2016

Facile One-Pot Synthesis of Nanoscale Light-Emitting Organometal Halide Perovskites

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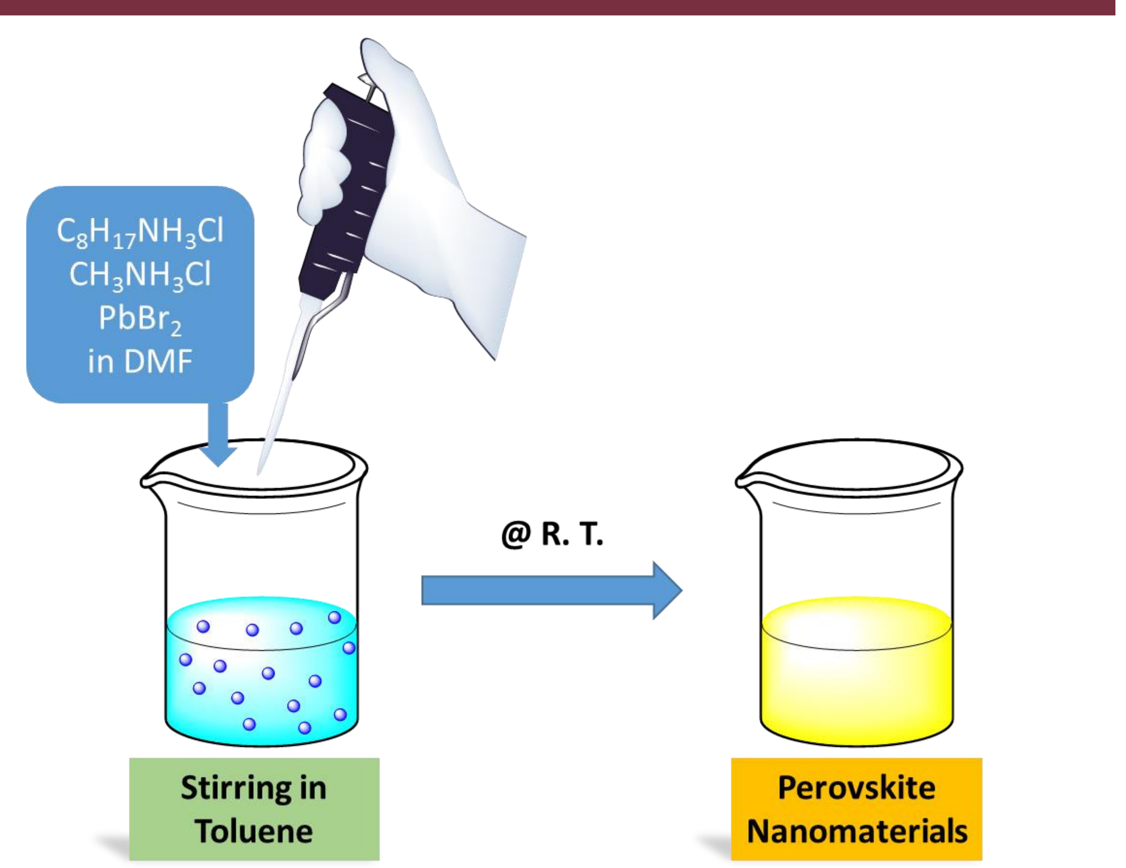
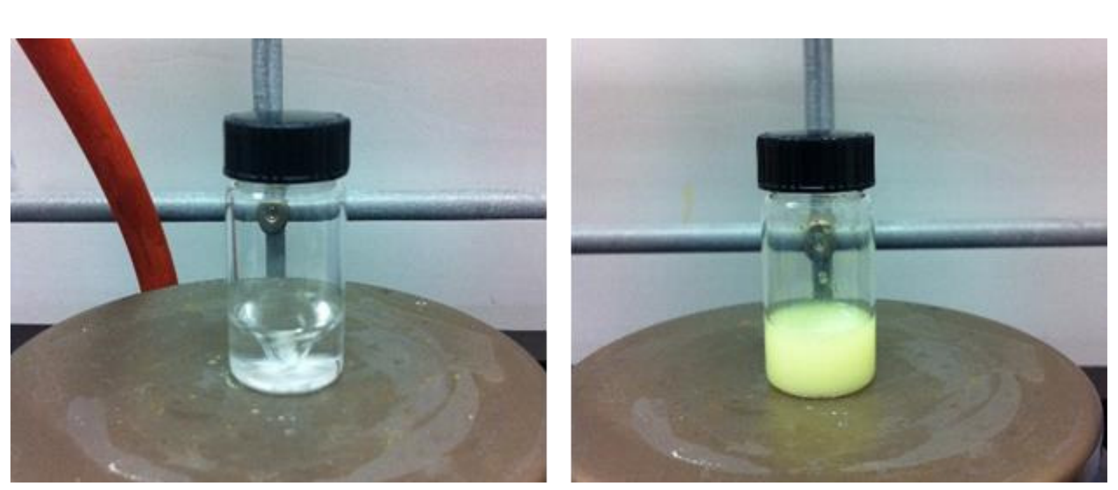
Introduction

