SDC-91-00068

SDC
SOLENOIDAL DETECTOR NOTES

MEASUREMENTS OF FLUORESCENCE EFFICIENCY OF SCINTILLATORS BEFORE AND AFTER IRRADIATION

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October 14, 1990

Measurements of Fluorescence Efficiency of Scintillators Before and After Irradiation*

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Abstract

Various polystyrene-based scintillators were prepared in the Chemistry Lab. of Fermi National Accelerator Laboratory and cut into discs of 1.2 cm dia and 1.0 cm thick. They were irradiated with a ^{60}Co source to 10 Mrad dose. The scintillation light output and fluorescence and transmittance spectra were measured. After annealing for 10 days in oxygen and 3 days in the air the light output of the best scintillators was 90% of the light output of the original samples.

1 Introduction

This study is part of the effort to develop a high-rate tracking subsystem appropriate for SSC experiments using scintillating fiber technology*. Our goal is to develop highly-efficient and fast scintillators that are resistant to radiation damage.

Common commercial plastic scintillators consist of a polymer base and wavelength shifting fluors.Ionising particles excite polymer molecules which normally emit in UV region. In the presence of the fluors,however, the energy is transfered to the primary,and often to a secondary fluor, which emits at longer wavelengths.For standard scintillators the emission spectrum peaks in the blue violet region and coincides with the wavelength region most strongly affected by the radiation,thus causing a decrease in light output[1,2,3]. The radiation problem is alleviated in plastic scintillators doped with 3HF(3-hydroxyflavone) emitting green light at 530 nm since at these long wavelengths the radiation induced damage is minimal. One obtains still brighter scintillators using 3HF derivatives[4].

In this study we manufactured various polystyrene-based scintillators using the fluors listed in Table 1. BBQ and K27 emit green light and therefore could lead to radiation hard and possibly bright scintillators . They were coupled to a polystyrene base through the following primary fluors:MOPOM,OLIGO408 and OLIGO415A. The latter two primaries were expected to be radiation hard[5] in polystyrene. p-Terphenyl and DMPOPOP are familiar dyes used for the production of standard scintillators. DAT was tested as a replacement for p-terphenyl because of its high solubility and expected radiation hardness[6].

Table 1. Fluors used in this study.

Fluor[a]	Description
MOPOM(420)	syntesized by J.Kauffman
O415(415)	OLIGO415A[b,c]
O408(410)	OLIGO408[c,d]
BBQ[e](470)	Isoquinoline derivative[f]
K27[g](500)	Benzoxanthene derivative[g]
DAT(375)	di-t-amyl-p-terphenyl[d]
DMPOPOP[e](430)	dimethyl-POPOP[h]
3HF[g](530)	3-hydroxyflavone[h]
pT(360)	p-terphenyl [d]

[a]Wavelength of emission peak in brackets. [b]Exciton,Inc. product Exalite 416. [c]Bridged oligophenylenes. Obtained from [d]Bicron Corp.,[f]Sigma Chem. Co., [g]Hoechst Chem. Co.,[h]Aldrich Chem. Co. [e]Purified by recrystalization.

2 Preparation of scintillators

The styrene was first deinhibited through a column and then purified by vacuum distillation.The glass polymerisation tubes were cleaned with nitric and hydrochloric acids,rinsed in distilled water and treated for about 4 h in a 30% solution of dimethyldichlorosilane in chloroform,and finally rinsed with chloroform,methanol,and de-ionized water. This treatment builds a hydrophobic Langmuir layer on the walls of the tube which helps in the removal of the plastic after polymerisation. Styrene and fluors were placed in the tubes and degassed with repeated freeze-pump-thaw cycles.The solutions were polymerised in an oil bath at 110°C-24h,125°C-48h,140°C-12h and ramped back down to 90°C at a rate of 10°C/h. Test tubes were quenched in liquid nitrogen for fast release of the plastic rods and the rods were cut and polished into discs 1.2 cm diameter and 1 cm thick.

At first we prepared scintillators with one fluor only(binary scintillators), varying the amount of the fluor from 0.05% to 2% of the total weight. In Figure 1 we plot the scintillation light output resulting from the excitation of the samples by 1 MeV electrons from a ^{207}Bi source.(In the case of DAT the amount of DAT was varied in the

ternary scintillator DAT+0.01%DMPOPOP. DMPOPOP was added to DAT to render the fluorescence visible to a standard phototube). The saturation occurs at 1 percent concentration by weight.This minimal concentration was chosen for primary fluors in ternary scintillators to minimize possible absorption from the fluor.

