RESEARCH INTO THE SCINTILLATION BEHAVIOUR OF A FEW FAST ORGANIC PLASTIC AND FLUID SCINTILLATORS

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Nuclear Instruments and Methods 91, 667-668 (1971)

Translated at CERN by J. Nicholls
(Original: German)
Revised by H. MacCabe

(CERN Trans. 71-38)

Geneva
August 1971

The Scintillation decay of several fast organic scintillators is studied. The pulse shapes were measured by a sampling technique and corrected for instrumental time resolution.

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The scintillation behaviour as a function of time of a number of plastic and fluid organic scintillators, some of which are novel and none of which had previously been examined in detail, has been investigated with a view to their use in fast scintillation counters for nuclear physics research.

The measurements were made by a sampling storage method[1-3]: The scintillators to be examined were placed on the photocathode of the XP 1021 fast photomultiplier, the shape of the anode pulse was measured with a sampling oscillograph and the signal heights associated with the successive scanning times were suitably stored in a multi-channel analyser. It is possible, by this method, to add the results measured for a predetermined number of individual pulses, and thus to average out any statistical background noise superimposed on the pulse (considerable background noise may, for instance, occur when the light yield of the scintillator is poor).

The pulse shapes thus measured were corrected, having regard to the transfer function of the photomultiplier and the electronic equipment connected to it, in the following manner[4]:

1. The equipment recorded the mean shape of the individual electron pulse, i.e. of the pulse triggered by a single (photo-)electron striking the first dynode. Among other items, the form of this pulse incorporates the jitter in the transit time of the electrons in the multiplier system.

2. The transit time jitters of the photoelectrons in the space between the cathode and the first dynode, which are not present in the individual electron pulse, were approximately

determined by scanning the cathode area occupied by the scintillators by means of brief pulses of light.

3. For the scintillation behaviour S(t) under examination, a function with two exponentially decreasing components and a finite rise time was assumed:

$$S(t) = [1 - \exp(-t/\tau_a)] \times [I_1 \exp(-t/\tau_1) + I_2 \exp(-t/\tau_2)].$$

Taking into consideration the measured transit time jitters in the space between the photocathode and the first dynode, this function was convoluted with the individual electron pulse and the parameters of S(t) were varied until a satisfactory correspondence was found between the convoluted function G(t) and the measured pulse shape. The convolution was done with a computer. The initial parameters were approximate ones obtained from the measured pulse shapes.

Fig. 1 gives an example of an analysis made for the scintillator SPB 31 under alpha particle irradiation. It shows the measured pulse shape, the adapted function G(t), the related function S(t) and its two components $S_1(t)$ and $S_2(t)$, all plotted on a logarithmic scale.

The time axis was calibrated by means of sinusoidal oscillations of known frequency.

The results obtained are set out in Tables 1 and 2. The parameters listed refer to the function S(t); τ_r is the rise time from 10 to 90% of the maximum value, τ_h the width at 50% of the maximum value (half-width), τ_e the decay time to the e-th part of the maximum value, τ_1 the decay time of the fast component S_1, τ_2 that of the slow component S_2 and V the ratio of the maximum values of S_2 and S_1. τ^* is the decay time indicated by

the manufacturer, which is not specified in greater detail. All times are given in ns. α and γ indicate irradiation of the scintillator with alpha particles or γ quanta.

The fluid scintillators were made by dissolving the crystalline scintillator substance BIBUQ ($C_{48}H_{66}O_2$), supplied by Messrs. Merck of Darmstadt, in toluene or xylene. In the column labelled "description" in Table 2, the letter indicates the solvent (T = toluene, X = xylene) and the figures give the concentration of the solution in grams of BIBUQ per litre of solvent. The solutions were flushed through with argon and poured into cylindrical glass vessels coated on the outside with a reflective paint. Only γ-quantum-induced scintillation was studied in the case of fluid scintillators.

