Light Output Evaluation of 3D-Printed Plastic Scintillators Irradiated with 100 MeV Proton Beams at KOMAC

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Introduction

Plastic scintillators have been used in various fields as radiation detectors for the use and control of radiation sources. The availability of plastic scintillator in extreme conditions such as space environments is emerging as a technical issue. In this environment, radiation hardness is an important issue to maintain the detector normal. There have been prior studies on the change of plastic scintillators by irradiation with electron beams or gamma rays, but studies on high-energy protons are insufficient.

In this study, plastic scintillators made of different monomers were exposed to high-energy proton beams at different doses, and relative light output was observed for each plastic scintillator.

Materials and Methods

1. Manufacture of Plastic scintillators

Three of these scintillators are made from different monomers using a 3D printer, and other compositions are shown in Table 1. BC408, a commercial plastic scintillator based on polyvinyltoluene, was selected as a comparator. All scintillators are made in sizes of 10 × 10 × 10 mm3.

Table 1. Four types of plastic scintillators composition

Composition / Sample type	PPO (wt%)	ADS086BE (wt%)	TPO (wt%)
BPA(EO)15DMA	1.5	0.03	0.1
D0241			
OPPEA			
BC408	(Commercial scintillator)		

2. Method of proton beam irradiation

Figure 1. Irradiation setup

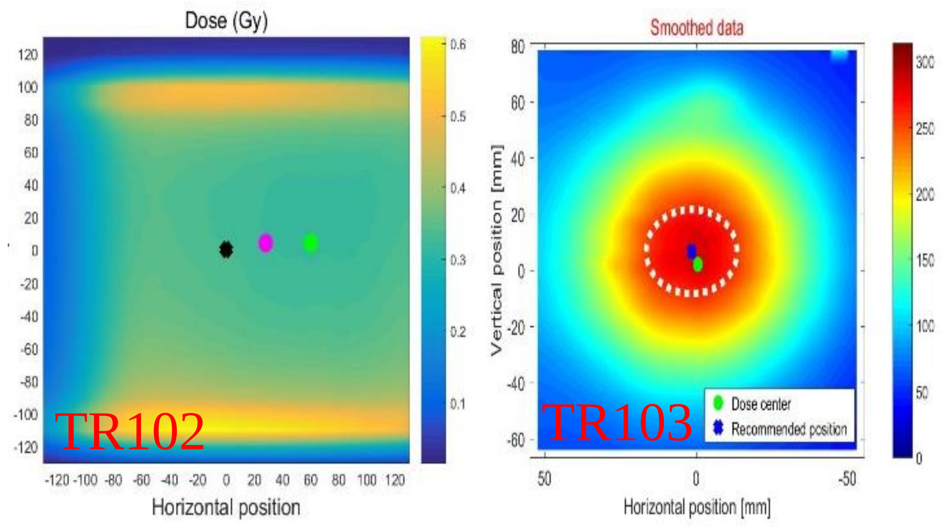

Figure 2. Beam profile

Table 2. Used beam line with irradiation method

Total Dose	0.1k Gy	1k Gy	10k Gy	100 kGy
Beamline	TR102	TR102	TR103	TR103
Dose rate	1k Gy/h	1k Gy/h	200k Gy/h	200k Gy/h
Exposure time	6 min	60 min	3 min	30 min

Table 3. TR102 and TR103 proton beamline properties

Beam line	TR102	TR103
Available energy [MeV]	30 - 100	30 - 100
Exposed flux [#/cm2sec]	2.6E+08	5.49E+10
Dose rate [Gy/h]	1k	200k
Beam shape	Flat	Gaussian
Exposed beam area	100 × 100 mm2 (Plane)	d = 30 mm (Circle)

- Each sample exposed 100MeV proton beam conducted by Korea Multi-Purpose Accelerator Complex (KOMAC)
- Uniformity was measured as 8.86% in TR102 and 6.20% in TR103 at the sample position.
- Energy was measured as 97.9 ± 1.0 MeV in TR102 and 96.4 ± 0.1 MeV in TR103

3. Measurement of scintillation light output

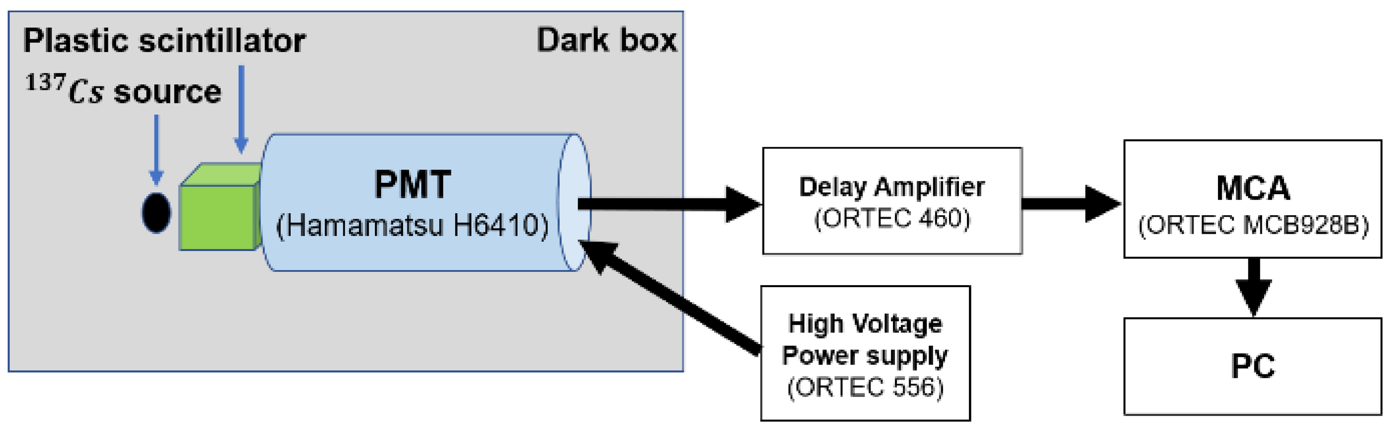

Figure 3. Measurement system for scintillation light output.

