9
3.5	XPS spectra of Cs 3d (a), Pb 4f (b), Br 3d (c), and Zn 2p of CPB@ZIF-8.	3-10

3.6	TEM and HRTEM images of CPB@ZIF-8 composite (a, b), SEM image of CPB@ZIF-8 (c).	3-11
3.7	N ₂ absorption-desorption isotherm and pore size distribution graph of pristine MOF and CPB@ZIF (c).	3-12
3.8	Absorption (black) and emission (blue) spectra of CPB@ZIF (a) inset shows the CPB@ZIF-8 dispersion under 365 nm UV irradiation (right) and daylight (left), TRPL decay curve of CsPbBr ₃ (Red) and CPB@ZIF-8 (black) (b).	3-13
3.9	Intensity variation of CPB@ZIF-8 as a function of time with various solvents (a), Photostability test of the composite for 50 h (b), Storage study of bare CPB (c) and CPB@ZIF-8 (d).	3-14
3.10	PL emission response of CPB/ZIF-8 with various concentration of nitrobenzene.	3-15
3.11	Emission spectra of CPB@ZIF-8 with various concentrations of p-NA (a), Calibration graph versus concentration of p-NA (b), Change in PL intensity vs. time graph with p-NA addition for 1200 sec incubation period (c).	3-16
3.12	Quenching efficiency of various aromatic analytes (a), PL quenching of the CPB@ZIF-8 probe when p-NA was mixed with another metal ion (b), and Variation of PL intensity with various competitive NACs (c).	3-18
3.13	PL response of CPB@ZIF-8 with o-NA (a), Stern-Volmer plot (b).	3-19
3.14	PL response of CPB@ZIF-8 with 2,4 DNA (a), Stern-Volmer plot (b).	3-19
3.15	PL response of CPB@ZIF-8 with PA (a), Stern-Volmer plot (b).	3-19
3.16	PL response of CPB@ZIF-8 with m-NA (a), Stern-Volmer plot (b).	3-20
3.17	Photograph showing the loss of green emission of paper strips with 4-NA addition.	3-21
3.18	CV profile of CPB@ZIF-8.	3-22
3.19	Absorption spectra of 4-NA (blue), and PL spectra (black) of CsPbBr ₃ @ZIF-8 (a), UV-vis spectra of CPB@ZIF-8 (black), CPB@ZIF-8/4-NA (Red), 4-NA (blue) (b), TRPL decay dynamics of	3-23

	CPB@ZIF-8 with 4-NA addition (c), FTIR spectra of 4-NA (blue), CPB@ZIF-8 (Red) and CPB@ZIF-8 with 4-NA (black) (d).	
3.20	Overlapping between the absorption spectrum of RhB (blue) and emission spectrum (black) of CPB@ZIF-8 (a), PL response of CPB@ZIF-8 with increasing concentration of RhB (b), Calibration plot between the ratios $I_{dye}/I_{CPB@ZIF-8}$ vs. concentration of RhB (c).	3-24
3.21	Normalized PL intensity of CPB@ZIF-8 vs. time response plot at 518 nm and 565 nm wavelength (a), TRPL measurement in the presence of RhB (b).	3-25
3.22	Images taken with a 365 nm UV lamp of the CPB@ZIF-8 dispersed solution (a) and coated test paper with increasing concentrations of RhB dye.	3-27
3.23	Selectivity of the CPB@ZIF-8 sensing probe towards RhB dye.	3-28
4.1	Powder XRD pattern of ZIF-8, HZIF-8 MOF, and CsPbBr ₃ /HZIF-8 (a), FTIR spectra of HZIF-8 MOF and CPB/HZIF-8 MOF composite (b).	4-6
4.2	EDX spectra of HZIF-8 (a), CsPbBr ₃ /HZIF-8 (b).	4-6
4.3	XPS survey spectrum of CsPbBr ₃ /HZIF-8 (a), High resolution XPS spectra of Cs 3 <i>d</i> (b), Pb 4 <i>f</i> (c), and Br 3 <i>d</i> (d).	4-7
4.4	XPS fine spectra of Zn 2 <i>p</i> (a), C 1 <i>s</i> (b), and N 1 <i>s</i> (c).	4-8
4.5	SEM image of HZIF-8, inset: close up view of the MOF (a), TEM images of CsPbBr ₃ /HZIF-8 MOF composite (b, c), and HRTEM images of enlarge view of the selected zone (d, e).	4-9
4.6	Pore size distributions and N ₂ adsorption-desorption isotherms (inset) of HZIF-8 and CsPbBr ₃ /HZIF-8 (d).	4-10
4.7	PL spectra of CsPbBr ₃ (No MOF- Red) and CsPbBr ₃ /HZIF-8 (Black), inset: corresponding photographs of CsPbBr ₃ (B) and CsPbBr ₃ /HZIF-8 (A) under 365 nm UV lamp (a), Absorption spectra of HZIF-8 (black), CsPbBr ₃ /HZIF-8 (green) and CsPbBr ₃ (purple) (b), TRPL decay graphs of CsPbBr ₃ (red) and CsPbBr ₃ /HZIF-8 (black) (c).	4-12
4.8	Storage test of CsPbBr ₃ /HZIF-8 (a, b), Intensity vs. time plot of bare CsPbBr ₃ (red) and CsPbBr ₃ /HZIF-8 (black), inset: Photographs of	4-13

