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Direct detection of 5 MeV protons by mixed 3D-2D Perovskite Flexible Films

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The development of detectors for protons and heavy particles is a long-lasting research topic not only for fundamental applications, but more recently, in the medical field for hadron therapy of cancer. In this application, ion beams are used for the controlled treatment of cancer by focusing them onto small volumes, to avoid the spreading of the radiation to healthy tissues. For this reason, there is an increasing demand of systems optimized for the accurate in-situ, real-time recording and mapping of the dose delivered during a treatment plan.
Metal halide perovskites are rapidly emerging as active materials in lowcost high performing ionizing radiation detectors thanks to strong absorption of ionizing radiation, high charge carrier mobilities, long exciton diffusion, long charge carrier lifetime, and excellent optical properties. [1] Further, they combine the high performance of traditional inorganic semiconductors with the lowcost, large area scalable, deposition methods (i.e., printing technologies) typical of organic semiconductors. However, the direct proton beam detection or dose-monitoring by perovskite based devices has not been explored yet and only one paper has been published so far on direct proton detection, implemented by fully organic flexible devices.[2]
In this work, we propose a novel flexible proton detector based on mixed 3D and 2D perovskites films deposited from solution. Mixed 3D-2D perovskites are formed by mixing 3D (based on methylammonium (MA) cations) and 2D (based on larger organic ammonium (OA) cations) structure perovskites. Their employment has been reported as an effective strategy to retain the exceptional transport properties of 3D perovskites and the high stability induced by the layered structure of 2D perovskites. By adding the 3D phase (MAPbBr3) we here aim to enhance the radiation absorption of protons by the perovskite film, thanks to the higher density of MAPbBr3 and to the higher thickness of the active layer for mixed compounds.
The here proposed devices demonstrate an accurate monitoring of proton dose with instant feedback and low limit of detection, and provide a stable response even after hard and long-lasting proton irradiation.
In fact, the detector exhibited a stable response to repetitive irradiation cycles with sensitivity up to (290 ± 40) nC Gy-1mm-3 and a radiation tolerance is also assessed up to a total of 1.7 × 1012 protons impinging on the beam spot area, with a maximum variation of the detector's response of 14%.
The presented results provide an effective solution to the challenge of identifying novel functional materials and portable devices for real-time accurate monitoring of proton dose, addressing the quest for radiation hardness, low-cost scalability over large areas and mechanical flexibility, still unsolved for a range of application which span from personal dosimetry to large area and lightweight detectors for large accelerators facilities and space missions.
[1] Wei and Huang, Nat Commun 10, 1066 (2019)
[2] Fratelli et al., Sci. Adv. 2021; 7 : eabf4462

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