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Advances in halide perovskite semiconductors for energy-integrated and energy-resolved X-ray detection

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Interaction of X-rays and γ-rays with matter

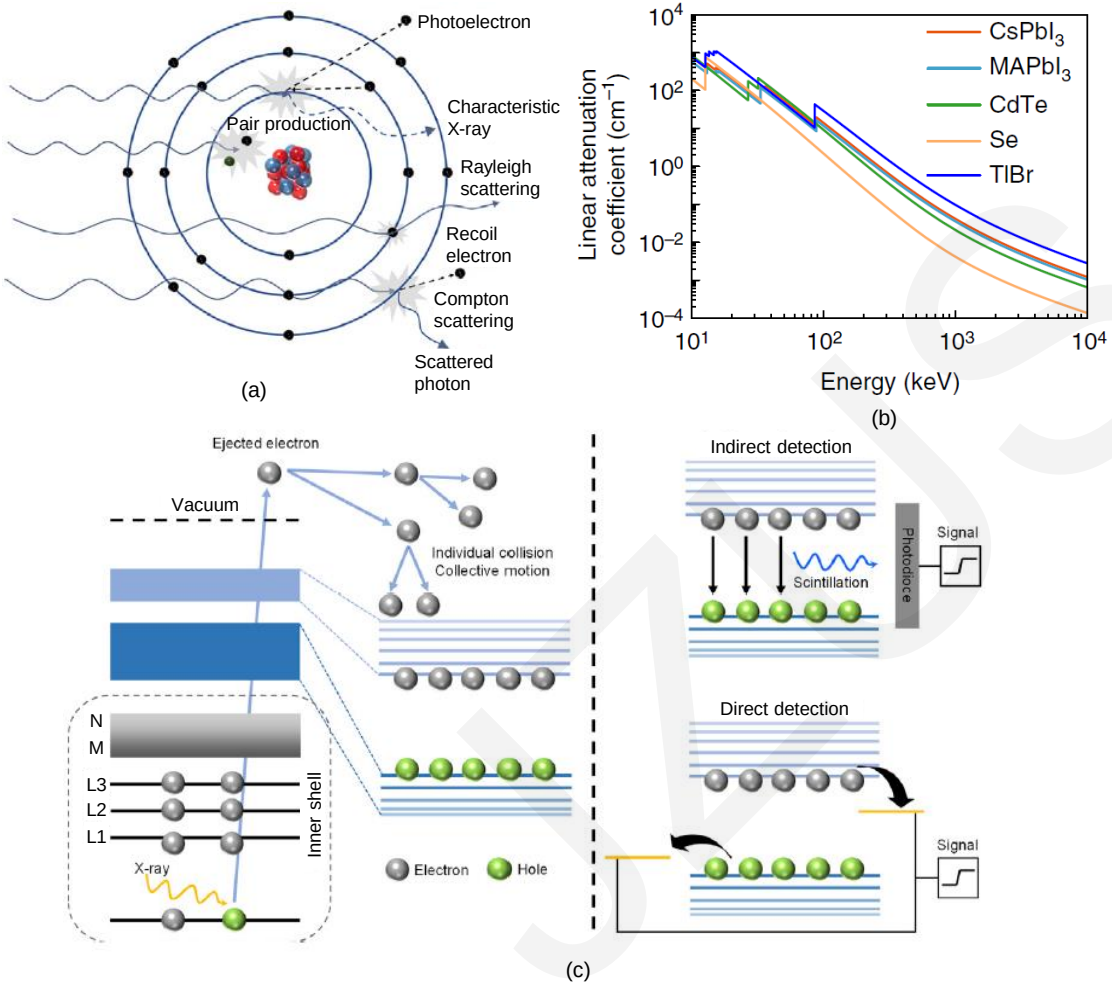

Fig. 1 (a) Processes by which X-ray (γ-ray) photons interact with matter: photoelectric absorption, Rayleigh scattering, Compton scattering, and pair production; (b) Linear attenuation coefficient for various materials; (c) Mechanism of electron-hole generation in semiconductors under X-rays (γ-rays) and the mechanisms of indirect and direct detections.

