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G.I.Britvich, A.S.Solovjev[1], V.G.Vasil'chenko

COMPOSITE MEDIA BASED ON SiO_2-GELS POLYMERIZED IN A NEW GREEN EMITTING LIGHT POLYSTYRENE SCINTILLATOR

[1]Joint Institute for Nuclear Research, Dubna, 141980, Moscow region

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Abstract

Britvich G.I., Solovjev A.S., Vasil'chenko V.G. Composite Media Based on SiO_2-Gels Polymerized in a New Green Emitting Light Polystyrene Scintillator: IHEP Preprint 97-62. – Protvino, 1997. – p. 4, figs. 2, tables 1, refs.: 4.

Scintillation properties of a new green emitting light polystyrene scintillator containing 2% pTP + 0.05% K-27 dopants with the light output of about ∼50% in comparison with anthrathene and composite scintillators based on SiO_2-gels were studied. Under high energy particles excitation a light output of about 15% in comparison with anthracene for a composite scintillator was attained.

Аннотация

Бритвич Г.И., Васильченко В.Г., Соловьёв А.С. Композиционные среды на основе SiO_2-гелий заполимеризованные в новом зеленом полистирольном сцинтилляторе: Препринт ИФВЭ 97-62. – Протвино, 1997. – 4 с., 2 рис., 1 табл., библиогр.: 4.

В работе представлены результаты исследований радиационных и сцинтилляционных характеристик нового зелёного полистирольного сцинтиллятора, содержащего добавки 2% pTP + 0.05% K-27 и имеющего световыход ∼50% от антрацена и композиционных сцинтилляторов на основе заполимеризованных SiO_2-гелей. При возбуждени люминесценции частицами высоких энергий в образце композиционного сцинтиллятора был достигнут световыход около 15% от антрацена.

Among promising materials that extend their applications for single particles detection are SiO_2-gels [1]. So, SiO_2-gels saturated with efficient liquid scintillators showed the intrinsic light output of about 14% in comparison with crystal anthracene [2].

The main advantages of recently found green emitting light polystyrene (PS) scintillators [3] using K-27 dopant (a benzoxanten derivative with the maximum light emission at λ_{em}=500 nm and decay time τ=12 ns) are high levels of their light outputs of about I =50% in comparison with crystal anthracene scintillator (with λ_{em}=447 nm), with account for the photoreceptor quantum efficiency.

It is well known that porous media with diameter of pores < 100 μm absorb much more liquids. Having taken an opportunity, we instigated here a possibility to create new composite scintillators based on SiO_2-gels by saturating them with monomers containing scintillating dopants and then polymerized. On the one hand, the optical properties of such new composite scintillators should be similar to those of PS scintillators containing fine powders of inorganic materials [4]. On the other hand, with the use of gels in our case, good initial homogeneity of the inorganic matter (SiO_2) in the scintillator and the gels structure in the volume of composite materials were retained, which is very important for some applications.

This work is devoted to the investigation of luminescent and radiation properties of new composite scintillating media based on SiO_2-gels polymerized in PS scintillators.

Fig.1 shows the transparency T of one of the pure SiO_2-gels samples under study. In order to reduce the infuence of SiO_2-gels absorbtion in the short wavelength region on the light output of new composite materials, efficient green PS scintillators should be taken as base [3]. So, recently we found a green emitting light PS scintillator containing 2% pTP (paraterphenyl with λ_{em}=340 nm) + 0.05% K-27 having a light output of about I=50% in comparison with crystal anthracene. The luminescent spectrum L of K-27 dopant is presented in Fig.1. Our SiO_2-gel samples of $\oslash$ 1.6x0.5 cm^3 were saturated (the procedure was presented in [3]) with styrene containing 2% pTP + 0.05% K-27 + 1% DAK (dinitril 2,2-iso-di-iso-oil acid, an activator used for the polymerization temperature reduction) and 5% PPO (2,5-dipheneloxazole with λ_{em}=365 nm)+ 0.05% K-27 + 1% DAK. The process of polymerization was carried out in vacuum at a temperature of about 60^{o}C during 4 days.

