Advances in 3D-printed plastic scintillators: new results on timing performance, PSD, optimization, and environmental durability

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Plastic scintillators play a central role in radiation detection across nuclear and particle physics, medical imaging, national security, and environmental monitoring due to their fast timing response, mechanical robustness, scalability, and cost-effectiveness. Conventionally, plastic scintillators are fabricated through thermal bulk polymerization, a process that requires elevated temperatures, prolonged curing times, dedicated molds, and extensive post-processing, including cutting and polishing. These steps not only increase fabrication cost and time but also limit achievable geometrical complexity and pose safety risks.

Fig.: 3D-printed scintillators under UV-illuminination

Additive manufacturing, particularly Digital Light Processing (DLP)-based 3D printing, provides an attractive alternative by enabling room-temperature, layer-by-layer photo-polymerization of scintillating resins with high spatial resolution, reduced waste, and rapid prototyping capability [1,2]. The ability to directly print complex and application-specific geometries makes 3D printing especially appealing for next-generation radiation detectors. In the present work, DLP-based 3D printing is employed to fabricate plastic scintillators with tailored resin formulations, and their scintillation performance is systematically investigated. The effect of primary fluor concentration and different photo-curable co-monomers on optical, timing, and pulse shape discrimination (PSD) properties was systematically investigated. The printed scintillators exhibited fast decay times down to 1.5 ns, outperforming the commercial standard EJ-200 [3]. A relative light output of up to ~70% of EJ-200 was achieved for samples containing high PPO concentrations, and they demonstrated good linearity for γ-rays from 60 keV to 1 MeV. Neutron-gamma discrimination was demonstrated using a ^{252}Cf source and DT5751 desktop digitizer, with a maximum PSD figure of merit of 1.55, attributed to enhanced triplet–triplet annihilation at high dopant loadings. The issue of dye leaching, commonly encountered at high PPO loading, was addressed. The influence of print parameters such as individual layer thickness and surface finishing on light output was examined, revealing that thicker printed layers reduce internal scattering losses. Long-term stability tests showed less than 5% degradation in light output over a six-month period, due to the use of suitable cross-linkers and oxygen-rich compounds. These results establish DLP-printed plastic scintillators as promising candidates for fast timing, neutron detection, and custom-geometry radiation detectors.

[1] D. G. Kim, et al., Nuclear Engineering and Technology **52** 2910 (2020).
[2] Y. Kim, et al., NIMA **1055** 168537 (2023).
[3] http://eljentechnology.com/