Wu, H. et al, *Matter* **4**, 144-163, (2021).
Wei, H. & Huang, J. Nature Communications 10, 1066, (2019).

Direct detection of X-rays and γ-rays

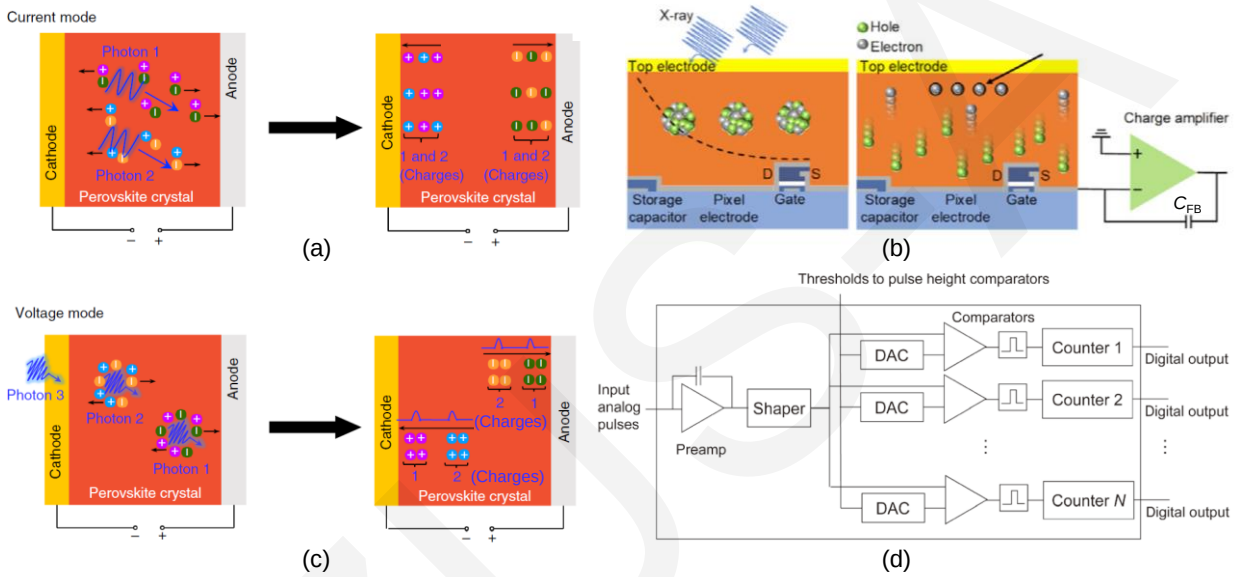

Fig. 2 (a) Mechanism by which energy integrating detectors (EIDs) work in the current mode; (b) Device configuration of EIDs; (c) Mechanism by which photon counting detectors (PCDs) work in voltage mode; (d) Schematic diagram of the application-specific integrated circuit (ASIC) .

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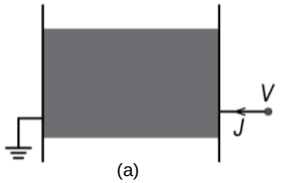
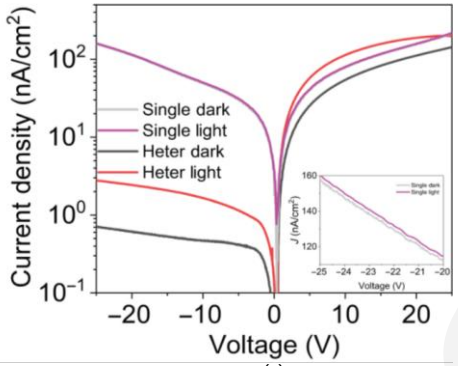
Development of perovskite EIDs

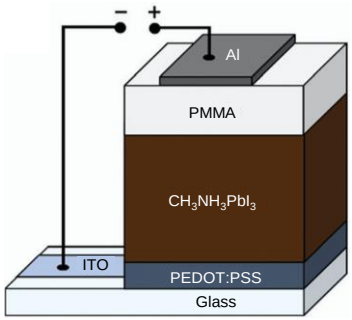


(a)