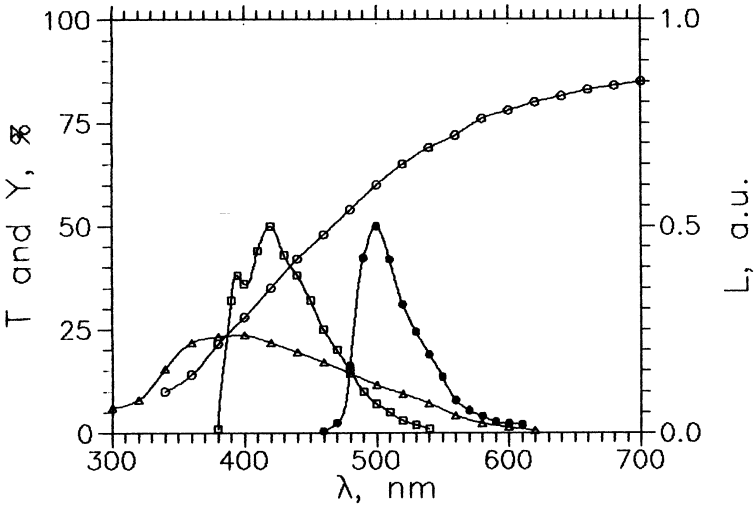

Fig. 1. Transparency T (solid line) of 0.5 cm thick SiO_2-gel sample (○), quantum efficiency Y (dashed line) of our PM (△) and luminescent spectra L (solid lines) of POPOP (□) and thick sample of polystyrene containing 0.05% K-27 (•) as functions of the wavelength λ.

Our new scintillators light outputs were determined at 20^oC in air. For this purpose we measured relative positions of their total absorption peaks for 976 keV conversion electrons from a ^{207}Bi radioactive source in a crystal anthracene and new scintillator samples. The source and samples were fixed upon the entrance window of a photomultiplier (PM) FEU-143 having a bialcaline photocathode. The PM quantum efficiency Y is presented in Fig.1. There were optical contacts between the PM and samples. The integration time in our pulse height analyzing channel was about 400 ns.

Some experimental results on the pulse height measurements of our anthracene and new scintillators are presented in Fig.2 where N are counts/channel. One can see that a tested new scintillator sample has shown a light output of about 8% (without taking into account the PM quantum efficiency) in comparison with the anthracene of a comparative size. Having considered the PM quantum efficiency Y (Fig.1), the scintillator light output was estimated to be about I=15%. Note that the light output of our crystal anthracene was set equal to 100%.

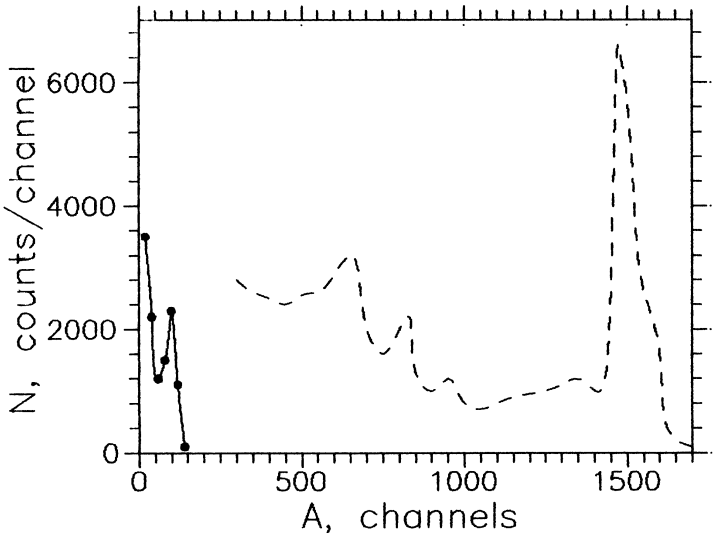

Fig. 2. Pulse height spectra (solid lines) of scintillation signals from ^{207}Bi in SiO_2-gel sample polymerized in PS scintillator containing 2% pTP + 0.05% K-27 + 1% DAK (•) — solid line and in crystal anthracene — dashed line.

