Scintillation Material for Detection of α-, β- Radiation Based on Polymer-Dispersed p-Terphenyl

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Abstract

Two types of scintillaters are described based on polyorgano-polysiloxane carbosil block co-polymers for detectors of α- and β-radiation. It is shown that scintillators of the first type, obtained by casting of 2-4% solution of carbosil (in toluene, etc.) comprising p-terphenyl and a spectrum-shifting activator, have conversion efficiency which, with thickness of 0.1-0.5 mm, is 2.5 times higher than that of standard polystyrene sample (for α-radiation). The second type, based on grinded crystals of p-terphenyl (size particles 0.5-1 mm) in carbosil, have scintillation efficiency 20% higher than that of anhracene single crystals.

I. INTRODUCTION

Organic scintillators are widely used in radiation monitoring of antropogenic environment pollution. As a rule, detecting of α-, β- radiation is carried out at the background of other radiations, e.g. γ-, the intensity of which can significantly exceed the values to be measured. In this case scintillators of different thickness and form (film scintillators) are used, or electronic circuits are involved which allow to identify components of radiation field using the shape of the scintillation puse.

Among the most efficient organic scintillators are activated crystals of p-terphenyl (scintillation efficiency of 120% with respect to anthracene). However, producing large area p-terphenyl scintillators constitutes a difficult problem.

Large-area detectors can be produced using plastic scintillators, but for their most common types (e.g.,polystyrene) scintillation and operation characteristics are not satisfactory for many purposes.

Use of polysiloxanes as a polymer base for scintillators of high radiation stability was shown to be a promising way [1-4], with synthesis of block co-polymers allowing to obtain required properties of polyorganosiloxane polymers.

Bloc co-polymers, containing a rigid organic block and a flexible siloxane one, have high physico-mechanical characteristics. Thermodynamic incompatibility of organic and siloxane blocs leads to micro-phase separation in these systems, which allows to consider them as pseudo-filled. The emerging physical network increases deformation strength and influences other physico-chemical properties. Such polymers, e.g., carbosil which contains rigid polycarbonate block, conserve their high mechanical characteristics up to softening temperatures of the rigid block. From the other side, the flexible siloxane block provides low temperature of glass transition, high chemical, hydrolitic, radiation and thermal stability, low sensitivity to temperature variation, low surface tension, hydrophobic properties, and stability under low temperatures. This makes carbosil a promising material to be used as a polymeric base of organic scintillators.

In this paper, we present results of our studies on such a material produced in our laboratory, which provides high qualities required for production of detectors of complex shape and developed surface.

II. EXPERIMENTAL

Technique 1. Thin-film scintillators were prepared by casting onto optical glass of the saturated solution of p-terphenyl in an organic solvent (e.g. toluene) containing 2-4% of carbosil. After casting the glass was covered by a hood.

After slow evaporation of the solvent small p-terphenyl crystals precipitated over the film volume, morphology of which depended upon the evaporation regime. Then the film was once more dried under vacuum. To ensure easy detachment of the film from the substrate surface, the latter was lubricated by anti-adhesives.

Technique 2. We have also used another technique, which consisted of two stages: preparation of the crystalline powder and fabrication of one- and multilayer scintillators using casting. Crystalline powders were obtained by low temperature brittle destroying of the p-terphenyl crystals grown by the Bridgman technique. The crystalline powder was rinsed by toluene and annealed at 110-120 C for 2-2.5

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hours. Then the layer of crystalline powder uniformly distributed over the surface was cast in by the film-forming composition as described above.

Scintillation characteristics were studied in the pulse mode using a Nokia multi-channel amplitude analyzer. Radionuclides ^{109}Cd and ^{239}Pu were used as sources of β- and α-particles, respectively. The measurements were carried out using films deposited onto optical glass of 20 mm in diameter. The side of the film which is opposite to glass was covered, for light reflection, by 6 mm thick mylar layer. Between the glass substrate and the photomultiplier window an optical contact was established by a silicone lubricant. The relative light yield of the samples under exitation by b-particles was determined using conversion electrones of ^{109}Cd (84.5 kev).

III. RESULTS AND DISCUSSION

Table 1 presentes light yield of six randomly chosen samples prepared using the technique 1. Light yield during β-particle detection is 1.6 times higher than with the standard polystyrene, and during detection of α-particles - 2 times.

Table 1
Relative light yield of organic film detectors under excitation by α-particle

No	Polymeric matrix	Thickness, mm	Light yield, % (α-particles, 239Pu)
1	Polystyrene	0.1	100
2	Carbosil	0.1	217
3	Carbosil	0.1	214
4	Carbosil	0.1	178
5	Carbosil	0.1	188
6	Carbosil	0.1	189
7	Carbosil	0.1	205

In Table 2, characteristics are presented for scintillators prepared by the technique 1 (No.1-5) and by the technique 2 (No.6-8). Higher thickness leads to higher light output, which is presumably related to better matching of sample thickness and free path length of β-particles. Besides that, thicker samples are thought to possess better structure (with optimum quality at 1.0 mm), leading to better optical characteristics.