- A class of direct bandgap semiconductors known as organometal halide perovskites have received much attention for their low cost and high performance applications in optoelectronic devices.[1-4]
- These nanoscale crystals are classified as perovskites due to their ABX_3 chemical formula[2] ("A" & "B" = organic and inorganic cations; "X" = halide anion)
- Can be solution processed; they have the ability to be "color tuned" throughout the visible to near-infrared regions.[1]
- Tuning the color of these perovskite nanomaterials could be achieved by altering their organic cations (and their ratios).[3]
- Main purpose: to optimize the synthesis and characterize the properties of a three-dimensional (3D), pure blue light-emitting perovskite nanomaterial known as Methylammonium (MA) lead bromide-chloride ($MAPbBr_xCl_{3-x}$, where $MA=CH_3NH_3$)

Synthesis





Before Injection   After Injection

Photophysical Data

Under Ambient Light   Under UV Light

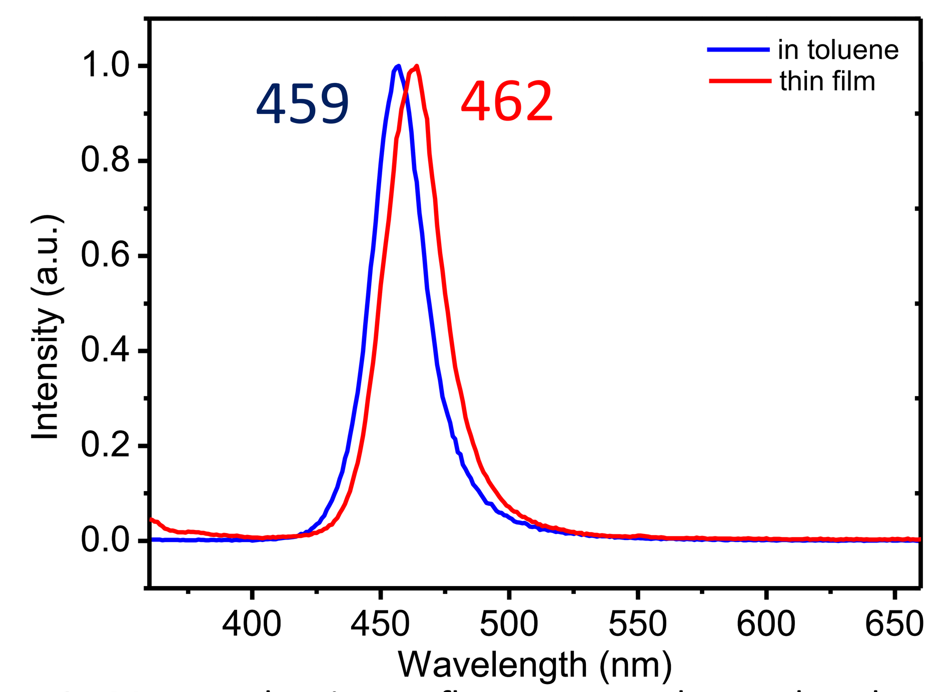


Figure 1: Measured using a fluorometer, these photoluminescence spectra show the emission spectra and corresponding peak of the $MAPbBr_xCl_{3-x}$ Perovskite: in Toluene and on glass thin film.

