Conclusion and Future Scope

6.1. Conclusion

Metal halide perovskites have emerged as one of the most promising new materials of current trend, and find potential in diverse applications from optoelectronic devices to sensing materials. The present thesis highlights the potential application of perovskite based nanomaterials in sensing for the detection of various target analytes (metal ions, nitroaromatics, dye, melamine, and volatile organic amines).

As a result of the high fluorescence characteristics, inorganic $CsPbX_3$ (X=Br, Cl, I) PeNCs with the conventional perovskite architecture have recently demonstrated immense potential as chemical sensor materials. However, the main issue associated with the material is their lack of long term stability in humid condition which limit their real analytical applications.

In this backdrop, our current investigations address the improvement of the stability of halide based perovskite materials by introducing $CsPbX_3$ in different porous metal organic framework matrix (Zn-HIMDC, ZIF-8, HZIF-8, Eu-BDC) to produce perovskite/MOF (Pe-MOF) composite. The detailed structural, morphological, and optical property investigations of the Pe-MOF composites were analyzed carefully in this thesis. To be mentioned, the synthesized Pe-MOF composite exhibited improved stability and optical properties over its bare perovskite quantum dots. Consequently, the thesis emphasized the application of Pe-MOF composites for the luminescence-based sensing of various analytes. The performance of the sensor in ambient environmental condition was also evaluated. For the detection of target analytes, different fluorometric technique such as fluorescence quenching (turn-off), fluorescence enhancement (turn-on), and dual emissive fluorescence intensity ratio method (FIR) are employed. The significant outcome of the thesis is summarized as follows:

Chapter 1 presents a survey of research background, motivation behind the current investigation, various synthesis routes, general properties, and the applications of perovskite materials. The experimental sections were presented in next subsequent chapters (**Chapter** 2, 3, 4 and 5).

In **Chapter 2,** a highly luminescent $CsPbX_3$ perovskite was stabilized in a porous Zn-HIMDC MOF for fluorescence based metal ion detection application. The resulting perovskite/MOF composite exhibited better stability (e.g., photostabilty, long term storage, thermal, and polar solvents) over bare $CsPbBr_3$ perovskites. The designed sensor had a faster time response (< 60 sec) and highly sensitive towards Cu^{2+} metal ions with LOD value of 63 nM. The emission response showed a quenching behavior with Cu^{2+} metal ion addition and it is followed a dynamic quenching mechanism.

Chapter 3 of the thesis introduced design of an intense green $CsPbBr_3$ integrated zeolitic imidazolate framework via an in-situ (one step) technique. The $CsPbBr_3$/ZIF-8 Pe-MOF have improved optical properties over bare $CsPbBr_3$ perovskite. The highly luminescent $CsPbBr_3$/ZIF-8 Pe-MOF can act as fluorescence turn-off sensing probe for the sensing of organic pollutants (4-nitroaniline and rhodamine blue dye) with a detection limit of 8.367 ppb and 0.088 ppm respectively.

In **Chapter 4,** the stable $CsPbBr_3$/HZIF-8 composite was used as on-off-on fluorescence sensing probe for melamine detection in aqueous medium and extend its applicability for real sample analysis in milk samples. In the proposed sensing system, the Cu^{2+} metal ion was acted as a quencher of the PL signal of $CsPbBr_3$/HZIF-8 at 510 nm. The quenched emission of $CsPbBr_3$/HZIF-8 was restored by the competitive adsorption of Cu^{2+} from the surface of the sensor by the functional amine group of melamine. The calculated limit of detection value for melamine was found to be 2.64 nM.

Chapter 5 of the thesis presented a dual emitting fluorescence sensor by combining $CsPbBr_3$ with a luminescent Eu-BDC MOF for toxic volatile organic amines. The sensor displayed excellent photoluminescence response with primary aliphatic organic amines with an enhancement of the PL signal of $CsPbBr_3$ at 518 nm. The Eu-BDC signal at 615 nm served as a standard to construct the ratiometric sensing system. Under optimal experimental condition, $CsPbBr_3$/Eu-BDC dual sensor exhibited selective turn on response for only primary aliphatic amines. The potential of the proposed fluorescence sensor was utilized for monitoring the food freshness.

Overall, the thesis compiles a systematic and comprehensive study on metal halide Pe-MOF composite for fluorescent based sensing potential of various analytes.

6.2. Future Scope and directions

Owing to the intriguing properties and versatility in diverse applications, perovskites have and will, in the future, continue to attract the scientific community. As an emerging material Pe-MOF composite combines the advantages of both perovskite nanocrystals with the distinct porous nature of MOFs to create a material with new and exciting properties. Pe-MOF composites are in their infancy of research and there can be many unexplored opportunities. Therefore, further investigation is necessary to employ this material for specific purposes. Keeping that in mind, future efforts will be directed as mentioned below-

- Similar Pe-MOF composite materials can be extended to other applications such as LED fabrication, bio-imaging, security ink material etc.
- Exploration of lead-free perovskite-MOF system for sensing applications.
- Study of size dependent sensing properties of perovskite nano materials.
- Mixed halide perovskite system can be considered for sensing applications.
- Further in-depth study of fluorescence sensing mechanism.