Nanofiber Gamma Ray Sensors via Lead-Based Perovskite Quantum Dots

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Gamma rays are high-energy and can penetrate most materials, thereby serving as unique "fingerprints" for radioactive isotopes. Gamma rays have also been linked to genetic damage and cancer [1]. For the military, gamma ray detection could prove vital for security both in weapons detection and personal safety applications. In our work, we demonstrated fabrication of high surface area, electrospun scintillators using $CsPbBr_3$ and $CsPbCl_2$ perovskite quantum dots (PQDs, ***Fig 1***) for gamma ray detection. Researchers investigating the use of perovskites as sensors for gamma ray detection have demonstrated improvements in efficiencies in recent years [2]. Electrospinning (ES) utilizes a high voltage electrostatic field to form micro- to nano-scale fiber materials that exhibit high surface area and flexibility. These characteristics enable production of a low-profile, highly sensitive detector that could be adhered to a variety of complex surfaces [3].

In this work, $CsPbBr_3$ PQDs were synthesized through a sono-chemical process which achieve particle size distribution at around 20 nm. The $CsPbBr_3$ PQDs dispersed in toluene or hexane as a precursor were used in an ion-exchange process to substitute the bromine with chlorine, creating $CsPb(Br_{(1-x)}Cl_x)_3$, with the goal of reaching reach stoichiometrically pure $CsPbCl_3$ (***Fig 2***). In past work, results of the ion-exchange process using SEM-EDS have shown ion exchange efficiencies of around 66 %. Alternate synthesis and processing conditions are currently being investigated to achieve a greater degree of purity.

Scintillators were fabricated using a SprayBase electrospinner (***Fig 3***). Polycaprolactone (PCL) was used as the carrier polymer for PQDs due to hydrophobicity and stability. The electrospun scintillators were visually examined using UV-light and electron microscopy, evaluated under UV-Vis, and tested at Idaho National Laboratory for fluorescence under interrogation with gamma rays. Efficiencies of modified synthesis methods will be reported.

[1] W. Sudprasert, P. Navasumrit, and M. Ruchirawat, "Effects of low-dose gamma radiation on DNA damage, chromosomal aberration and expression of repair genes in human blood cells," *Int J Hyg Environ Health*, vol. 209, no. 6, pp. 503–511, Nov. 2006, doi: 10.1016/j.ijheh.2006.06.004.

[2] F. Liu *et al.*, "Recent Progress in Halide Perovskite Radiation Detectors for Gamma-Ray Spectroscopy," Mar. 11, 2022, *American Chemical Society*. doi: 10.1021/acsenergylett.2c00031.

[3] X. Chen *et al.*, "Development and application of electrospun fiber-based multifunctional sensors," Apr. 15, 2024, *Elsevier B.V.* doi: 10.1016/j.cej.2024.150204.