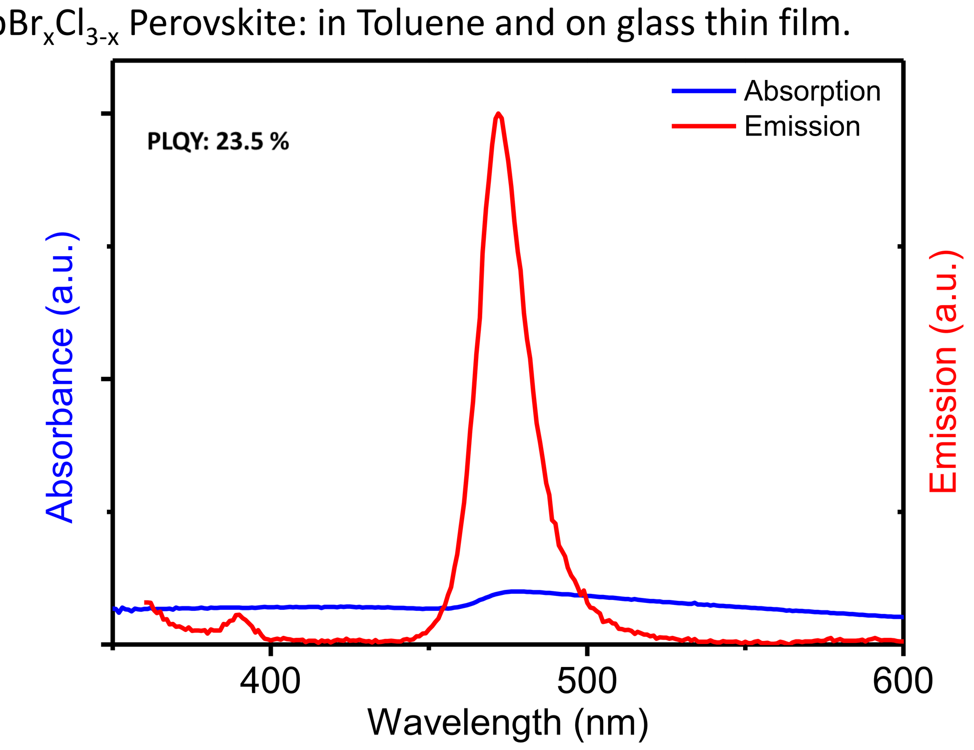


Figure 2: This image shows the absorption and emission spectra of a sample in Toluene, which calculated the Photoluminescence Quantum Yield (PLQY) to be 23.5%.

