Decay Time Measurement for 3D Printed Plastic Scintillator

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1. Introduction

Recently, 3D printing technique has been applied to manufacture of plastic scintillator. The previous study reported that the light output of 3D printed plastic scintillator was measured and analyzed [1]. However, for the application to various medical and industrial purpose, decay time of this 3D printed plastic scintillator is required.

In this work, we constructed a specific setup for Thomas-Bollinger single photon method [2] coupled with fast-slow coincidence setup [3] to measure the decay time profile of two plastic scintillator of BC408 and 3D printed plastic scintillator. The decay time profile was analyzed by reconvolution fitting combined with light signal function and time resolution function.

2. Methods and Results

2.1 Experimental Setup

The decay time profiles were measured for BC408 and 3D printed plastic scintillator (sample). The sample was fabricated with the composition of the UV-polymerizable plastic resin that was developed in the previous study [1]. An experimental setup was constructed for Thomas-Bollinger single photon method [2] coupled with fast-slow coincidence setup [3] (Figure 1). Only the sides of the tested plastic scintillator were wrapped with Teflon tape, and the scintillator was coupled with Hamamatsu H7195 photomultiplier and a light guide in good optical coupling using optical grease BC-630. A diaphram was connected with the light guide and Hamamatsu H6152-70 photomultiplier. The hole size in the diaphram was adjusted to make the average number of photons formed per event be roughly 0.5 for single photon detection. This whole setup is located inside a black box.

When the tested plastic scintillator was irradiated by ^{137}Cs γ-ray source, the signal generated in H7195 was used to give the zero-time signal for scintillation excitation, and the signal generated by the single photon detected in H6152-70 were used as delayed timing pulse. These two signals were reversed to improve time resolution, and the time differences between these two signals were measured using ORTEC 567 time-to-amplitude converter & single channel analyzer (TAC/SCA). For stop signal, the measurement was gated to choose the event with the energy corresponding to the maximum energy for recoiling Compton electron 477 keV in H7195. The events were registered using ORTEC 928 multichannel analyzer (MCA). The time range of TAC was set to 2,000 ns and calibrated by using the logic pulses of a pulse generator and delay amplifier ORTEC 427A module.

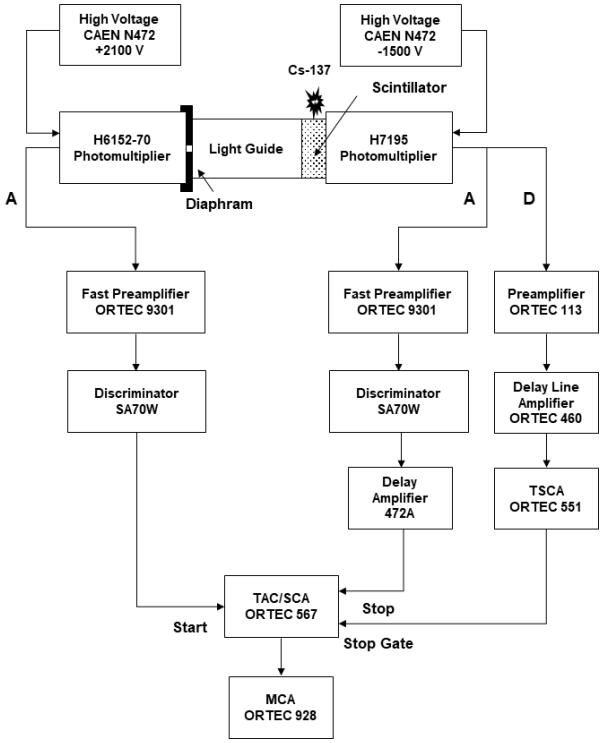


Fig. 1. The schematic of the experimental setup used to measure the decay time profile of the tested plastic scintillators (BC408 and sample). "A" and "D" stand for the anode and dynode signal of PMT, respectively.

