



Characterization of BaCl₂ scintillation crystal at low temperature

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ABSTRACT

A BaCl₂ scintillation crystal was grown by the Czochralski method. The grown crystal was cut to a size of 10 × 10 × 5 mm³. The scintillation properties of the crystal such as pulse height spectra, energy resolution, and fluorescence decay time were measured with a ¹³⁷Cs (662 keV) γ-ray source at room temperature. We measured the temperature dependence of the scintillation light yield and decay time with a bi-alkali photomultiplier tube for the BaCl₂ crystal. The BaCl₂ crystal was cooled down with compressed helium gas from room temperature to 10 K. We measured the light yield and decay time changes of the BaCl₂ crystal from 10 K to room temperature. The light yield of the BaCl₂ at 200 K was four times higher than that at room temperature. The decay time increases as temperature decreases. The BaCl₂ scintillation crystal has a low light yield but a fast decay time so that it can be a calorimeter candidate for high energy physics experiments.

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1. Introduction

Recently, various new and improved inorganic scintillators have been investigated with the goal of finding heavy, fast, and more efficient materials with a high light yield and good energy resolution for X- and γ-ray radiation detectors. These scintillators are useful not only in nuclear physics, high energy physics, astrophysics, but also medical imaging and industrial applications such as security systems at airports [1–3].

Halides of various metals are well-suited materials for scintillators. The most widely used materials in scintillation technology are alkali halide crystals. Crystals of alkaline-earth fluorides (CaF₂, SrF₂, and BaF₂) have high chemical, thermal, and radiation stability when compared to alkali halide crystals. The cross-sections for the interaction of Ca, Sr, Ba, and F atoms with thermal neutrons are substantially smaller than those of Na, Cs, and I atoms with thermal neutrons. Therefore, these fluorides have a much lower sensitivity to thermal neutrons than the alkali halide crystals. Consequently, alkaline-earth fluorides are suitable for monitoring neutrons against the γ background. Among the halides of elements in the second group, the crystals CdF₂, CdI₂, SrCl₂:Eu, and BaCl₂ are considered as candidate compounds for scintillators. The melting point of the BaCl₂ crystal is lower than that of alkaline-earth fluorides crystal. The atomic number of BaCl₂ is larger than that of SrCl₂. These properties provide an advantage in X- and γ-ray detection. The BaCl₂

scintillation crystal has low light yield but fast decay time. That is why it is useful for high energy physics experiments like pure CsI or PbWO₄ crystal [1–9].

We measured the scintillation properties of the BaCl₂ crystal with a ¹³⁷Cs (662 keV) γ-ray source and X-ray luminescence using an X-ray tube. In this paper, we present measurement results of pulse height spectra, energy resolution, relative light yield, fluorescence decay time, and X-ray luminescence at room temperature. We also measure the light yield and decay time changes of the BaCl₂ crystal from 10 K to room temperature for understanding the quenching mechanism of the BaCl₂ crystal.

2. Experiments

2.1. BaCl₂ crystal growing

The BaCl₂ single crystal was grown by the Czochralski technique in an induction heated platinum crucible with a diameter of 30 mm. The growing process was performed in an Ar-gas atmosphere with a pulling rate of 2–2.5 mm/h and rotation rate of 20–25 rpm. To reduce crystal cracks, a low thermal gradient was set up in the furnace. The chemical used for the crystal growth was BaCl₂ (99.95% purity, Sigma-Aldrich). The samples of BaCl₂ crystals with a dimension of 10 × 10 × 5 mm³ were cut from the grown crystals and polished using mixed Al₂O₃ powder (grain size of 0.02 μm) in mineral oil with a polishing cloth (Buehler, no. 40-7218) for scintillation characterization [10].

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2.2. Experimental setup

First, we studied the scintillation properties of the BaCl_2 at room temperature. The BaCl_2 crystal was wrapped in a few layers of the Teflon tape and optically coupled with a 2 in. bi-alkali photomultiplier tube (PMT), XP2260 made by Photonis, by optical grease. A signal from the PMT was fed to a preamplifier and then 400 MHz flash analog-to-digital converter (FADC) board made by NOTICE KOREA [11]. The digitized signal was read out by a Linux-based computer and the data were analyzed with the C++ based data analysis program, ROOT package [12].

We also measured the X-ray excited luminescence of the BaCl_2 crystal using an X-ray tube (DRGEM Co.). The BaCl_2 crystal was wrapped with several layers of Teflon tape except the one for attachment with an optical fiber. To avoid the light loss when the BaCl_2 crystal was attached to the optical fiber, a holder with a hole at its center was made from the Teflon material. Scintillation light from the crystal by the X-rays irradiation was transmitted to the QE65000 spectrometer produced by Ocean Optics Co. through the optical fiber. The QE65000 was cooled down to -15°C . The Windows cased software provided by the manufacturer of the spectrometer was used for plotting the X-rays induced emission spectrum of the crystal.

The temperature dependence on the light yield and decay time of the BaCl_2 crystal were measured with temperature changes from room temperature to 10 K. The BaCl_2 crystal was cooled down in a refrigerator to 10 K, with compressed helium gas. A quartz bar of $\phi 15 \text{ mm} \times 70 \text{ mm}$ was used as light guide and the BaCl_2 crystal sample were placed in a vacuum environment of 10^{-2} – 10^{-3} Torr. The temperature of the refrigerator was

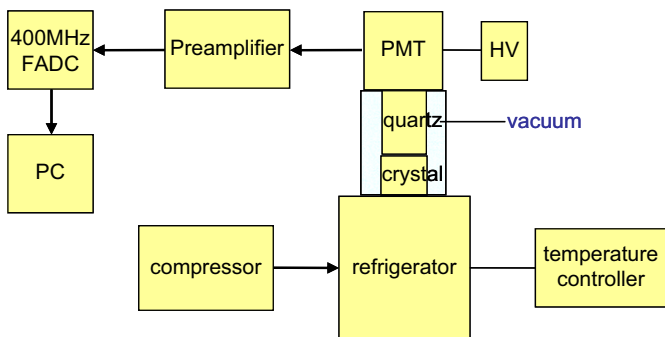


Fig. 1. Schematic diagram of the experimental setup for measuring the scintillation characteristics at low temperature.

