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Polymer-nanoparticle Composite Scintillators for Flexible Radiation Detectors

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1. Introduction

Recently, with a change in the research paradigm, research is being conducted on nanotechnology-based detection sensors that can be given new functionality to improve the physical performance of existing radiation detection sensors and overcome limitations, and nanoscale and nanoscale at the atomic layer level. By developing a material-based detection sensor, it is possible to make a breakthrough in technology that can overcome the physical limitations of current technology. Therefore, in order to apply nanomaterials specialized in radiation detection to radiation detection sensors, it is essential to establish synthesis and manufacturing processes for low-dimensional nanoparticles or nanomaterials having various shapes and sizes.

2. Methods and Results

2.1 Electrospinning

Electrospinning is a fiber production method that uses electric force to draw charged threads of polymer solutions or polymer melts up to fiber diameters in the order of some hundred nanometers. Electrospinning shares characteristics of both electrospraying and conventional solution dry spinning of fibers [1]. The process does not require the use of coagulation chemistry or high temperatures to produce solid threads from solution. This makes the process particularly suited to the production of fibers using large and complex molecules. Electrospinning from molten precursors is also practiced; this method ensures that no solvent can be carried over into the final product [2].

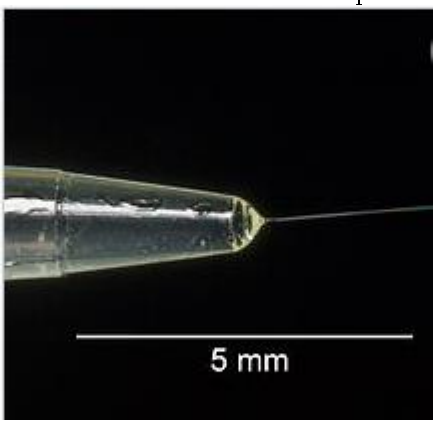

Fig. 1. Photograph of a meniscus of polyvinyl alcohol in aqueous solution showing a fiber being electrospun from a Taylor con [2].

2.2 $CsPbBr_3$ synthesis and UV scintillation test

Perovskite basically has a molecular formula of ABX3, mainly CH3NH3+, CH(NH2)2+, Cs+ etc. at the A cation site, Pb+, Sn+ etc. at the B cation site and halogens (I-, Br-, etc. at the X anion site). It is formed as a three-dimensional structure in which Cl-) elements are located. Since it has the advantage of being able to vary electrical and optical properties by changing the type and composition of organic materials or halogens, many studies are being conducted in the field of optoelectronics, and related research is also needed in the field of radiation. In this study, we focused on the establishment of high-concentration CsPbBr3 nanocrystal synthesis conditions and X-ray reactivity. CsPbBr3 nanocrystals were synthesized in a vacuum atmosphere and high temperature using the hot-injection method, and the degree of crystallization of quantum dots was controlled by adjusting the reaction time and temperature. Synthesis of ABX3 type nanocrystal proceeds in the following steps. The first step is to prepare an A precursor solution (metal or non-metal salt) containing the ligand, the second step is to inject the A precursor solution into the B precursor solution, and the reaction step between the precursors induces nucleation, and finally, after forming the nanocrystal, the nanocrystal is separated from the synthesis solvent and purified (purification, washing).

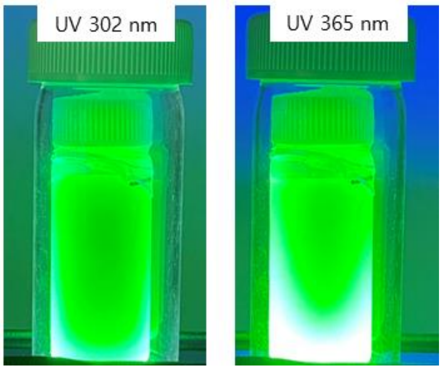

Fig. 2. UV scintillation test of $CsPbBr_3$ nanocrystal

2.3 Fabrication of $CsPbBr_3$-PVDF composite

In this study, a polymer nanofiber composite containing CsPbBr3 nanocrystals was coated on a flexible metal foil using electrospinning coating technology to manufacture a film, and the luminescent properties were confirmed to obtain a flexible CsPbBr3 nanocrystal-PVDF polymer composite film manufacturing technology developed.

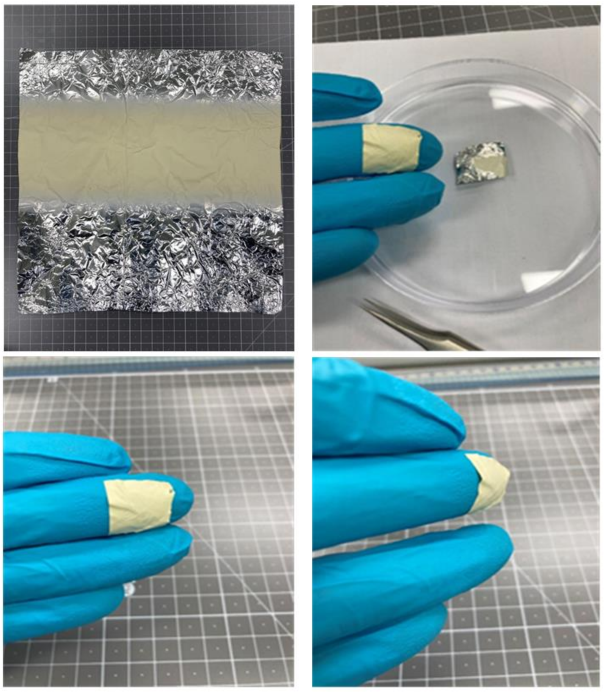

Fig. 3. The picture of flexible CsPbBr3-PVDF composite.

2.4 Scintillation test of $CsPbBr_3$-polymer composite

The 2.5 wt% CsPbBr3-PVDF polymer film fabricated by electrospinning on Al foil (25 cm × 22 cm) is shown in the figure above, and the luminescent properties were confirmed using a UV lamp, indicating that CsPbBr3 quantum dots were stably formed in the PVDF polymer. The nanofiber network structure helps CsPbBr3 to maintain crystallinity stably in PVDF and at the same time prevents aggregation.

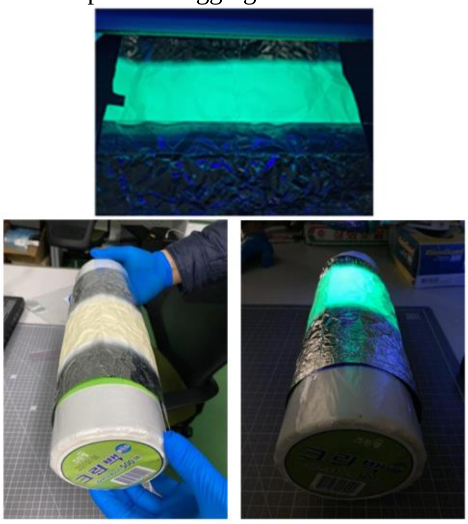

Fig. 4. The picture of flexible CsPbBr3-PVDF composite scintillation under UV light.

3. Conclusions

In this research, CsPbBr3 nanocrystal-polymer composite film manufacturing technology and photoliminescence properties were secured. It is possible to stably maintain nanocrystals and nanophosphors through the composition of polymers and composites. It is a technology that can be converted to various solution processes such as coating and printing processes when manufacturing devices, and can be applied to a large area relatively easily at low cost.

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