Nanostructured multiphase polymeric scintillators for fast γ/neutron discrimination

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Pulse shape discrimination (PSD) is a key technique for separating fast neutrons from γ-rays. Traditional PSD materials include liquid scintillators, which offer high light yield (LY) and excellent discrimination but are challenging to handle, and plastic scintillators, which are safe and robust but generally exhibit lower LY and slower PSD.[1] Nanostructured plastic scintillators, embedding liquid nanodroplets within a polymer matrix, aim to combine the advantages of both approaches. In the first-generation version of our nanostructured scintillator, DPA was employed as the sole emitter at a low concentration (0.5 wt%), resulting in a limited LY of ~900 ph/MeV.[2]

The low LY originates from the small fraction of active scintillating material and from energy losses during charge conversion and transfer processes within the droplets. To improve light output, PPO was introduced as a primary dye in the droplets, enabling more efficient energy capture and transfer to DPA as a secondary emitter. This approach results in a threefold increase in LY, demonstrating the beneficial role of introducing PPO within the nanodroplets in enhancing energy capture and conversion. However, PPO also alters the temporal emission dynamics of the system. In particular, the prompt emission of DPA occurs on a timescale comparable to the fastest PPO triplet–triplet annihilation (TTA) processes, which are further enhanced by nanoconfinement. This leads to a partial temporal overlap between prompt and delayed emission components, reducing the waveform contrast that underpins PSD and revealing an intrinsic limitation of the PPO–DPA combination.

Building on this insight, we replaced DPA with a faster-emitting molecule, POPOP. Preliminary results indicate that this choice could effectively mitigate the temporal bottleneck. The faster emission kinetics are expected to allow light production to be completed before PPO TTA contributions become significant, thereby preserving fast PSD while further increasing LY. These findings highlight that molecular engineering of the droplet composition enables independent control over light yield and emission timing, providing a promising pathway toward safe, solid-state scintillators optimized for high-rates (up to 1 MHz) neutron detection and advanced radiation monitoring.

1. Bertrand, G. H. V., Hamel, M., Normand, S., & Sguerra, F., "Pulse shape discrimination between (fast or thermal) neutrons and gamma rays with plastic scintillators: State of the art", *Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment,* **776**, pp. 114–128 (2015).

2. Hu, X., Rigamonti, D., Villa, I., Pollice, L., Mauri, M., Tardocchi, M., Meinardi, F., Weder, C., Monguzzi, A, "Sensitized triplet-triplet annihilation in nanostructured polymeric scintillators allows for pulse shape discrimination", *Advanced Materials*, **36**, 2400443 (2024)