(b)



(c)



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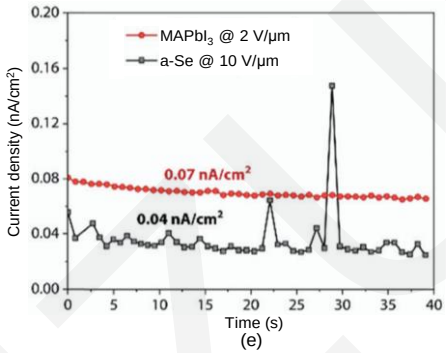
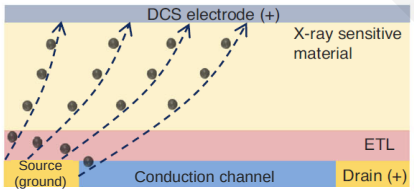
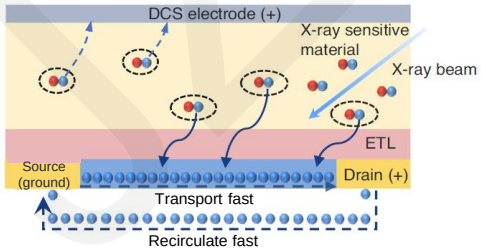


(e)



DCS detector under dark
(f)



DCS detector under X-ray
(g)

Fig. 3 (a) Schematic of a single junction device; (b) Schematic of heterojunction device; (c) Device performance of single junction and heterojunction device; (d) Schematic diagram of the PMMA inserted EIDs; (e) Dark current density of $MAPbI_3$ EIDs and a-Se EIDs; (f) Working mechanism of dark-current-shunting (DCS) detector under dark (g) Working mechanism of DCS detector under X-ray.

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Development of perovskite PCDs