	CsPbBr ₃ /HZIF-8 powder in day 1 and day 60 under 365 nm UV light, (c) Emission spectra evolution of aqueous CsPbBr ₃ /HZIF-8 dispersion for 15 days and (d) UV Photo-stability test of the composite.	
4.9	PL spectra of CsPbBr ₃ /HZIF-8 with various concentration of Cu ²⁺ (a), Calibration graph versus concentration of Cu ²⁺ metal ions (b).	4-14
4.10	PL recovery of the CsPbBr ₃ /HZIF-8 with melamine addition for an incubation period of 30 min (a), effect of pH (b).	4-15
4.11	CsPbBr ₃ /HZIF-8 for melamine sensing- (a) inset: Photographs showing the recovery of green emission of CsPbBr ₃ /HZIF-8-Cu with melamine addition (left to right), (b) PL response of (CsPbBr ₃ /HZIF-8 + Cu) with the addition of different concentration of melamine, (c) Calibration curve, (d) Selectivity of the sensing probe with other biological molecules.	4-16
4.12	FTIR spectra of CsPbBr ₃ /HZIF-8 with copper metal ion (a), UV- vis absorption spectra of melamine (red), Cu ²⁺ (purple), Cu-melamine (blue, green).	4-17
4.13	(a) High resolution XPS spectra of Br 3d with and without the addition of Cu ²⁺ metal ion, (b) Comparison with the XPS spectra of Br after melamine addition to the CsPbBr ₃ /HZIF-8-Cu.	4-17
4.14	Fluorescence decay graph of CsPbBr ₃ /HZIF-8-Cu with various concentration of melamine.	4-18
5.1	FTIR spectra of bare Eu-BDC, CsPbBr ₃ , and CsPbBr ₃ /Eu-BDC.	5-6
5.2	XRD pattern of bare Eu-BDC (red) and CsPbBr ₃ /Eu-BDC (black).	5-7
5.3	EDX spectra of Eu-BDC (a), and CsPbBr ₃ /Eu-BDC (b), EDX mapping images of Cs, Pb, Br, and Eu elements of CsPbBr ₃ /Eu-BDC (c).	5-7
5.4	XPS survey profile of CsPbBr ₃ /Eu-BDC (a), core level XPS spectra of Cs 3d (b), Pb 4f (c), Br 3d (d), and Eu 3d (e).	5-8
5.5	XPS fine spectra of C 1s (a) and O 1s of CsPbBr ₃ /Eu-BDC nano composite.	5-9
5.6	SEM micrograph images of Eu-BDC (a) and CsPbBr ₃ /Eu-BDC (b).	5-9
5.7	TEM image (a) and HRTEM image (b) of CsPbBr ₃ /Eu-BDC composite, inset shows the interplanar spacing of lattice fringes for	5-10

