Sensing by Perovskite-Filled Electrospun Fibers

Amos Taiswa,[1,2] Xavier Vorhies,[1,2,3] Kiyo Fujimoto,[4] Jack L. Skinner,[1,2,3] and Jessica M. Andriolo[1,2]

[1]Mechanical Engineering, Montana Technological University, Butte, MT 59701
[2]Montana Tech Nanotechnology Laboratory, Montana Technological University, Butte, MT 59701
[3]Materials Science PhD, Montana Technological University, Butte, MT 59701
[4]Idaho National Laboratory, Idaho Falls, ID 83415

Perovskite research can be dated back to 1839.[1] Since that time, perovskites have been utilized in a variety of fields ranging from sensing applications to solar cells and even biomedical research. Perovskites exhibit attractive photonic and electronic properties, are relatively inexpensive, and may be used in flexible applications. Recently, perovskites have been explored for applications in gamma ray detection. Gamma rays are utilized in the medical industry for cancer treatments and equipment sterilization, in industry for monitoring nuclear and radiation levels, and for archaeological searches.[2] Perovskite elements exhibit high atomic numbers, provide a high carrier mobility-lifetime product, and are defect tolerant making them particularly attractive for this application.

In this work, we utilized a variety of metal halide perovskites restricted to quantum dot scale during synthesis and incorporated into the core of electrospun fibers to provide high surface area sensors for gamma ray detection. In the final sensor configuration, electrospun fibers will contain semiconducting polymer shells and be deposited into a thin film layer across two electrodes (Fig. 1). At present, a variety of sensor configurations are being developed to provide an effective combination of perovskite quantum dots (QDs), polymers, and sensor design for gamma ray detection. In the initial configuration, $CsPbBr_3$ QDs and polypyrrole (PPy) were used to form the sensor. Synthesis of $CsPbBr_3$ QDs was performed using modified methods from Huang et al.[3] $CsPbBr_3$ QDs were synthesized using a 1:1 molar ratio of $PbBr_2$ and CsBr powder in dimethyl sulfoxide (DMSO). Hydrobromic acid (HBr) was then titrated dropwise into the solution with continuous stirring to precipitate perovskite crystals (Fig 2A). The mixture was subsequently decanted, washed with ethanol, and centrifuged to remove DMSO and HBr. The resulting mix of ethanol and CsPbBr3 perovskite was then placed in a vacuum desiccator to dry before being added to a ligand mix containing oleylamine, oleic acid, and dimethylformamide (DMF) and stirred at 60 °C for 3 hr. Size of the $CsPbBr_3$ QDs was confirmed on SEM and averaged 50 nm (Fig. 2b), and stability in toluene was evaluated (Fig. 3). PPy was prepared in chloroform, and coaxial electrospinning (ES) was carried out in a SprayBase horizontal ES system using a concentric core-shell spinneret.

Here, we present the electrospun $CsPbBr_3$ QD sensor with morphological evaluations performed with electron microscopy and atomic force microscopy, compositional analysis by energy dispersive spectroscopy, and structural determination by X-ray diffraction. Sensor performance will be evaluated by electron mobility studies using a Hall effect measurement system.

[1] L. Zhang, et al., "Advances in the Application of Perovskite Materials," 15, 177 (2023).
[2] X. Wang, et al., "Cascade perovskite single crystal for gamma-ray spectroscopy," IScience 26(10), 107935 (2023).
[3] C.Y. Huang, et al., "CsPbBr 3 Perovskite Powder, a Robust and Mass-Producible Single-Source Precursor: Synthesis, Characterization, and Optoelectronic Applications," ACS Omega 4(5), 8081–8086 (2019).

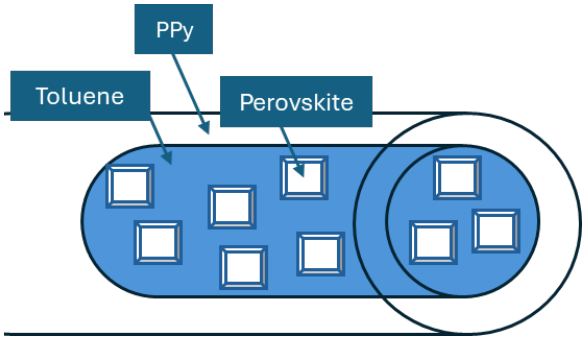

Fig. 1. Schematic showing the gamma ray sensor design. The sensor was core-shell structured with an absorptive perovskite QD core and semiconducting polymer shell.

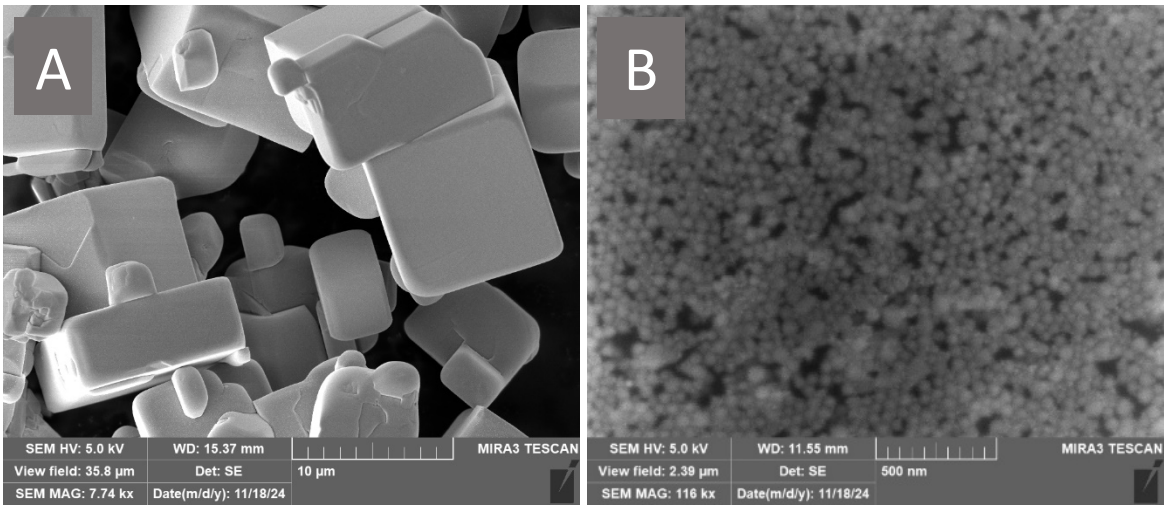

Fig. 2. Scanning electron micrographs showing CsPbBr3 perovskites at several steps throughout the synthesis process. A) CsPbBr3 perovskite precursor powder used to form QDs. B) CsPbBr3 perovskite QDs.

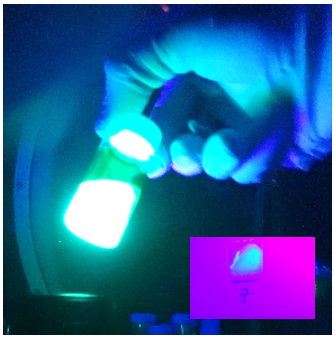

Fig. 3. CsPbBr3 perovskite QDs in toluene exhibited a strong green fluorescence. The QDs were also examined after drying on the surface of a silicon wafer (inset). In that case, green fluorescence was still present.