

Energy Transfer and Luminescence Regulation Enabling Enhanced Scintillation Efficiency for High-Resolution X-Ray Imaging in Mn²⁺/Eu²⁺-Doped Cs₃Cu₂I₅ Single Crystals

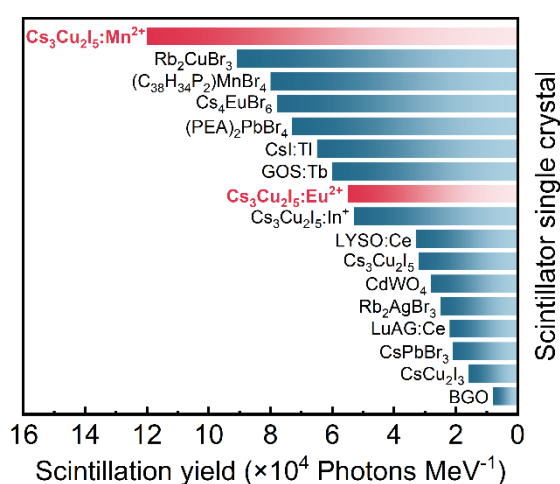
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Copper-based low-dimensional halides have attracted extensive attention due to their high ionization radiation luminescence efficiency resulting from strong quantum confinement effects. The zero-dimensional Cs₃Cs₂I₅ crystal exhibits excellent air and luminescence stability, low afterglow, and a high light yield under X-ray irradiation, rendering it highly promising for X-ray imaging applications. However, non-radiative recombination arising from exciton–exciton interactions remains a key factor limiting the crystal’s performance. Introducing luminescent ions provides an effective strategy to engineer additional radiative recombination channels in Cs₃Cu₂I₅ crystals, leading to enhanced carrier utilization. The introduction of Eu²⁺ establishes efficient Eu-centered radiative recombination pathways and Eu²⁺/Eu³⁺ charge-transfer processes under ionizing irradiation, effectively suppressing non-radiative energy loss and enabling a light yield of 55,000 photons MeV⁻¹ with a spatial resolution of 23 lp mm⁻¹ under X-ray excitation. Importantly, efficient exciton utilization was achieved in Cs₃Cu₂I₅ single crystals by introducing Mn²⁺ to establish dual energy-transfer pathways. The energy transfer from STEs to Mn²⁺ enhances the efficient Mn²⁺-centered emission, while energy migration between adjacent Mn²⁺ modulates the emission dynamics, achieving an excellent light yield of 120,000 photons MeV⁻¹ under X-ray irradiation. Based on excellent luminescence performance, the Cs₃Cu₂I₅:Mn single crystals achieve a superior spatial resolution of 30 lp mm⁻¹ and a low detection threshold of 91 nGy s⁻¹ while maintaining a high detective quantum efficiency. Our work clarifies the exciton-dopant interactions in luminescent ion-activated Cs₃Cu₂I₅ scintillators and provides guidance for designing efficient materials for X-ray imaging.



The light yield of different scintillator single crystals under X-ray irradiation.

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