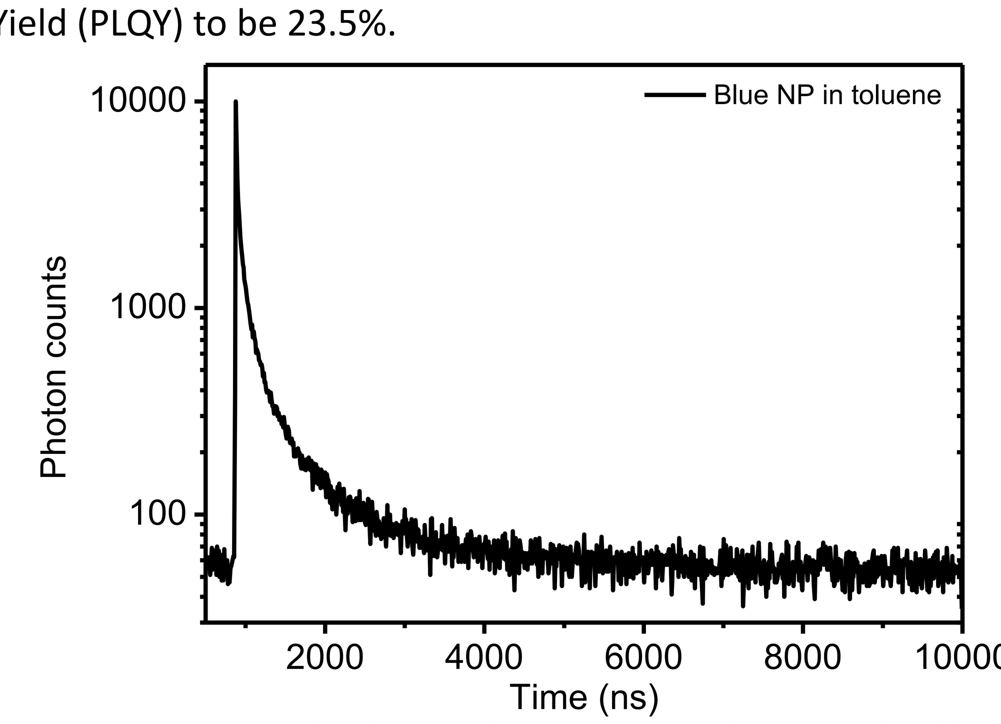


Figure 3: Time resolved photoluminescence decay of the blue emissive nanoparticles in Toluene.

Characterization

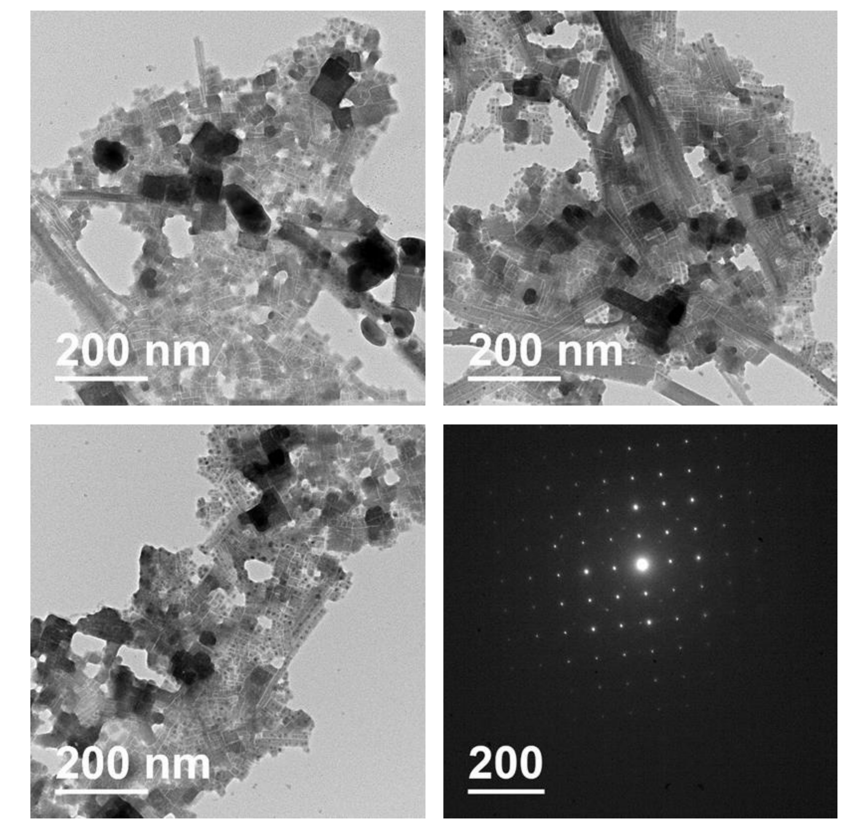


Figure 4: Transmission electron microscopy (TEM) images showing the sizes of the nanocrystals (10 nanometers) as well as electron diffraction (4th image).

