Growth and Radiation Hardness of Organic Scintillation Crystals for Particle Detection

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Organic plastic scintillators are used for detection of particles such as neutrons or muons, and their advantages are generally fast decay (< 10 ns) and low sensitivity for gamma-rays when compared to inorganic scintillators such as Tl:NaI, Ce:Lu_2SiO_5. Under high gamma-ray dose conditions (i.e. nuclear fusion reactor) decay time is also an important factor to suppress the pile-up events. Although plastic scintillators are easier to handle when compared to liquid materials, their melting point is generally lower than that of inorganic materials; the typical softening point is approximately 343 K (i.e. [1]). Radiation measurements at higher temperatures (over 372 K), including neutrons and alpha-rays detection, are required in several fields such as nuclear fusion [2]. Therefore, we have developed novel organic scintillators with fast decay times and high melting temperatures above 372K which would replace inorganic scintillators.

We grew *p*-terphenyl and carbazole crystals by the self-seeding vertical Bridgman technique [3] which enables to grow the crack-free crystal. As raw materials, p-terphenyl (99.0% up purity, Tokyo Chemical Industry) and carbazole (97.0% purity, Tokyo Chemical Industry) powders were used and loaded into quartz ampoules. Crystal growth was performed under 99.999% purity nitrogen atmosphere in a sealed chamber. The ampoule was heated by a resistance heater. The rates of pulling down and up for the purification were 720 mm/h and 72 mm/h, respectively. The pulling-down rate of the practical crystal growth was 1.44 mm/h. To evaluate the light output, Pulse height spectra were measured for the crystals excited by alpha-rays from an ^{241}Am source and gamma-rays from a ^{137}Cs source.

We succeeded in the growth of *p*-terphenyl and carbazole with a diameter of 5 mm. We confirm the crystal phase and component using the results of powder X-ray diffraction pattern and Fourier Transform Infrared Spectroscopy, respectively. The light yields were estimated by comparing the peak position to that of GS20 as a reference scintillator and considering the quantum efficiencies of a photo-multiplier tube at Radio luminescence emission peak wavelength.

We also grew 2-inch diameter *p*-terphenyl crystals and assembled a pixel scintillation array to obtain two-dimensional radiation images for neutron detection. On the other hand, growth of carbazole with such a large size was hard without cracks. After the *p*-terphenyl bulk crystals were cut into pixels with a size of 5 mm x 5 mm x 5mm, the radiation hardness of the pixels was evaluated using ^{60}Co gamma-ray source with an activity of ~80 TBq.The result shows the light output did not degrade after the irradiation. We show the details of the above results in this paper.

Table 1 Light yield for *p*-terphenyl and carbazole compared to GS20 reference scintillator and (α/γ) ratios

	Light yield [photons /5.5 MeV (α)]	Light yield [photons /MeV (γ)]	(α/γ)
GS20	5,060	4,000	0.23
p-Terphenyl	9,030	18,500	0.09
Carbazole	10,870	13,700	0.14

References

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