Overcoming the Notorious Radiation Softness of Acrylate-Based Plastic Scintillators

V. Anand[1], B. Bansal[1], M. Tyagi[2], G. Anil Kumar[1]

[1]*Department of Physics, Indian Institute of Technology Roorkee, Roorkee-247667, India*
[2]*Technical Physics Division, Bhabha Atomic Research Centre, Mumbai-400085, India*
Corresponding Author Email: vivek_a@ph.iitr.ac.in

3D printing has recently emerged as a promising alternative for fabricating plastic scintillators with reduced energy consumption, rapid prototyping capability, and unprecedented control over geometry and resin composition [1,2]. While progress has been made in improving the scintillation performance and timing characteristics of 3D-printed plastics, their radiation hardness, a critical requirement for operation in accelerator tunnels, nuclear reactors, and space missions, has remained largely unexplored. Photocurable acrylate-based formulations, widely used in 3D printing, have long been regarded as *notoriously radiation soft* [3]. This perception arises from their aliphatic-rich polymer backbones and ester linkages, which are highly susceptible to radiation-induced chain scission and oxidation, resulting in rapid optical darkening and performance degradation even at moderate doses. Consequently, acrylate polymers have historically been considered unsuitable for radiation detector applications requiring sustained exposure.

In this work, we demonstrate that this long-standing limitation can be mitigated through rational resin design. We systematically investigate the γ-radiation hardness of 3D-printed plastic scintillators based on an acrylate monomer having higher aromaticity than the conventional vinyl toluene (VT) in cojugation with an intermediate dye having an extended conjugated π-system. The results are directly compared with VT-based formulations. Samples were irradiated using a ^{60}Co γ-ray source up to cumulative doses of 20 kGy. Post-irradiation characterization included pulse height spectroscopy, optical transmission, steady-state and time-resolved photoluminescence, and mechanical hardness measurements. The acrylate-based scintillators exhibited significantly improved radiation hardness, retaining ~70 % of their initial light output at 20 kGy, compared to ~40 % for VT-based samples, a two-fold higher retention. Transmission losses at 430 nm were found to be 54% for VT-based and 32% for acrylate-based scintillators, indicating suppressed formation of radiation-induced color centers. Photoluminescence decay profiles remained unchanged after irradiation, confirming preservation of fluor emission kinetics. By combining greater aromaticity and cojugated π-delocalisation with photocurable processing, we demonstrate that acrylate-based 3D-printed scintillators can achieve significantly improved resistance to radiation-induced optical and scintillation degradation, establishing a new class of radiation-hard, additively manufactured plastic scintillators.

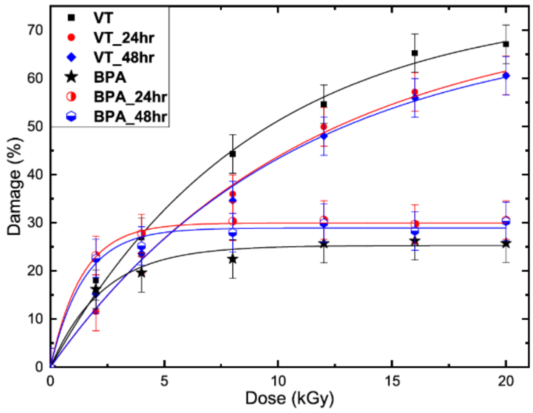

Fig.: Percentage of damage in light output in the case of Vinyl Toluene-based (VT) and acrylate-based (BPA) scintillators as a function of radiation dose.

[1] D. G. Kim, et al., Nuclear Engineering and Technology **52** 2910 (2020).
[2] Y. Kim, et al., NIMA **1055** 168537 (2023).
[3] C. Zorn, Nuclear Phys. B-Proc. Suppl. **32** 377 (1993).