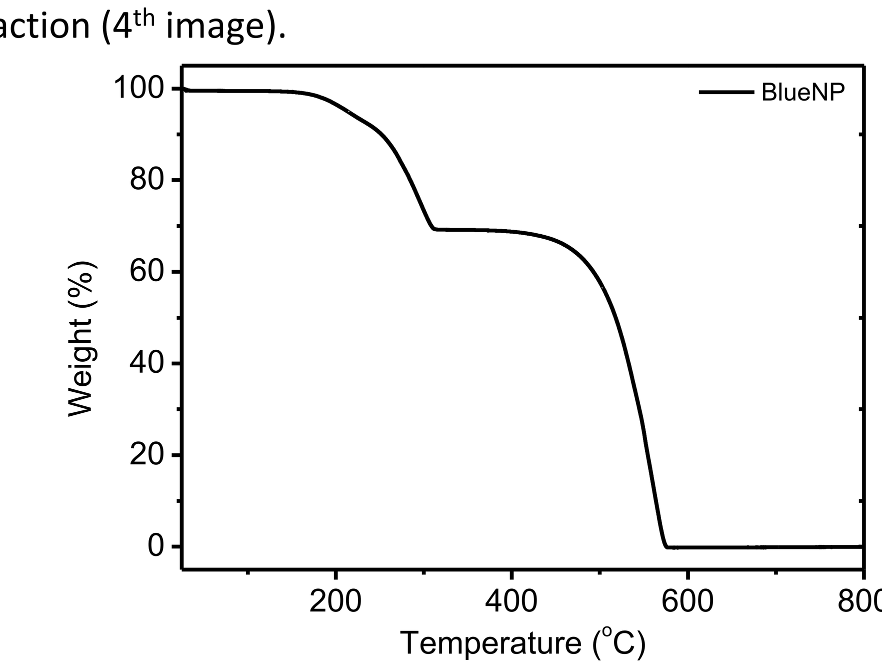


Figure 5: This shows the change in weight percent versus temperature using Thermogravimetric Analysis (TGA) of the perovskite.

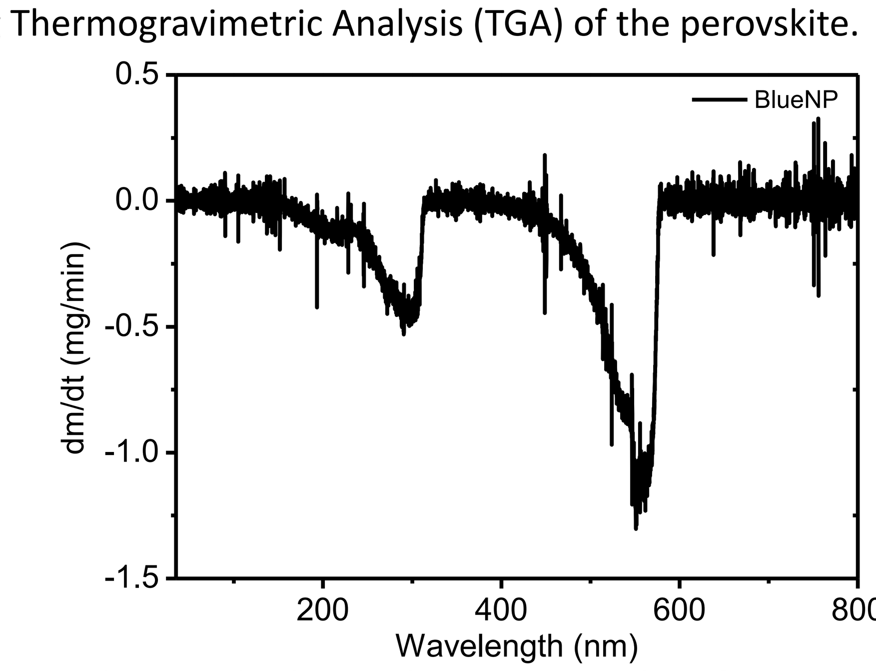


Figure 6: This graph shows the corresponding first derivative of the perovskite nanoparticle.