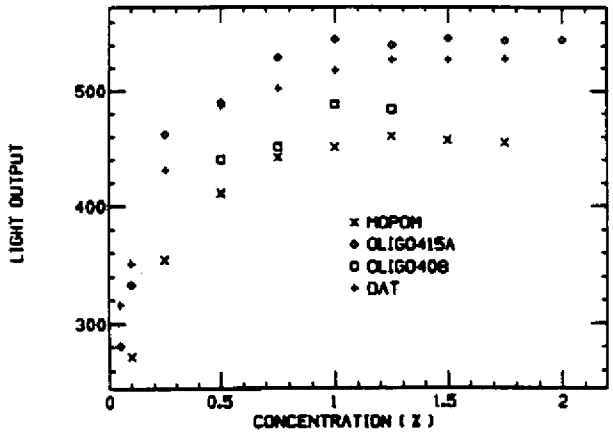

Figure 1.Scintillation light output as a function of weight concentration of the fluor in percent.

Next,the samples with two fluors were prepared with the concentrations of secondary fluors 0.01% and 0.02%. The light output was the same at both concentrations.

The composition of scintillators used for radiation studies is given in Table 2.

3 Measurements and Results

Samples were irradiated in nitrogen gas with a ^{60}Co source at the Nuclear Reactor Laboratory of the University of Michigan at a rate of 1 Mrad/h,to a total dose of 10 Mrad.

To evaluate the scintillators the measurements were performed with both a spectrophotometer and radiation source. The fluorescence and transmittance spectra were recorded with a Hewlett Packard model 8451A diode array spectrophotometer.Fluorescence spectra presented in this paper are from back surface excitation. They were obtained by illuminating one side of the sample with 254 nm light and then measuring the emission spectrum from the other side(samples are 1 cm thick). For the transmission spectra,the absorption of undoped,un-irradiated polystyrene was subtracted out. The fluorescence spectra from back and front surface irradiation with 313 nm light were also taken[7].

Tests with a radiation source used ^{207}Bi conversion electrons and Hamamatsu photomultoplier R669(our photomultiplier has quantum efficiency which is almost constant from 430 nm to 600 nm). The scintillator discs were placed directly on the photomultiplier with immersion oil providing optical contact. The source was put directly on the top of the discs and pulse height spectra were registered with a LeCroy qVt multi-channel analyser.

The fluorescence and transmittance spectra for scintillators with OLIGO408+K27 and DAT+3HF are presented in Figures 2 and 3.After irradiation ,transmittance in the peak of emission is 0.5 and 0.9 respectively,which cau decrease in light output.The decrease in DAT+3HF is however worse than what we would expect from the deterioration of transmittance alone.This effect has been observed before[3]. Similar data were taken for all studied samples.

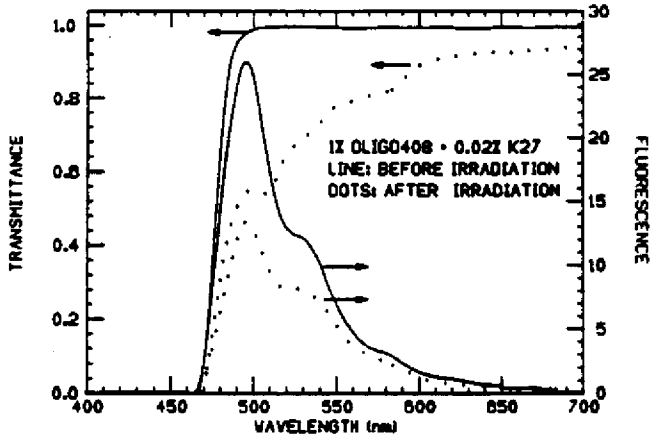

Figure 2. Transmittance and flurescence spectra for the scintillator with OLIGO408+K27.

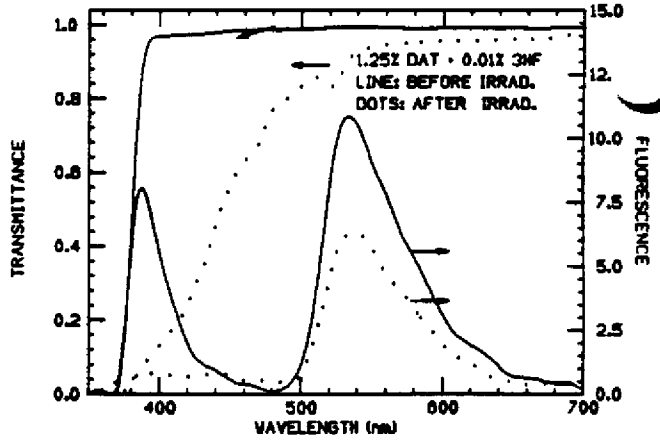

Figure 3. Transmittance and fluorescence spectra for the scintillator with DAT+3HF.

