Studies on the characterization and development of halide perovskite quantum dot liquid scintillator for next-generation neutrino detection

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Introduction

Motivation

- ✓ In this research, we aim to develop a liquid scintillation solution (LS) for particle detection in the low-energy range (~keV)
- ✓ Utilizing the unique luminescent and scintillation characteristics of perovskite quantum dots.
- ✓ LS based on perovskite quantum dots is designed to resolve the limitations of existing scintillators and is aimed at achieving enhanced light emission at a particular wavelength.
- ✓ We try to develop a simple synthesis method that can be expanded at room temperature & pressure without the need for special high costing equipment for the next generation neutrino experiment

Experiment Setup

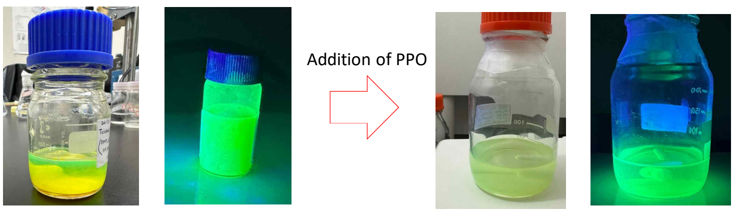
- ✓ $CsPbBr_3$ perovskite quantum dots were synthesized and coated with oleic acid (OA) and oleylamine (OAm), using toluene as the solvent.
- ✓ The synthesized sample was centrifuged into upper and lower fractions, and both were analyzed for particle size distribution and luminescence to assess sample stability.

Development of perovskite based LS

Visible | UV 365 nm

I. The majority of the quantum dots settled at the bottom.
II. Immediately : green fluorescence emitted mainly from the sediment, indicating the concentration of quantum dots at the bottom.
III. Over time : No further light emission.

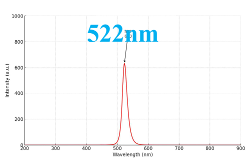
Visible | UV 365 nm | Visible | UV 365 nm

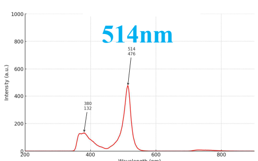


- ✓ Coating the quantum dots significantly reduced sedimentation, allowing stable green fluorescence under UV light.
- ✓ After adding PPO, the solution remained clear without visible sedimentation, and green fluorescence was consistently emitted over time.

Fluorescence Measurement

- ✓ The $CsPbBr_3$ quantum dots exhibited a strong emission peak near 522 nm in the fluorescence spectrum.
- ✓ After the addition of PPO, a similar emission peak was observed around 514 nm, indicating a slight blue shift.
- ✓ This suggests that energy transfer occurred between PPO and the quantum dots. PPO was added to investigate the energy transfer phenomenon.

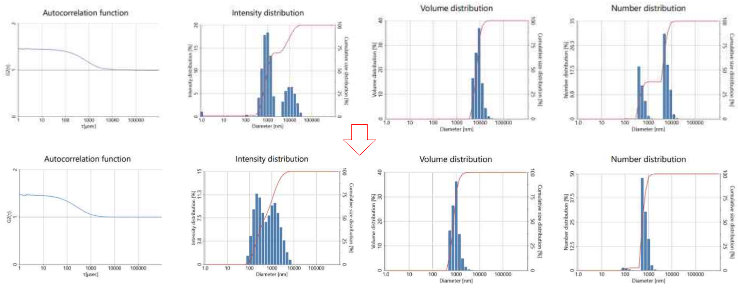




Material Characterization

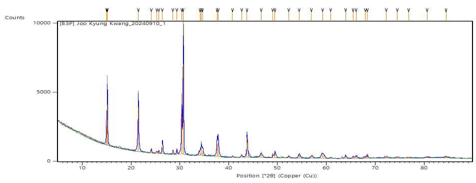
Particle Size Distribution

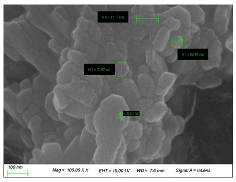
Before/After Centrifugation



- ✓ Before) The particle sizes are divided into two groups, indicating a non-uniform particle size distribution
- ✓ After) The distribution narrows into a single size range, resulting in more uniform particle sizes.

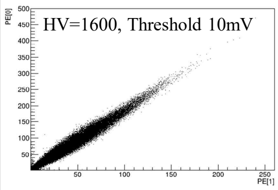
XRD & SEM Analysis





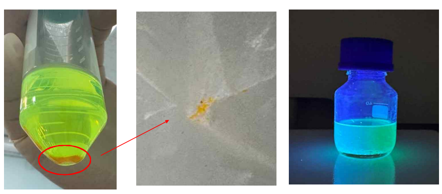
- ✓ The XRD analysis showed the crystal structure of the perovskite $CsPbBr_3$ quantum dots. The major peaks indicated a cubic and tetragonal structure, suggesting the possibility of mixed phases.
- ✓ Most $CsPbBr_3$ quantum dots were found to range from 3.3 nm to 20 nm based on XRD analysis. However, some particles extended up to around 70 nm, indicating a mixed particle size distribution. The sample predominantly consisted of smaller particles.

Light Yield Measurement



- ✓ Light yield measurement using a radioactive source(cf-252)
- ✓ The strong correlation between the photoelectron (PE) values detected by both PMTs indicates that the scintillation events resulting from particle interactions were captured in a stable and efficient manner.
- ✓ The points on the graph represent PE events detected simultaneously by the two PMTs.

Redisperse of Crystals



- ✓ The crystals were redispersed in a DIN(C9H12)solution, confirming their potential use as a new LS.
- ✓ Upon exposure to UV light, stable green fluorescence was observed, indicating that the perovskite material can effectively function in the DIN solution as well.

Summary &Future Plan

- ✓ The synthesis and characterization of PVLS have shown promising results, with improved stability and consistent light emission.
- ✓ Through centrifugation methods, sizes control can be possible between 10 nm and 60 nm, indicating a reduction to smaller and more uniform particles.
- ✓ Further research will focus on more scintillation efficiency of the PVLS and improving sample stability.

Reference :
- ✓ William R. LEO,"Techniques for Nuclear and Particle Physics Experiments ", 2 ed, Springer (1994)
- ✓ Q Zhang, F Guo, RC Zhao, ZH Mo.,"Toward the green synthesis of CsPbBr 3 perovskite nanocrystals using ethanol as an antisolvent and cyclodextrin as a ligand" ,New Journal of Chemistry(2023)