Fluorescence yield for plastic scintillators after irradiation

Zishuo Yang[a,*], Alberto Belloni[a], Sarah C. Eno[a], Charles Hurlbut[b], Geng Yuan Jeng[a], Yao Yao[a]

[a] *Dept. Physics, U. Maryland, College Park MD 30742 USA*
[b] *Eljen Technology, 1300 W. Broadway, Sweetwater, Tx 79556 USA*

Abstract

The ratio of the fluorescence yield versus wavelength for plastic scintillators EJ-408 and EJ-260 before and after irradiation by a ^{60}Co source for doses of 50, 30, 10, 4, and 2 Mrad at various dose rates and for different concentrations of the primary and secondary dopant. While the nominal dopant concentration gives the highest light output prior to irradiation, a higher concentration is found to be optimal for irradiated plastics.

Keywords: plastic scintillator, fluorescence, radiation hardness,

1. Introduction

Organic scintillators (such as toluene, polystyrene, and naphthalene) containing wave-length shifting additives in solution have long been popular elements in detectors used in particle physics, nuclear physics, radiation safety, and heath physics applications due to their high light output, low cost, fast response, and versatility of physical construction. Plastic scintillators and wavelength shifters, including wavelength shifting fibers, are currently available from companies such as St. Gobain, Kuraray, and Eljen. Prolonged exposure of plastic scintillator to ionizing radiation has harmful effects: it can increase light self-absorption (yellowing) and decrease initial light yield. In this paper, we

*Corresponding author
Email address: yangzs@terpmail.umd.edu (Zishuo Yang)

present measurements of ratio of the light output before and after irradiation for two different types of plastic scintillator manufactured by Eljen corporation, EJ-408 and EJ-260, before and after irradiation by a ^{60}Co source for doses of 50, 30, 10, 4, and 2 Mrad at various dose rates and for different concentrations of the primary and secondary dopant.

The induced attentuation length in plastic scintillators has been the study of extensive studies [1], [2], [3], [4],[5],[6],[7]. Especially, the presense of oxygen plays an important role. As discussed in [6], the presense of oxygen increases the number of migration mechanisms for the radicals produced during irradiation. The diffusion of oxygen into the scintillator provides a mechanism for radiation damage to depend not only on dose, but also on time and on dose rate. Simulations based on oxygen diffusion have been shown to reproduce time dependence of the induced attentuation length in scintillators based on polystyrene and PMMA[2]. They show that the penetration depth of oxygen into the substrate depends on the dose rate, presumably because interactions of the oxygen with radicals affects its ability to diffuse. At lower dose rates, oxygen penetrates more deeply. Because of the importance of the interaction of oxygen with radicals, this can lead to dose rate effects for radiation damage. They also show that the recovery of the induced self absorption after irradiation (bleaching) is consistent with oxygen diffusion. They show that there is little bleaching without oxygen, and that a very large number of color centers form if there is no oxygen, although the permanent damage after bleaching (exposure to oxygen after the radiation) is slightly larger if there is oxygen.

2. Measurements

Both EJ-408 and EJ-260 have

3. Conclusions

4. Acknowledgements

The authors would like to thank Neil Blough and Anna Pla-Dalmau for advice on taking fluorescence measurements, and Blough for the use of his machine. This work was supported in part by U.S. Department of Energy Grant YYYYY.

References

[1] U. Holm, K. Wick, Radiation stability of plastic scintillators and wave-length shifters, Nuclear Science, IEEE Transactions on 36 (1) (1989) 579–583. `doi:10.1109/23.34504`.

[2] K. Wick, D. Paul, P. Schrder, V. Stieber, B. Bicken, Recovery and dose rate dependence of radiation damage in scintillators, wavelength shifters and light guides, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 61 (4) (1991) 472 – 486. http://dx.doi.org/http://dx.doi.org/10.1016/0168-583X(91)95325-8 `doi:http://dx.doi.org/10.1016/0168-583X(91)95325-8`.
URL `http://www.sciencedirect.com/science/article/pii/0168583X91953258`

[3] B. Bicken, U. Holm, T. Marckmann, K. Wick, M. Rohde, Recovery and permanent radiation damage of plastic scintillators at different dose rates, Nuclear Science, IEEE Transactions on 38 (2) (1991) 188–193. `doi:10.1109/23.289295`.

[4] B. Bicken, A. Dannemann, U. Holm, T. Neumann, K. Wick, Influence of temperature treatment on radiation stability of plastic scintillator and wavelength shifter, Nuclear Science, IEEE Transactions on 39 (5) (1992) 1212–1216. `doi:10.1109/23.173180`.

[5] G. Buss, A. Dannemann, U. Holm, K. Wick, Radiation damage by neutrons to plastic scintillators, Nuclear Science, IEEE Transactions on 42 (4) (1995) 315–319. doi:10.1109/23.467829.

[6] B. Wulkop, K. Wick, W. Busjan, A. Dannemann, U. Holm, Evidence for the creation of short-lived absorption centers in irradiated scintillators, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 95 (1) (1995) 141 – 143. http://dx.doi.org/http://dx.doi.org/10.1016/0168-583X(94)00435-8 doi:http://dx.doi.org/10.1016/0168-583X(94)00435-8.
URL http://www.sciencedirect.com/science/article/pii/0168583X94004358

[7] A. Bross, A. Pla-Dalmau, Radiation damage of plastic scintillators, Nuclear Science, IEEE Transactions on 39 (5) (1992) 1199–1204. doi:10.1109/23.173178.