Both the total area under the fluorescence spectra ,and the peak position in the pulse height spectra from ^{207}Bi excitation measure light output of the scintillators. Both measurements agreed to within a few percent except OF the annealed samples OLIGO+BBQ(or K27) for which the fluorescence spectra measure 15% more light than the photomultiplier. In Table 2 we give the values of light output measured by the photomultiplier viewing the scintillator samples excited by 1 MeV electrons from ^{207}Bi source. The light output from the scintillators before irradiation, irradiation, and after annealing for 10 days in oxygen 3 days in air are given in Table 2(in arbitrary units). In the last row we give the light output from the standard

scintillator p- terphenyl+DMPOPOP manufactured in our Laboratory and cut to the same size as all studied samples.

Table 2. Light output before and after 10 Mrad radiation dose from ^{60}Co source in arbitrary units.

Scintillator[a]	λ[b] (nm)	Light output Before	After	After 13 d[c]
MOPOM	420	0.79	.04	.42
MOPOM+.01%BBQ	470	0.95	.13	.63
MOPOM+.02%BBQ	470	0.96	.16	.69
MOPOM+.01%K27	500	0.95	.27	.75
MOPOM+.02%K27	500	0.95	.27	.75
O415A	415	0.92	.49	.79
O415A+.01%BBQ	470	1.01	.42	.86
O415A+.02%BBQ	470	1.02	.34	.89
O415A+.01%K27	500	0.97	.57	.87
O415A+.02%K27	500	0.99	.53	.88
O408	410	0.88	.48	.76
O408+.02%BBQ	470	1.02	.34	.87
O408+.02%K27	500	0.97	.57	.89
DAT	375	0.73	.16	.46
DAT+DMPOPOP	430	0.86	.31	.70
DAT+.01%3HF	530	0.85	.40	.63
pT	360	0.84	.21	.41
pT+DMPOPOP	430	0.88		

[a]Fluor concentrations are by weight,the concentrations of primaries are 1%(1.25% for DAT).[b]Wavelength of peak emission. [c]Annealed 10 days in oxygen and 3 days in air.

The light output of non-irradiated samples is given in the column "Before" of Table 2. All new fluors used in this study produced bright scintillators(DAT emitting at 375 nm is the only exception).The brightest ones are OLIGO+BBQ and OLIGO+K27 and their output is ten percent higher than that from pT+DMPOPOP. Light output after irradiation is given in the column "After".Here we note big differences between various scintillators,OLIGO+K27 being least effected .After irradiation the light output of OLIGO415A+K27 and OLIGO408+K27 is 0.55 and 0.57 compared to 0.88 for non-irradiated pT+DMPOPOP.After annealing for 10 days in oxygen and 3 days in air the above scintillators and OLIGO+BBQ are the brightest ones with average light output 0.88.The next brightest green scintillator is MOPOM+K27 with light output 0.75.We note here that after irradiation OLIGO+BBQ and OLIGO+K27 exhibited phosphorescence in room light with the time constant of minutes. This phenomenon disappears in the annealed samples. By dividing the numbers in the column "After 13 d" by the numbers in the column "Before" ,we compute he ratio of the light output of the annealed scintillators o the light output of the original samples.This ratio is as high as 90 percent for OLIGO+K27 scintillators.

4 Conclusions

We have identified several candidates for radiation hard scintillators :OLIGO415A(or OLIGO408)+K27(or BBQ). Their fluorescence emission peaks at 500 nm (470 nm). After irradiation with a 10 Mrad dose from a ^{60}Co source followed by 13 days of annealing,the light output was observed to be the same as of the non-irradiated standard scintillator pT+DMPOPOP.

Acknowledgements

We thank C.Hurlbut of Bicron Corporation and J.Kauffman of the Philadelphia College of Pharmacy and Science for helpful discussion and for providing some of the fluors used in this work.

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[*]This research was conducted by the Fiber Tracking Group,a list of authors can be found in "Scintillating Fiber Tracking for SSC", R.Ruchti,et. al.,these proceedings.

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