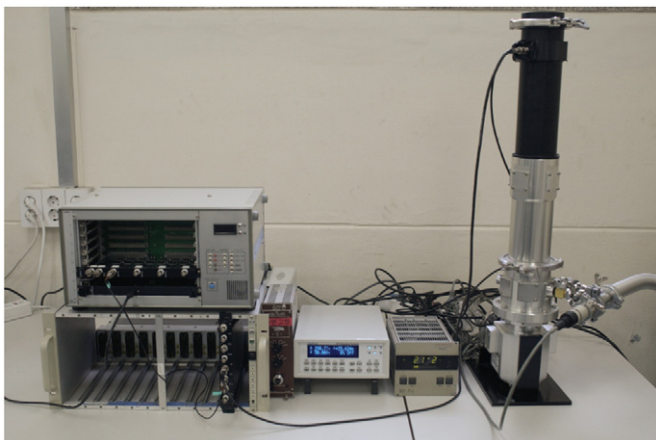


Fig. 2. Low temperature experimental setup with temperature controller and DAQ system.

controlled with a temperature controller, LakeShore 331. We used the ^{137}Cs (662 keV) γ -ray radioactive source to measure the pulse height spectra, energy resolution, and fluorescence

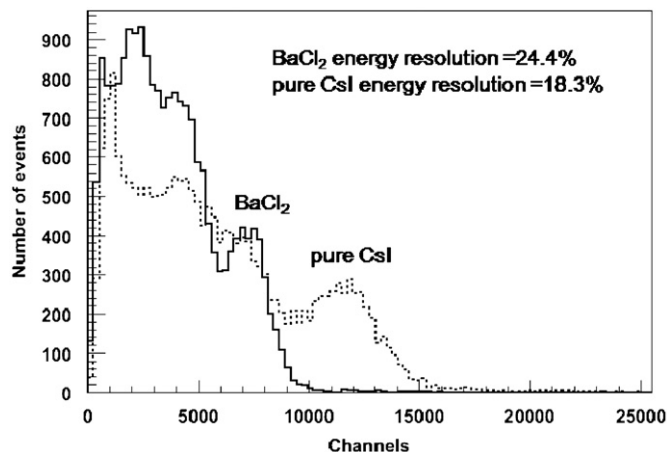


Fig. 3. Relative light yield and energy resolutions of the BaCl_2 and pure CsI for ^{137}Cs (662 keV) γ -ray excitation.

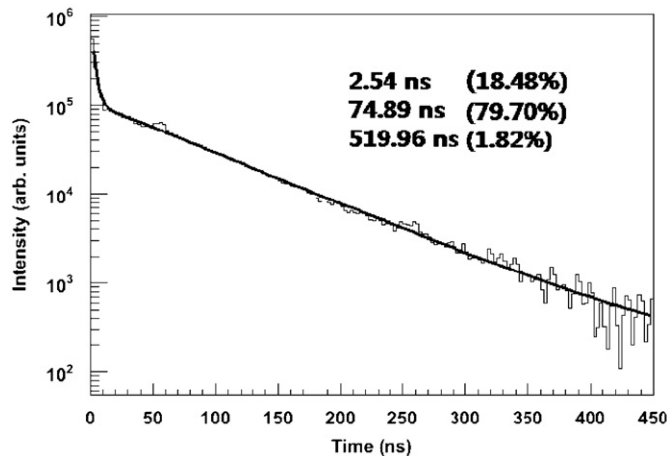


Fig. 4. Fluorescence decay time spectrum obtained from the BaCl_2 crystal at room temperature. Solid curve is the best fit to the data.

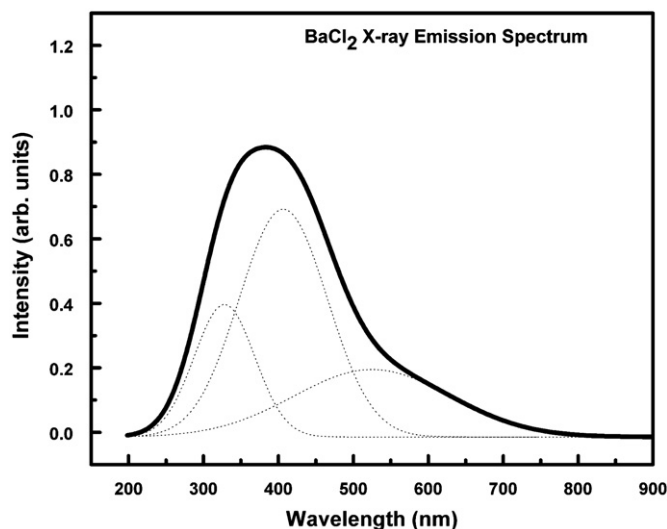


Fig. 5. Emission spectrum of the BaCl_2 crystal excited by X-ray. The peak wavelength of the BaCl_2 crystal was about 390 nm. There are three main emission peaks of 330, 410, and 530 nm.

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