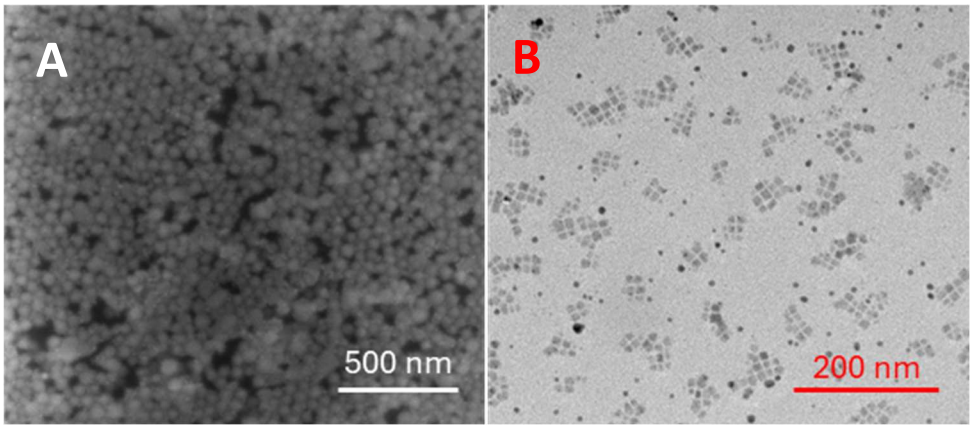

Fig 1: *(A) TEM micrograph of $CsPbBr_3$ PQDs synthesized via sonochemical synthesis process. Average diameter of PQDs was under 20 nm. (B) TEM micrograph of $CsPb(Br_{1-x}Cl_x)_3$ PQDs after 4.5 hours of stirring at 50°C in toluene. Individual nuclei sizes show a size distribution sub 20 nm. Samples were deposited on a 400 mesh SiO coated copper grid.*

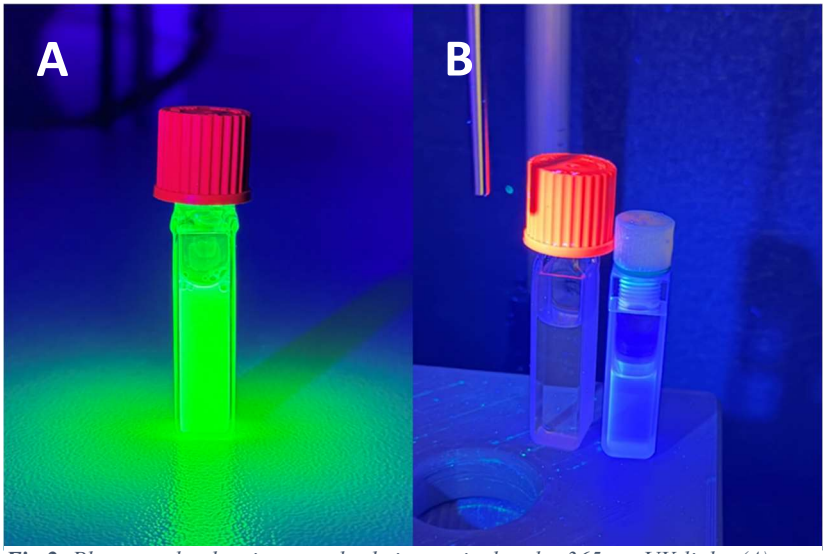

Fig 2*: Photographs showing samples being excited under 365 nm UV-light. (A) $CsPbBr_3$ dispersed in toluene, often used as the precursor in the ion-exchange process. (B) Cuvette containing the final product from the 4.5 hour ion-exchange process dispersed in toluene. Results showed the final product exhibits fluorescence under UV excitation.*

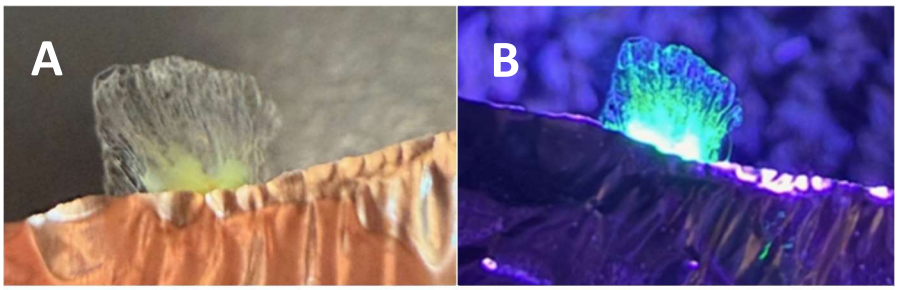

Fig 3: *Photographs showing the PCL-$CsPbBr_3$ scintillator before and after illumination under UV light. (A) Electrospun PCL-$CsPbBr_3$ scintillator prior to excitation under UV light. (B) Electrospun PCL-$CsPbBr_3$ scintillator under UV light excitation. Future work will examine excitation response under interrogation with gamma rays.*