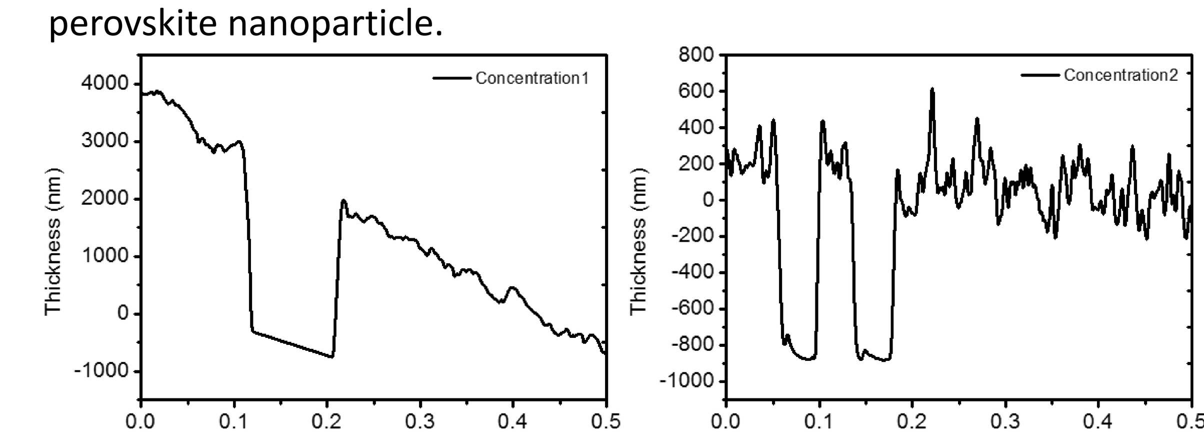


Figure 7: Using Atomic Force Microscopy (AFM) imaging, glass thin film thickness was determined for 2 different concentrations of the $MAPbBr_xCl_{3-x}$ perovskite nanoparticles. NOTE: Concentration decreases from left to right.

Conclusion

The Ma Group has established a one-pot synthetic approach to produce these nanoscale perovskites, which takes place at room temperature. Having improved yields and enhanced color quality of the products, this simplified reaction system is far more advantageous over other methods. This 3D pure blue light-emitting perovskite nanomaterial, known as Methylammonium Lead Bromide-Chloride ($MAPbBr_xCl_{3-x}$), proves to become more emissive with time when in solution. From the TEM images (Figure 4) of bulk samples, this nanoparticle can be seen to have an average size of about 10 nanometers. As seen in the emission spectra (Figure 1), the perovskite shows to have a near pure blue emission of ~459 nm and ~462 nm in Toluene and on glass thin film, respectively. From further photoluminescence data, the PLQY calculations have shown up to 25% for a given sample. Based on TGA analysis, two major weight changes occurred for the nanoparticle: (1) the loss of the organic ammonium halides of 30% at about 310°C and (2) the loss of inorganic lead (II) bromide of 70% at about 574°C. When applied to thin film at different concentrations, AFM shows the thickness of the film to be from 1200-2500 nm. Given their exciting photophysical properties, these pure-blue emitting organolead halide perovskites can potentially have a wide variety of applications in the lighting and display industries.

References

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Acknowledgements

First and foremost, I would like to thank the Undergraduate Research Opportunity Program (UROP) at Florida State University for providing me with the chance to partake in this research project for the 2015-2016 school year. Along with funding this research, I have also been given the ability to gain vital experience in academic research and development within a field that interests me. I also want to thank both my supervising professor, Dr. Biwu Ma, and my research mentor, Dr. Zhao Yuan, for enlightening me to the fullest extent possible throughout the duration of this project. A final thanks goes to my UROP Leaders, Keval Patel and Bradley Ringler, for providing me with the necessary informational insight on the true meaning of research, which has helped me in all aspects through the course of this school year .