Process Development for Lab-Scale Fabrication of Plastic Scintillators from Commercial Polystyrene Beads

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Introduction

Plastic scintillators are widely used for radiation detection in nuclear physics, high energy physics, industrial applications, such as cargo scanning, tomography, and home land security [1]. Conventionally and at laboratory scale, the plastic scintillators are fabricated through standard thermal polymerization method. Typically, the technique for the preparation of polystyrene (widely used polymer matrix) based plastic scintillators involves following steps: (a) purification of the monomer styrene by vacuum distillation; (b) addition of dopants to monomer; (c) removal of dissolved gasses, (d) complete polymerization in an inert atmosphere or under vacuum; and (e) a careful annealing. All these steps are time consuming (require several days) and labour intensive making the process costly. In addition, the handling of styrene is risky without proper precautions as there is the possibility of runway accidents, and also styrene is hazardous [3]. Thus, when the requirement for plastic scintillators is large, the monomer process is not a suitable method. Therefore, for voluminous production, the scintillators are fabricated directly by melting commercially available polymer and appropriate dopants together in an extruder [3]. Since the process does not involved monomer, it is fast, safe, and cost-effective. Despite such advantages, in laboratory scale the fabrication of plastic scintillators from polymer method is hardly reported mainly because of requirement of extruder for proper mixing and melting of polymer beads and dopants.

Here we have shown the fabrication of plastic scintillator from polymer beads without an extruder. The fabrication process takes nearly 18 hrs to complete for 2''x 2" scintillators which is much faster than the monomer method that requires days.

Results and Discussion

Our process is influenced by the thermal polymerization method, where in place of monomer, polystyrene was used. The first step of the process is the mixing of dopants and polymer in a desired mould, which was glass bottles in present study. The mixing of dopants and polymer is one of the biggest challenges for fabrication of plastic scintillators at lab-scale as all materials are in solid form. In industrial scale the mixing and melting are done by twin screw extruder. Thus, a method of mixing of dopants and polymer was developed in which the mixture was first soften at low temperature for 30 mins under inert condition. In the next step, the mixture was annealed by increasing temperature slowly to 180 ^{0}C at which the solid polymer became viscous liquid. It has been observed that optimization of annealing temperature is crucial as at high temperature, dopants start degrading making yellowish coloration.

The next challenge is to make viscous liquid bubble-free. In industry, the special designed mould is used, where the polymer melt is solidified in a control way. In present case, melting and solidification were done in same glass bottle. Moreover, during melting, the air gap between polymer beads got trapped generating many bubbles. Although, prolonged heating led to slow upward movement of bubbles, but it also caused degradation of the dye. Therefore, to remove bubbles a two-steps process has been developed. In step-1, the mixture of polymer beads and dopants was evacuated before melting to reduce trapped air, and in step-2, the melting was done under vacuum. The vacuum line was inserted into the

polymer melt for making it easy of sucking bubbles from the melt. Once the polymer melt became bubble-free, the temperature was lowered slowly to room temperature. The scintillator was taken out by breaking the glass bottle. For further characterization, the scintillators so obtained were cut and polished. Photographs of such developed plastic scintillators with and without bubbles under UV light source are shown in Fig. 1.

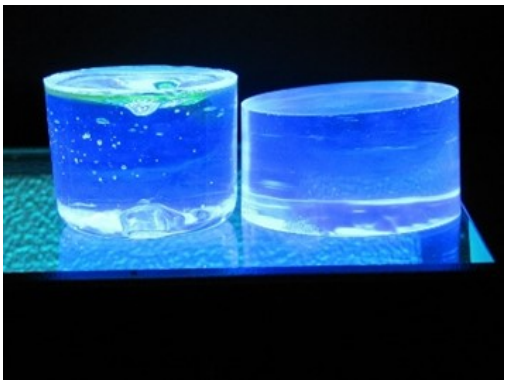

Fig. 1. Photographs of plastic scintillators under UV illumination (left with bubble and right without bubbles)

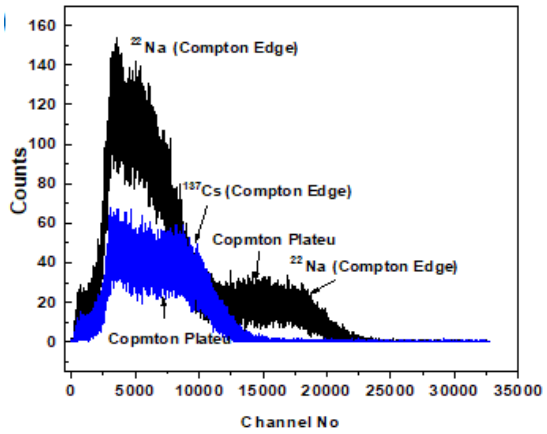

Fig. 2. γ-ray spectra recorded for different radiation sources.

The emission spectra of as fabricated plastic scintillators were measured and found to be peaking around 433 nm. The scintillators were also subjected to gamma sources such as ^{137}Cs, ^{22}Na. The measured spectra are presented in Fig 2. Compton edges for ^{22}Na and one for ^{137}Cs were detected, which is the characteristics of a typical plastic scintillator.

In conclusion, polymer beads have been used as starting materials and fabrication process for the plastic scintillator at lab scale has been developed.

References

[1] Yu N. Kharzheev, *Phys. Part. Nucl*. 46, 678-728 (2015).
[2] A. Pla-Dalmau, A. Bross, K, Mellott, Nucl. Instrum. Methods Phys. Res.A, 466, 482–491 (2001).
[3] Lin Zhao, Wen Zhu, Maria I. Papadaki, M. Sam Mannan, M. Akbulut, ACS Omega 4, 8136-8146 (2019).