2.2 Analysis of Decay Time Profile

The decay time profile I(t) of the scintillation light emission can be described by a convolution of a light signal function f(x) with the time resolution function R(x) of the measuring system [4]:

$$I(t) = f(x) * R(x) = \int_{-\infty}^{\infty} f(x) \cdot R(t-x)dx \qquad (1)$$

The light signal function f(x) can be described as the sum of three exponential decay components:

$$f(x) = \frac{A_1}{\tau_1} \cdot e^{-\frac{x}{\tau_1}} + \frac{A_2}{\tau_2} \cdot e^{-\frac{x}{\tau_2}} + \frac{A_3}{\tau_3} \cdot e^{-\frac{x}{\tau_3}} \qquad (2)$$

Table I: Decay components, their contributions and dispersion of BC408 and sample measured in the experimental system

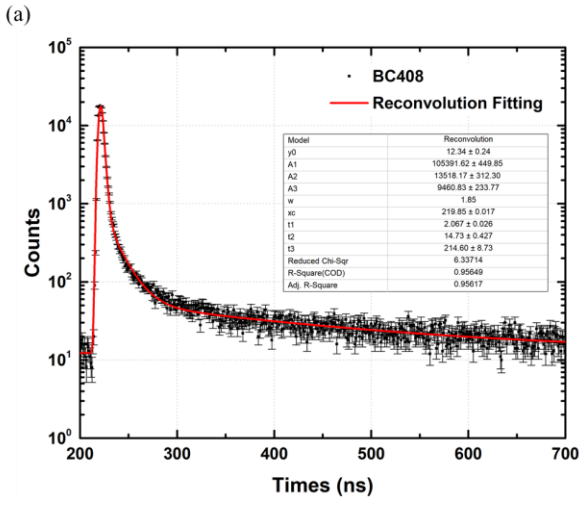
Scintillator	Decay Components			Contributions of Decay Components			Dispersion
	τ_1 (ns)	τ_2 (ns)	τ_3 (ns)	$A_1/\sum A_i$	$A_2/\sum A_i$	$A_3/\sum A_i$	σ (ns)
BC408	2.07 ± 0.03	14.73 ± 0.43	214.6 ± 8.73	0.82 ± 0.03	0.11 ± 0.02	0.07 ± 0.02	1.85 ± 0.1
Sample	1.9 ± 0.10	11.92 ± 0.67	90.72 ± 5.23	0.66 ± 0.07	0.21 ± 0.07	0.13 ± 0.04	2.43 ± 0.06

where τ_1, τ_2, and τ_3 is the decay time constants of the exponential decay function and A_1, A_2, and A_3 is the contributions of each component. The time resolution function R(x) of the system can be assumed as a Gaussian distribution with the dispersion σ and time delay x_c ns:

$$R(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-x_c)^2}{\sigma^2}} \quad (3)$$

The time resolution of the system is affected by the uncertainty in the determination of the pulse start time. Therefore, the dispersion can be achieved from a Gaussian fit to the left (sharply rising) part of the measured decay time profile.

Figure 2 shows the measured decay time profiles for the tested plastic scintillators (BC408 and sample). The data are presented with a bin size of 0.93 ns together with the statistic errors. A convolution fit of the sum of several exponential functions with a Gaussian curve also depicted by the red curve. The analyzed fluorescence decay time constants and dispersions are summarized in Table I. It was confirmed that the shortest decay time constant τ_1 was a value of few nanosecond and represented the main contribution of scintillation emission for BC408 (2.07 ns, 82%) and sample (τ_1 = 1.9 ns, 66%).



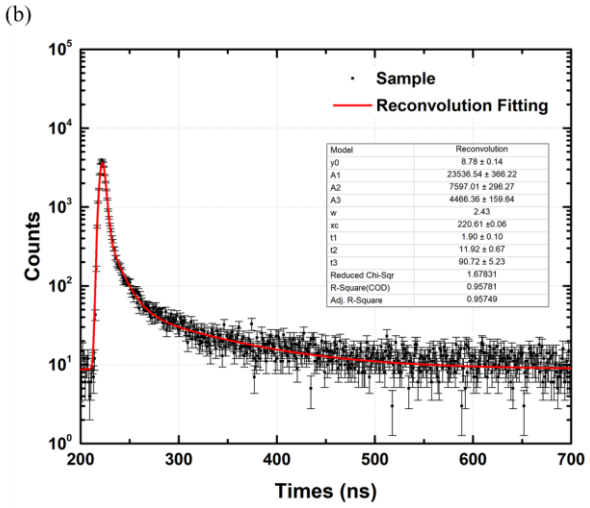


Fig. 2. Decay time profiles of the tested plastic scintillators (a) BC408 and (b) sample. The plots show the time dependence of the light emission fitted (curve in red) according to Eq. (1).

3. Conclusions

Decay time profiles were measured for the commercial plastic scintillator BC408 and 3D printed plastic scintillator. The measured time profiles were analyzed by the convolution of light signal function and time resolution function of the measurement system. As a result, it was confirmed that the shortest decay time of sample (τ_1 = 1.9 ± 0.10 ns) is comparable to that of BC408 (τ_1 = 2.07 ± 0.03 ns).

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