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News & Views

All-inorganic perovskite nanocrystal materials: new generation of scintillators for high quality X-ray imaging

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Scintillating materials, which can convert high energy X-ray radiation into visible luminescence [1], are crucial parts of X-ray imaging technology. Since the discovery of X-ray in 1895, scintillating materials have witnessed wild applications in various fields, including security inspection, space exploration, non-destructive detection, and medical diagnostics [2,3]. Conventional scintillators are generally large inorganic crystals and can only be grown at high temperature, which significantly increases the manufacturing difficulty and cost. The luminescence of current crystal scintillators is usually limited by low-efficiency or afterglow effects, and is difficult to be tuned cross the visible spectrum. As traditional scintillators have reached their performance limits, exploration of new scintillators has become a crucial topic considering the increased demands of X-ray imaging and detection technology [4–6].

To solve the limitations of conventional scintillator materials, Liu and co-workers [7] have recently reported a revolutionary discovery of novel scintillators based on all-inorganic $CsPbX_3$ (X = Cl, Br or I) perovskite nanocrystals, with the ability of converting small dose of X-ray radiation into intensive and multi-color visible luminescence (Fig. 1). Their discovery might open up new opportunities for advancing the X-ray imaging technology.

A series of cubic $CsPbX_3$ perovskite nanocrystals ($CsPbX_3$ PNCs) were prepared through a hot-injection method, which could exhibit color-tunable X-ray-excited luminescence by tailoring the halogen components, providing opportunities for multi-color X-ray visualization. The luminescence intensity of $CsPbBr_3$ PNCs is comparable to high-efficiency $CsI:Tl^+$ crystal scintillators and surpasses most of conventional bulky scintillators. Such intensive luminescence ability can be attributed to the quantum confinement effects [8], which increase the recombination rate of charge carriers and create discrete emission energy levels. The strong radiation stopping power of heavy Pb-atom as well as highly emissive triplet excited states also contribute to the high efficiency emission.

Besides the advantages of intensive and color-tunable luminescence, $CsPbBr_3$ PNCs are also featured with other excellent scintillating properties to deliver rapid, ultrasensitive and low-radiation-risk X-ray imaging technology. The scintillator film based on $CsPbBr_3$ PNCs exhibits lowest detectable dose rate of 13 nGy s^{-1}, which is more than 400 times lower than typical doses for X-ray diagnostics. The scintillator film also has a fast response time of 44.6 ns without afterglow effect, providing great opportunities for real-time X-ray imaging. The fast response and low detectable dose limit are also crucial to reduce the irradiation exposure in medical radiography. Additionally, the scintillator film allows convenient record of X-ray images using common digital cameras, offering promising chances for electronic inspection and biologic imaging. The flat-panel X-ray detector based on $CsPbBr_3$ PNCs is able to image internal structures of electronic circuit boards and smart phones with good spatial resolution. Thus, the breakthrough of Liu and co-workers surely provided a new generation of scintillator material which could light the way to high-resolution, low-cost and ultrasensitive X-ray imaging technology.

Since the revolutionary discovery of novel nanocrystal scintillators by Liu and co-workers, advances of $CsPbBr_3$ PNCs based scintillators have been made in the last year. Im and co-workers [9] developed a $CsPbBr_3$ PNCs based X-ray detector with high-performance scintillating abilities. Zhang et al. [10] reported the scintillating properties of easily accessible $CsPbBr_3$ nanosheets colloidal and solid film scintillators. The self-assembly of $CsPbBr_3$ nanosheets can offer convenient access to high-quality and large-area $CsPbBr_3$ solid film with intensive radioluminescence, fast response time, long-term radiostablity and good spatial resolution, providing potential approach to high quality and low-cost X-ray radiography.

Overall, all-inorganic $CsPbX_3$ nanocrystals have been demonstrated as potential candidates of scintillating materials for excellent X-ray scintillation and radiophotography with fast scintillation response, low detection limit, efficient multicolor radioluminescence and convenient solution-processability. Further developments of these promising nano-scintillator materials are also expected to be achieved in efficient and low-cost X-ray imaging areas.