	(111) plane.	
5.8	Absorption (a) spectra of Eu-BDC (black) and CsPbBr ₃ /Eu-BDC (red), Emission spectra (b) of CsPbBr ₃ (black) and CsPbBr ₃ /Eu-BDC.	5-11
5.9	Excitation and emission spectra of Eu-BDC (a), emission spectra of Eu-BDC at different excitation wavelength (b).	5-11
5.10	CsPbBr ₃ /Eu-BDC emission spectra at different excitation wavelength (330, 340, and 365 nm).	5-12
5.11	Emission spectra of CsPbBr ₃ /Eu-BDC with different aliphatic amines (concentration of the amines in ppm was indicated in parentheses).	5-12
5.12	PL intensity graph of CsPbBr ₃ /Eu-BDC dispersion with the addition of MA (a), correlation graph of intensity ratio vs. concentration of MA (b), optical photograph showing the color change of the sensor with the subsequent addition of MA under UV lamp.	5-13
5.13	Photostability of CsPbBr ₃ /Eu-BDC under UV light for 40 h (a), humidity stability test of the sensor for 25 h.	5-15
5.14	Emission spectra of pristine CsPbBr ₃ (a) and Eu-BDC (b) with methyl amine.	5-16
5.15	TRPL decay curves of CsPbBr ₃ /Eu-BDC (a) and Eu-BDC (b) without or with the treatment of methyl amine.	5-17
5.16	Absorption spectra (a) and PXRD patterns (b) of CsPbBr ₃ /Eu-BDC on exposure with MA.	5-18
5.17	Bar graph representing the PL ratiometric response of the sensor with various organic amines and organic solvents.	5-19
5.18	Fluorescence response of CsPbBr ₃ /Eu-BDC composite to methyl amine (a), cadaverine (b), ethylene diamine (c), diethyl amine (c), triethyl amine (e) saturated vapor exposure.	5-20
5.19	FL intensity measurements of the sensor probe upon exposure over chicken meat samples at room temperature (a) and at 4°C (c), Intensity vs. time graph for the meat sample stored at room temperature, inset: the photograph of probe coated test strips under UV light with (0 h, 24 h, 48 h) time in presence of rotten chicken flesh (b).	5.21

LIST OF TABLES

Table No.	Table Caption	Page No.
1.1	Summary of synthesis techniques followed for different MOFs with their building units.	1-15
2.1	Parameters derived from BET isotherm of Zn-HIMDC MOF and CsPbBr ₃ @MOF.	2-14
2.2	Summary of photo physical properties of synthesized perovskites.	2-16
2.3	Summary of TRPL decay measurements.	2-17
2.4	Chemical stability in various solvents.	2-22
2.5	Comparison of different MOF or MOF based composite material as a florescent probe for Cu ²⁺ ion detection.	2-26
3.1	Summary of Parameters derived from BET isotherm of ZIF-8 MOF and CPB/ZIF-8.	3-12
3.2	Comparison of performance of CPB@ZIF-8 FL sensor with previously reported literatures for 4-nitroaniline detection.	3-17
3.3	Comparison of quenching constant (K _{sv}), LOD and, correlation values of different NACs analytes.	3-20
3.4	Summary of TRPL decay parameters.	3-26
3.5	Summary of 4-NA analysis in real samples	3-29
3.6	Summary of RhB analysis in real samples	3-29
4.1	Parameters derived from BET isotherm of HZIF-8 MOF and CsPbBr ₃ /HZIF-8 MOF.	4-11
4.2	Summary of TRPL decay lifetimes result.	4-18
4.3	Summary of melamine detection in real samples.	4-19
4.4	Performance of CsPbBr ₃ /HZIF-8 MOF based fluorescent sensor and comparison with the previously reported literature for the detection of melamine.	4-20
5.1	Summary of various fluorometric sensors for aliphatic amines detection. (NM: Not mentioned)	5-14
5.2	Life time values from TRPL analysis.	5-17

LIST OF SCHEMES

Scheme No.	Scheme Caption	Page No.
1.3	Schematic illustration of the sensing mechanism.	2-29
3.1	Schematic of one step synthetic path for luminescent CsPbBr ₃ @ZIF-8 composite.	3-6