- Relative light output (Relative LO) of each scintillator sample was calculated as in the following equation.

$$\text{Relative LO }(\%) = \frac{C_{after}}{C_{before}} \times \frac{Q_{before}}{Q_{after}} \times \frac{G_{before}}{G_{after}} \times 100$$

C : Compton edge channel
Q : Quantum efficiency
G : Amplifier's gain

Results and Discussion

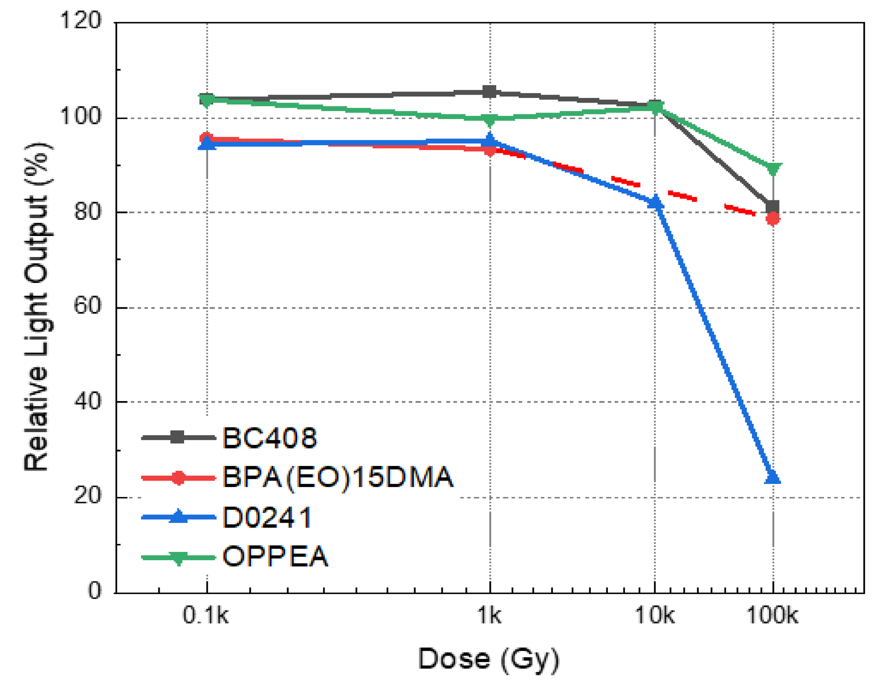

Figure 4. Changes of relative light output

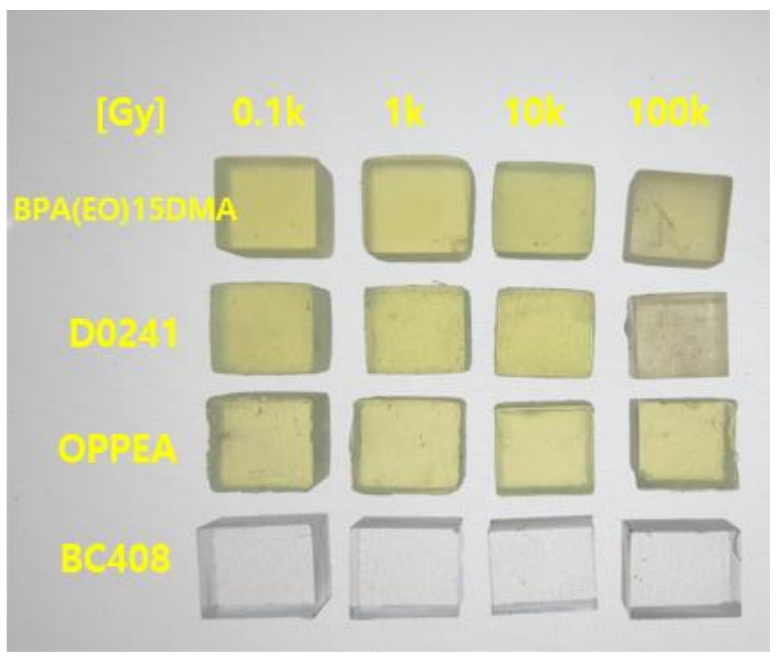

Figure 5. Appearance changes according to dose

Table 4. Absolute light output (photons/MeV) of each sample

	Non- irradiated	0.1k Gy	1k Gy	10k Gy	100k Gy
BC408	10,000	10,400	10,500	10,240	8,100
BPA(EO)15DMA	1,750	1,670	1,630	7,600	1,380
D0241	7,170	6,760	6,810	5,880	1,720
OPPEA	6,870	7,130	6,850	7,020	6,140

- Proton hardness
  - BPA(EO)15DMA, D0241 – 1k Gy
  - BC408, OPPEA – 10k Gy
- 10k Gy BPA(EO)15DMA sample was missed and predicted.

Conclusion

In this study, we aimed to investigate the changes of relative light output from plastic scintillator when it exposed to high energy proton beam.

The result shows that scintillators using D0241 are relatively vulnerable to high-energy protons compared to the rest types of scintillators. And finally, the long-term operation of plastic scintillation detectors in high-energy proton fields, such as the space environment, can be considered in the future.