Solution growth of $CsCu_2I_3$ single crystal for γ-ray detection

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Introduction

Inorganic Single Crystals (SCs) are extensively used as scintillators due to their high light output, high effective atomic number and good energy resolution. However, most of them are hygroscopic with a high cost of production. Metal halide perovskites are a cost-effective alternative to these inorganic scintillators. Lead-free metal halide perovskites, such as Rb_2CuCl_3, $Cs_3Cu_2I_5$, and $CsCu_2I_3$ are emerging SCs having high stability, non-hygroscopic nature, and can be grown using the Solution Growth (SG) method. $CsCu_2I_3$ SC can be grown through various growth methods. The photodetection and optoelectronic performance data have been reported for 1D $CsCu_2I_3$ SC grown using the SG method [1], and scintillation properties have been reported for the Bridgman-grown crystal in the literature [2].

In the present work, $CsCu_2I_3$ SC has been grown using the Inverse Temperature Crystallization (ITC) method. The growth method and the scintillation properties are presented for the SC.

Experiments and Methods

The $CsCu_2I_3$ solution was prepared using 2.5 millimoles of Cesium Iodide (CsI) and 5 millimoles of Cuprous Iodide (CuI) in 5 ml N,N-dimethylformamide (DMF), and 0.4 ml Oleic acid. The mixture was stirred for 30 min. All the steps were carried out at room temperature. Then, the 0.2 µm poly (tetrafluoroethylene) (PTFE) filter was used to filter the solution. After filtering, the solution was transferred to a reagent bottle. The bottle was placed in a hot air oven at a temperature of 30˚C. Subsequently, the temperature was increased at a rate of 2˚C/h up to 75˚C. Afterwards, the temperature was maintained at 75˚C for 24 hours. Transparent and crack-free $CsCu_2I_3$ SCs were obtained.

The X-ray Diffraction (XRD) patterns were recorded for finely ground crystal powder using a Bruker (D8-Advance Model) diffractometer equipped with a LINXEYE XE detector (using Cu-Kα, λ = 1.54 Å, with a step scanning of 0.02˚ in the 2θ range of 10˚- 60˚). The Photoluminescence Excitation (PLE) and Photoluminescence (PL) were performed with an RF-6000 Spectro-Fluorophotometer. The Energy Dispersive X-ray Analysis (EDX) was carried out to determine the SC's elemental composition using a Zeiss Ultra Plus field emission scanning electron microscope (FESEM).

The pulse height spectra were recorded using a 7 mm × 1.5 mm × 1mm $CsCu_2I_3$ SC. The crystal was wrapped with 5 layers of Teflon reflecting tape and coupled to a Photo Multiplier Tube (H10570 MOD). The PMT was placed in a black box to reduce the noise generated by ambient light. The PMT was biased to an operating voltage of −1400V. The decay pulse was recorded using 1 GSa/s Digital Storage Oscilloscope (DSO). The pulse height spectra were recorded with ^{133}Ba, ^{137}Cs, ^{22}Na, and ^{60}Co γ-ray sources using Multi-Channel Analyzer.

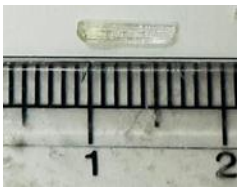

Figure 1. Photograph of $CsCu_2I_3$ SC under ambient light.

Results and Discussion

Metal halide inorganic 1D $CsCu_2I_3$ perovskite SC was grown using the ITC method as described in the experimental section. A

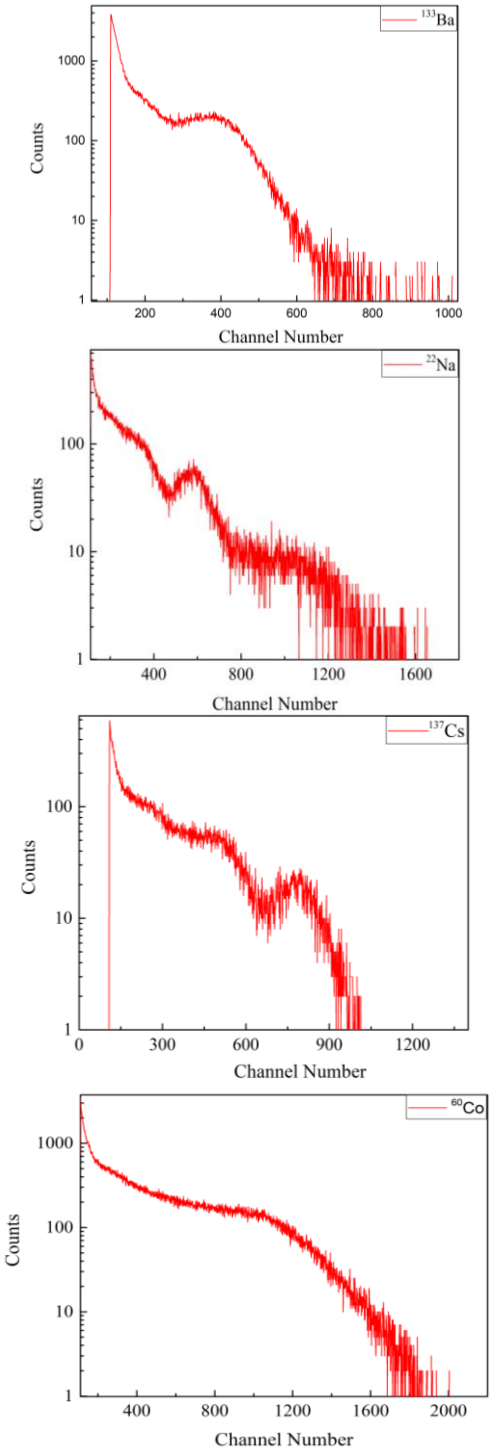

Figure 2. Pulse height spectra of $CsCu_2I_3$ for ^{133}Ba, ^{22}Na, ^{137}Cs, and ^{60}Co γ-ray sources

transparent and crack-free crystal of dimensions 7 mm × 1.5 mm × 1mm shown in Figure 1, was used for measurements. Powder XRD shows peaks corresponding to the orthorhombic structure with space group *Cmcm* [JCPDF No. 45-0076]. The atomic percentages of Cs, Cu and I atoms are 16.42%, 33.86% and 49.73%, as given by EDS, which is in good agreement with the stoichiometry of $CsCu_2I_3$.

Gamma radiation detection studies were performed with the SG $CsCu_2I_3$ perovskite SC. The SC was coupled to the PMT and the pulse height spectra were acquired using multiple γ-ray sources. The pulse height spectra taken with ^{133}Ba, ^{22}Na, ^{137}Cs, and ^{60}Co are presented in Figure 2.

Summary

This work explores the growth and characterization of $CsCu_2I_3$ single crystals (SC), an emerging lead-free metal halide perovskite used as a scintillator. The XRD pattern confirms the orthorhombic crystal structure with the Cmcm space group. The atomic percentages of Cs, Cu and I atoms are in good agreement with the stoichiometry of $CsCu_2I_3$. The crystal exhibits great potential as a scintillator material. However, the energy resolution needs to be improved. Better results can be achieved by coupling the crystal with SiPM or APD. Detailed characterization of the $CsCu_2I_3$ crystal will be presented and discussed in the symposium.

References

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