Amplitude spectra of pulses are presented in Fig.1 for scintillators of different thickness. The peaks corresponding to 62.5 keV and 84.5 keV electron energies are well resolved against the background noise. With higher thickness spectra gain in quality, and with 2 mm (curve 4) they correspond to 1 mm thick p-terphenyl crystals.

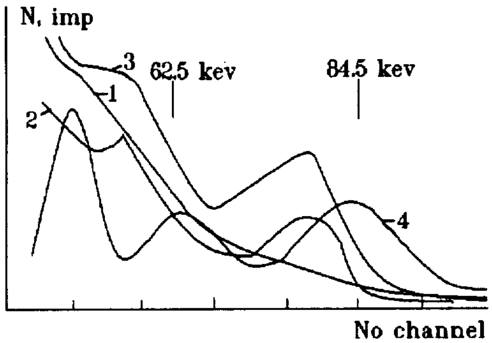

Fig.1. Amplitude pulse spectra obtained under excitation of carbosil film detectors by Cd electrons.

Luminescence spectra of activated p-terphenyl crystals at 300 K (Fig.2a) can be compared with similar spectra obtained for samples prepared by technique 1 (Fig.2b) and technique 2 (Fig.2c). It can be seen that no new luminescence bands appear, and the only effect is that the overall intensity is redistributed between these bands.

Table 2
Relative light yield of organic scintillators of different thickness under excitation by β-particles

No	Base of the organic scintillator	Thickness, mm	Light yield, % (^{109}Cd, 84.5 keV)
1	Single crystal of activated p-terphenyl	1.0	100
2	Anthracene	1.0	80
3	Carbosil film scintillator	0.17	72.7
4	Carbosil film scintillator	0.1	71.9
5	Carbosil film scintillator	0.08	64.8
6	Carbosil film scintillator	0.5	80.0
7	Grinded p-terphenyl crystals (0.5 mm)	0.5	90.0
8	Grinded p-terphenyl crystals (0.8 mm)	0.8	95.0
9	Grinded p-terphenyl crystals (1.0 mm)	1.0	97.0

IV. CONCLUSIONS

1.Samples have been prepared which,by their scintillation characteristics, are very close to those based on p-terphenyl crystals.

2.The techniques used allow to obtain highly reproducible results.

3.The results obtained form the basis for development of industrial production technology of relatively inexpensive large-area scintillators of complex shape with improved operational parameters.

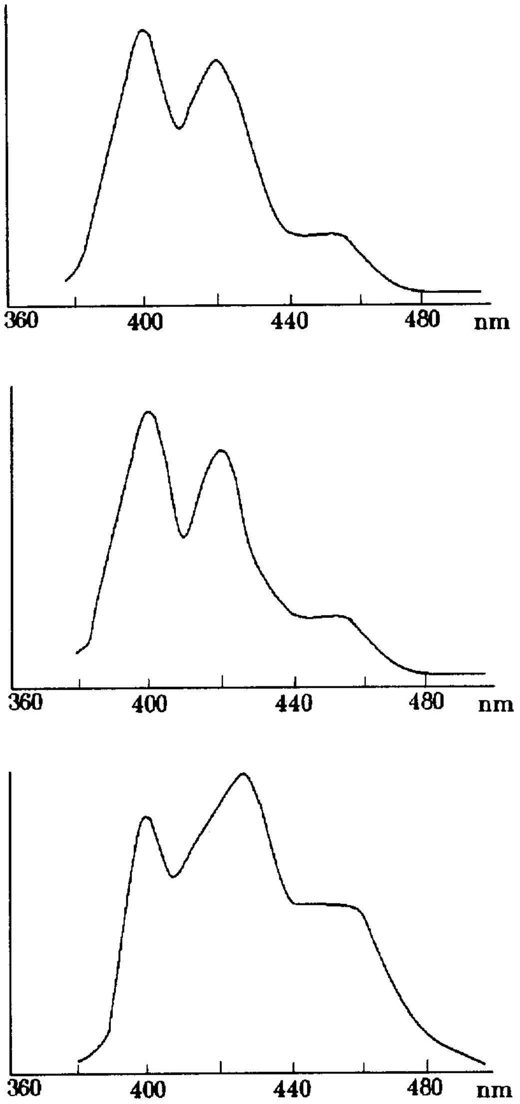

Fig.2. Luminescence spectra under excitation by light (l = 3.14 nm).

V. REFERENCES

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