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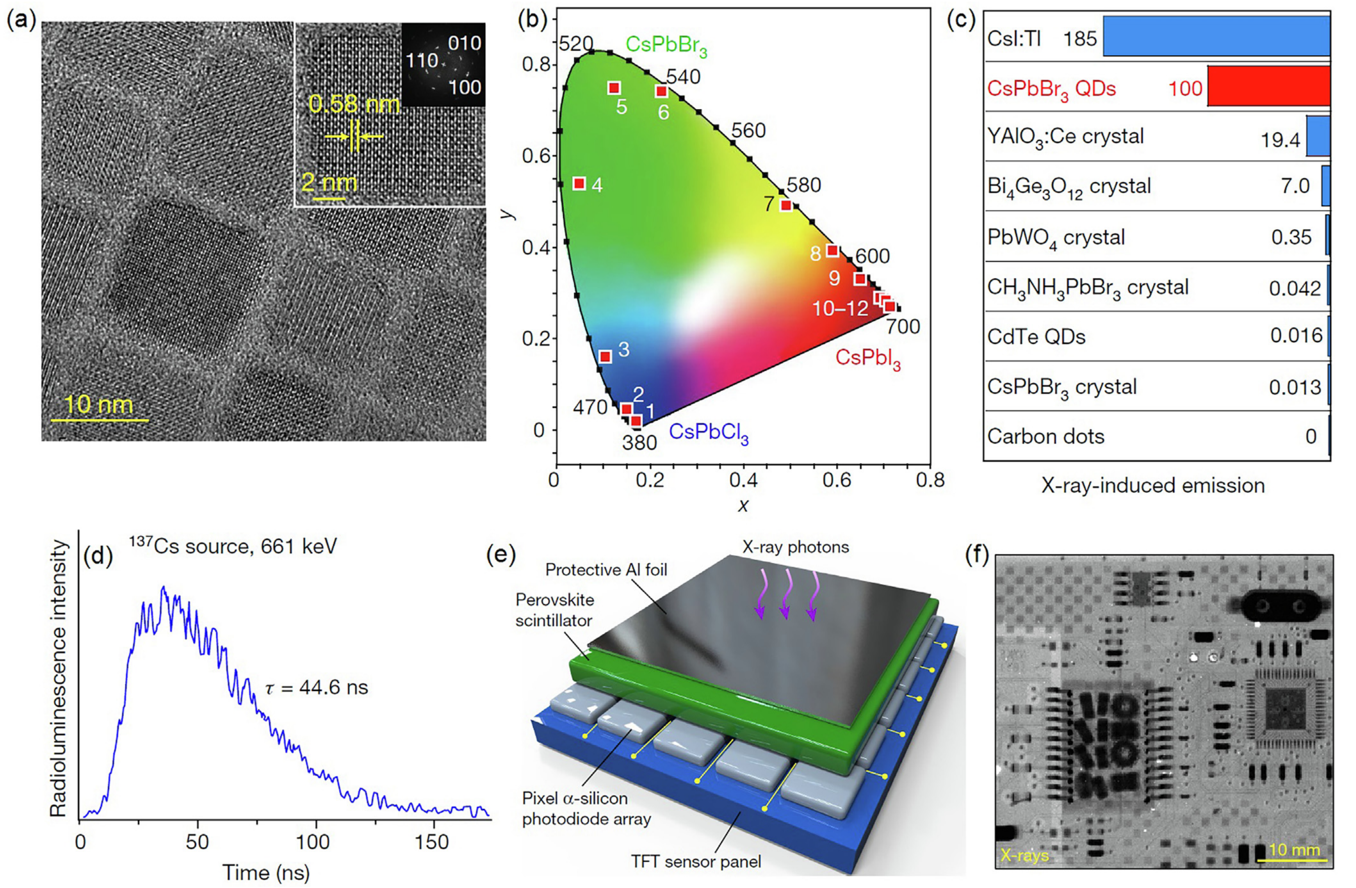

Fig. 1. Scintillation performance of $CsPbBr_3$ PNCs scintillators. (a) Low-resolution TEM image of $CsPbBr_3$ nanocrystals with the inset high-resolution TEM image of a single $CsPbBr_3$ nanocrystal. (b) $CsPbX_3$ (X = Cl, Br, I) nanocrystals with tunable emission wavelength. (c) Comparison of scintillation ability of different scintillator materials. (d) Measured radioluminescence decay of $CsPbBr_3$ scintillator excited by 661 keV photons from ^{137}Cs source. (e) Design of X-ray panels with perovskite nanocrystal film. (f) X-ray images of α-Si photodiode panel acquired with the $CsPbBr_3$ nanocrystal scintillators. Reprinted with permission from Ref. [7]. Copyright 2018 Nature/Springer/Palgrave.

Conflict of interest

The authors declare that they have no conflict of interest.

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