The experimental error was determined on the base of repeated measurements and came to about ±5% with a possible systymatic error of about ±8%. Some results of measurements are presented in Table 1.

Table 1. Radiation and scintillation properties of new polystyrene scintillators manufactured by the bulk-polymerized technique.

N	Scintillators	I_o, %	I/I_o, 3.4 Mrad	I/I_o, 10 Mrad	I/I_o, after 23 days
1	2% pTP + 0.05% POPOP	45	0.51	0.24	0.53
2	2% pTP + 0.05% K-27	50	0.53	0.36	0.42
3	2% pTP + 0.05% K-27 + 1% DAK*	15	0.49	0.37	0.44
4	5% PPO + 0.05% K-27 + 1% DAK*	8	0.39	0.26	0.46

∗ — as in [2], lower levels of the light outputs of these new composite PS scintillators were due to the process of excitation quenching on SiO_2 surfaces in fine micropores.

The radiation hardness of our samples was measured in a flux of γ-quanta from ^{137}Cs radioactive sources with a dose rate of about 5.2 rad/s (150 Mrad/yr) at 20^{o}C in air. Note that such dose rate will be tens times higher in comparison with what is expected at future experimental setups. Taking into account the prolonged time of scintillators irradiation in experimental setups, the study of recovery processes in plastic scintillators is an essential part of any radiation properties investigation. Because of that we measured the relative light output I/I_o both soon (10-20 min) after receiving doses 3.4 and 10 Mrad and in 23 days of recovery at 20^{o}C in air after having received the maximum dose. Some results of this investigation are presented in Table.

For comparison, at the beginning of Table scintillation and radiation properties of our standard PS scintillator 1 containing 2% pTP + 0.05% POPOP (1,4-bis-(2-(5-phenyloxazolyl))-benzene with λ_{em}=420 nm and τ=3.6 ns) are presented. The luminescent spectrum L of POPOP is also presented in Fig.1. As is clear from Table, the intrinsic efficiency of our new green emitting light PS scintillator 2 is higher in comparison with sample 1. Although the recovery processes in sample 2 are slower compared with sample 1. As expected, the radiation hardness of new composite materials 3-4 just after irradiation are lower over sample 2 due to the use of DAK and PPO dopants. Thus, with account for the recovery processes after irradiation, the radiation hardness of samples 3-4 is similar to that of sample 2.

In conclusion it should be noted that the light outputs of these new composite scintillators can be easily increased up to levels comparative with those of PS scintillators. To this end we should use gel samples having higher diameter of pores ($\geq$20 μm), more transparent in the light emission region of the luminescent dopant (K-27), with lower difference between the reflection indexes n of used gels and PS scintillators (n$\cong$1.6), etc. So, for SiO_2-gels with n$\cong$1.47, scintillators based on polymethylmethacrylate having n$\cong$1.49 are more preferable.

It is evident that other transparent porous media (ceramics, etc.) can also be used for this purpose. SiO_2-gels and other porous media can be doped at high concentration levels

with different compounds: Li_2O, CdO, In_2O_3, PbO, etc. or prepared on their bases. Such scintillating media are needed to detect γ-quanta, neutrons, neutrino, etc.

Note that such composite materials based on polymerized SiO_2-gels provide higher levels of isolation properties.

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Г.И.Бритвич, В.Г.Васильченко, А.С.Соловьев
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ГНЦ РФ Институт физики высоких энергий
142284, Протвино Московской обл.

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