Breaking the Concentration-Self-Absorption Trade-Off in Perovskite Nanoscintillators

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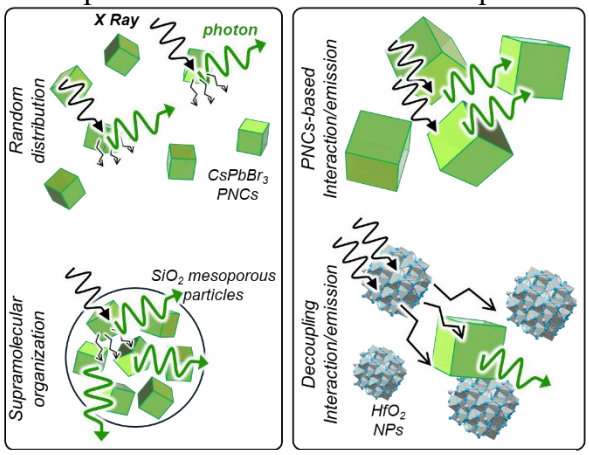
Polymer-based scintillating nanocomposites embedding lead halide perovskite nanocrystals (PNCs) represent a promising materials platform for radiation detection, combining the scalability of plastics with the exceptional optical properties of inorganic emitters. Among them, $CsPbBr_3$ PNCs are particularly attractive due to their high effective atomic number, high radioluminescence efficiency, and ultrafast recombination dynamics driven by multiexciton formation under ionizing excitation[1]. However, these systems are currently limited by a fundamental trade-off: increasing PNCs loading enhances radiation interaction but induces strong self-absorption and scattering losses, suppressing ultrafast emission, whereas lowering the PNCs concentration preserves fast kinetics at the expense of interaction efficiency[2]. To overcome this bottleneck, two complementary strategies have been developed.

The first relies on controlling PNCs spatial organization to improve secondary electron collection[3] using supra-particle architectures based on mesoporous SiO_2 nanoparticles densely loaded with $CsPbBr_3$ PNCs which enabled high local emitter density while maintaining a low average NCs concentration. These systems exhibited scintillation performances several times higher (up to ~4–5×) than unstructured PNCs dispersions at comparable overall loading, while strongly suppressing self-absorption.



Strategies for overcoming self-reabsorption in PNCs-based scintillators

The second strategy exploits functional decoupling of interaction with ionizing radiation and light emission by delegating the first one to optically inactive high-Z materials[4]. Hybrid system combining $CsPbBr_3$ PNCs with heavy, high-bandgap HfO_2, nanoparticles allows the total effective Z of the system to be preserved while reducing the PNCs fraction. At constant overall Z, these hybrids display scintillation intensities more than 200% higher than nanocomposites based solely on more concentrated PNCs, while fully retaining their ultrafast emission characteristics.

1. Anand A., *et al,* Advances in perovskite nanocrystals and nanocomposites for scintillation applications, *ACS Energy Letters* **2024** *9* (3), 1261-1287
2. Li X., *et al*, Are Inorganic Lead Halide Perovskite Nanocrystals Promising Scintillators?, *ACS Energy Letters* **2023** *8* (7), 2996-3004
3. X. Zhou X., *et al*, Harnessing Self-Sensitized Scintillation by Supramolecular Engineering of $CsPbBr_3$ Nanocrystals in Dense Mesoporous Template Nanospheres, *Adv. Mater.* 38, 4 (**2026**): e13469.
4. Bruni F., *et al*, Synergistic Compatibilization of $CsPbBr_3$ Perovskites and HfO_2 Nanocrystals for Hybrid Sensitized Nanoscintillators, *Adv. Funct. Mater.* (**2025**): e20228.