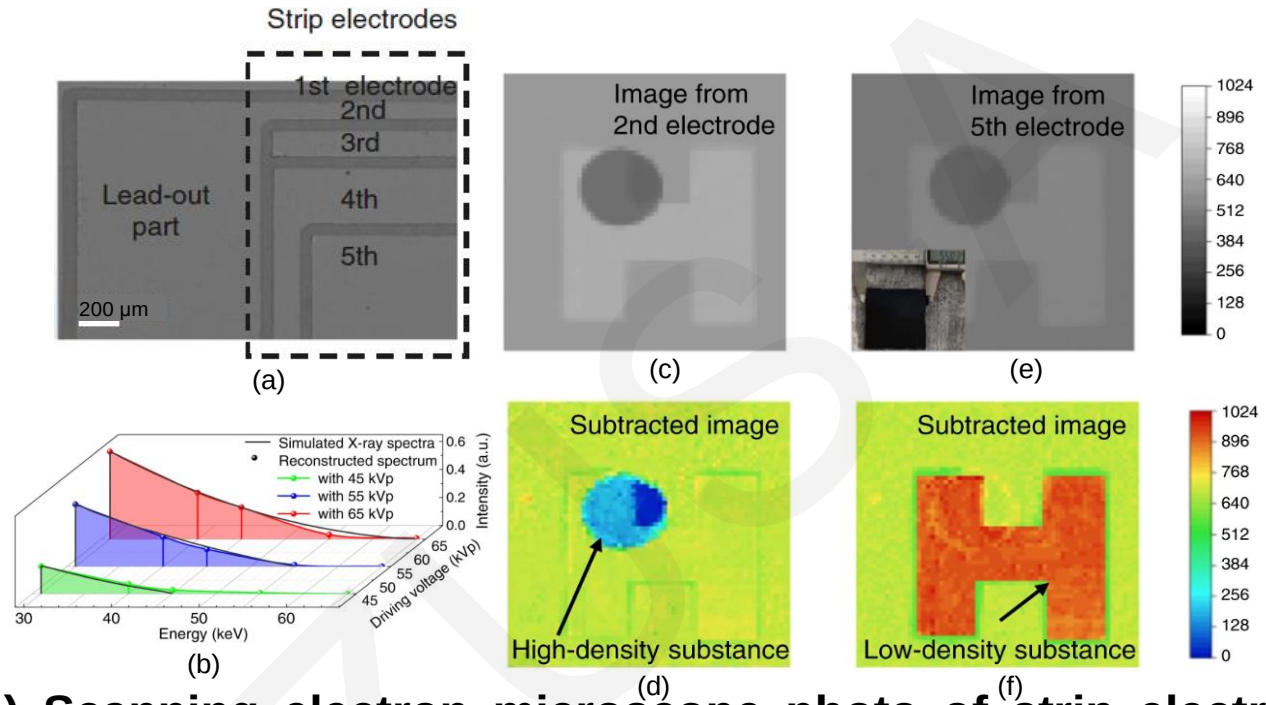

Fig. 4 (a) Scanning electron microscope photo of strip electrodes; (b) Simulated X-ray spectra and reconstructed spectrum when the driving voltages of the X-ray tube were 45, 55, and 65 kVp; (c) Image of the artificial sample from the 2nd electrode; (d) Subtracted image of a high-density substance $CaCO_3$ tablet; (e) Image of the artificial sample from the 5th electrode; (f) Subtracted image of a low-density substance paraffin 'H' letter.

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Development of perovskite PCDs

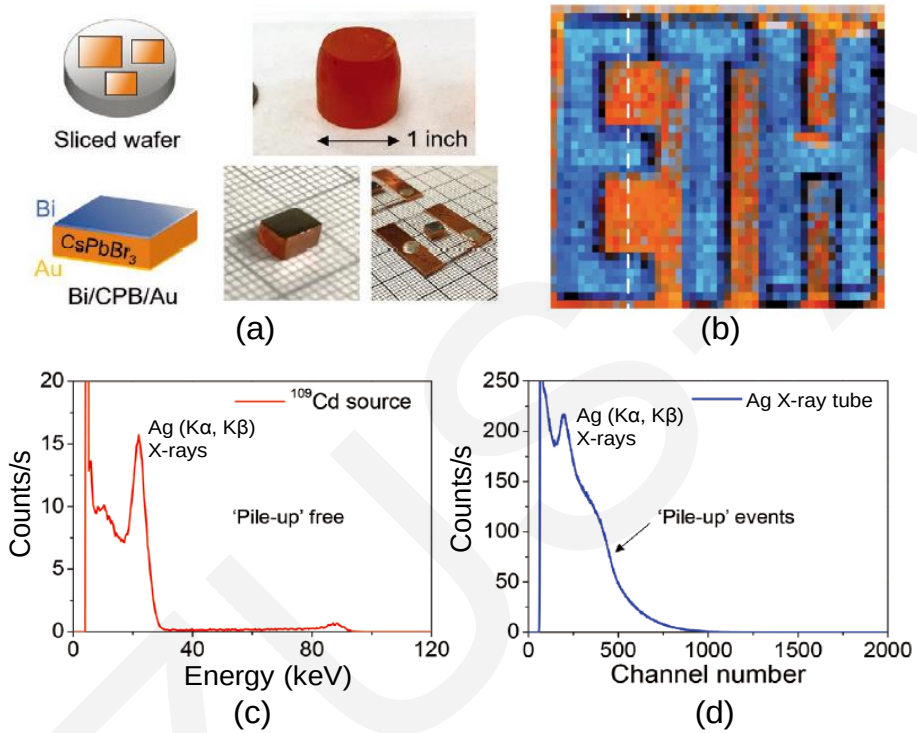

Fig. 5 (a) Wafer grown from Bridgman method and device configuration of $CsPbBr_3$; (b) Energy-resolved image of the characters 'ETH'; (c) Spectrum of the ^{109}Cd source measured by the $CsPbBr_3$ detector; (d) Spectrum of the Ag X-ray tube measured by the $CsPbBr_3$ detector. 。

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