The scintillation times τ shown in Table 1 are almost invariably shorter under alpha particle than under γ quantum irradiation. It was impossible to decide, within the framework of this investigation, to what extent this fact can be explained by the scintillation mechanism. Such effects as might have been caused by differences arising in the trigger time jitters of the sampling oscillograph as a result of the different pulse height spectra of the alpha and γ irradiation, were largely eliminated by allowing, by means of a side branch with a single-channel discriminator, only pulses belonging to a narrow height range to be measured in each case.

Because, under alpha particle irradiation, the scintillation light is generated in a thin surface layer, whilst, in the case of γ irradiation, the entire volume of the scintillator contributes to it, different decay times can be produced in the two cases by the special state of the scintillator surface and by the different mean absorption of the light on its way to the photocathode.

The scintillation behaviour of a stilbene crystal

scintillator was investigated during a control measurement. Here we established the fact, well known for this type of scintillator, that scintillation as a whole decays more slowly under alpha particle than under γ quanta irradiation.

We should like to thank Professor Neuert for his interest in our research and the Federal Ministry for Education and Science for the provision of the necessary funds.

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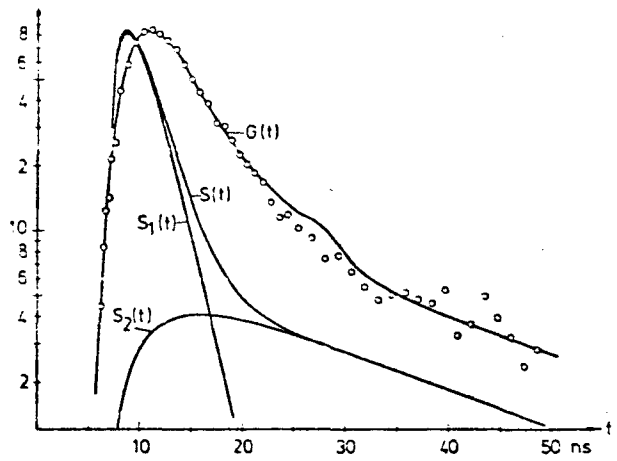

Figure 1: Example of an analysis for the scintillator SPB 31 under alpha particle irradiation.

Table 1

Plastic Scintillators

Description	Manufacturer	τ_r		τ_h		τ_e		τ_1		τ_2		V[%]		τ^*
		α	γ	α	γ	α	γ	α	γ	α	γ	α	γ	
NE 104	Nuclear	1,1	1,5	4,9	6,4	6,3	8,1	2,0	2.5	12.4	13.0	4,1	4,4	1,8
NE 110	Enterprises	1,2	1,7	5,4	7,6	6,9	9,7	2,2	3,0	10.4	14.3	4,2	4,2	3,3
NE 111	(G.B.)	0,2	1,3	1,4	5,5	1,9	7,0	1,2	2,3	12,4	19,4	1,5	3,0	1,7
SPB 21	Tesla-Omnipol	0,9	1,2	4,1	5,4	5,2	6,9	1,8	2,2	22.0	13.0	2,9	4,6	2–4
SPB 31	(Prag, C.S.R.)	1,0	1,3	4,3	5,7	5,6	7,3	2,0	2,3	24.4	14,3	4,9	5,0	2–4
SPB 51		0,9	1,2	4,0	5,4	5,0	6,9	1,6	2,2	12,2	15,6	3,3	4,5	2–4
KL 236	Koch Light (U.S.A.)	0,8	1,3	3,6	5,7	4,6	7,3	1,5	2,3	11,7	11,9	2,9	4,5	1,3

Table 2

Fluid Scintillators

Description	τ_r	τ_h	τ_e	τ_1	τ_2	V[%]
T 15	1,0	4,3	5,5	1,7	5,7	4,2
X 15	0,9	4.1	5.3	1,6	10,4	4.0
T 10	1,1	4,9	6,2	2,0	13.0	2.7
X 10	1,1	4,7	6,1	1,9	13,0	2,7
T 5	1,1	4,9	6,2	2,0	12,7	2,0
X 5	1,2	5,2	6,7	2,1	9,9	3,9