Stokes Shift-Engineering Strategies Toward Reabsorption-Free Nanoscintillators

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Nanomaterial-based scintillators have recently emerged as promising candidates for next-generation radiation detection, enabled by material design flexibility, scalable chemical synthesis, high emission yield, ultrafast decay, access to high effective atomic number (Z), defect tolerance, and radiation hardness [1][2]. However, practical deployment typically requires high nanomaterial loadings to reach sufficient stopping power and detection efficiency, where reabsorption becomes a dominant loss channel that suppresses light yield [3][4]. Here, this contradiction is addressed by developing reabsorption-suppressed (ideally "reabsorption-free") nanoscintillator concepts, and three Stokes-shift engineering strategies are reported:

(1) Sensitized nanocomposites: Nanocrystals/conjugated-polymer hybrid composites are employed, in which high-Z sensitization, optical sensitization via energy transfer, and plasmonic enhancement are utilized, thereby enabling boosted scintillation efficiency, ultrafast decay kinetics, and suppressed self-absorption (Nanocrystals /conjugated-polymer hybrids).

(2) Dopant-activated emission channel: Introduce a dopant-mediated radiative channel that produces red-shifted emission (effective large Stokes shift) to suppress reabsorption in dense quantum dot (QD) media (Au:CdSe, Ag:CdS QDs).

(3) Quasi type-II band engineering: Engineer quasi type-II band alignment to spatially separate carriers and red-shift emission, thereby reducing absorption-emission overlap and reabsorption losses (CdSe/CdS dot-in-rods).

Together, these results establish transferable design rules to enable high-loading nanoscintillators with strongly suppressed reabsorption for macroscopic radiation detectors.

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