Improvement of the sensitivity of Perovskite based photodetector fabricated with n-type conjugated polymers for indirect X-ray detection

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The organic-inorganic hybrid perovskite have various advantages, such as outstanding electronic properties, tunable bandgap, wide-range optical absorption, high ambipolar carrier transport properties, long carrier diffusion length, trivial exciton binding energy, and low-temperature processability and flexibility. However, a major challenge associated with organic-inorganic hybrid perovskite is their sensitivity to moisture and heat, mainly due to the presence of volatile organic compounds. There are various strategies to overcome moisture problem such as interface treatment, additive, antisolvent, dopant, etc. Among them, we demonstrate an interface engineering by blending non-fullerene polymers to transport layer.
In this paper, an organic-inorganic hybrid perovskite photodetector with binary-ETL was investigated as a candidate for the indirect-type X-ray detector. The active layer composed with $MAPbI_3$ and the non-fullerene Y_6 as the first acceptor (A1) and $PC_{71}BM$ as the second acceptor (A2). The incorporation of $PC_{71}BM:Y_6$ at the heterojunction interface facilitates electron extraction, leading to efficient separation and transport of photoexcited electron-hole pairs. Furthermore, The hydrogen bonds between $MAPbI_3$ and Y_6 passivate the defect on the surface of the perovskite, reducing the roughness and thickness of the ETL while maintaining good film morphology. Moreover, optimizing the spin coating process for $PC_{71}BM:Y_6$ binary-ETL results in enhanced crystalline and structural homogeneity, characterized by larger grain size and higher coverage. Consequently, this optimization enhances electron extraction ability and suppresses charge recombination loss, significantly enhancing the performance of the $PC_{71}BM:Y_6$ binary photodetector . Figure 1. shows a energy band diagram of the proposed indirect X-ray detector with $PC_{71}BM:Y_6$ ETL. Experiments to extract the current density-voltage (J-V) characteritics were performed by different blending ratios of $PC_{71}BM:Y_6$(100:0, 75:25, 50:50, 25:75). As depicted in Figure 2, to collect the charge generated during X-ray exposure, a −0.6 V bias was applied between the cathode and anode of the detector and it was irradiated for 1.57s. The radiation parameters during X-ray exposure, such as collected charge density (CCD) and sensitivity of the detector coupled with the CsI(TI) scintillator, were calculated based on the number of collected charges and absorbed dose.Up to now, the highest CCD of 20.87 $\mu A/cm^2$ and sensitivity of 6.24 $mA/Gy\cdot cm^2$ were obtained at the condition of $PC_{71}BM$:Y6 = 75:25 in Figure 3. The CCD and sensitivity tend to increase as the content of Y6 in the acceptor increases, and tend to decrease above 50:50 content.
Our results suggest that the use of binary-ETL represents a promising approach for enhancing the properties of the detector and have important applications in a wide range of fields, including electronics, optoelectronics. The synergy at the material interface not only optimizes the electronic characteristics of detector but also mitigates inherent vulnerabilities such as sensitivity to environmental factors.

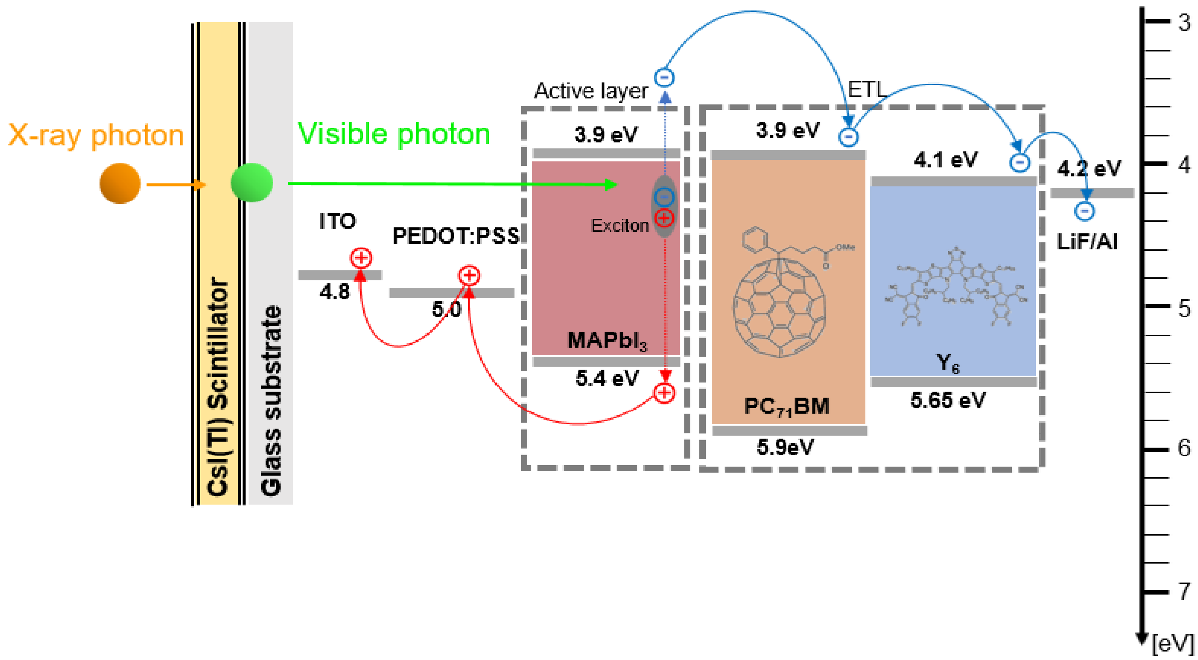

Figure 1. $PC_{71}BM:Y_6$ X-ray detector energy band diagram

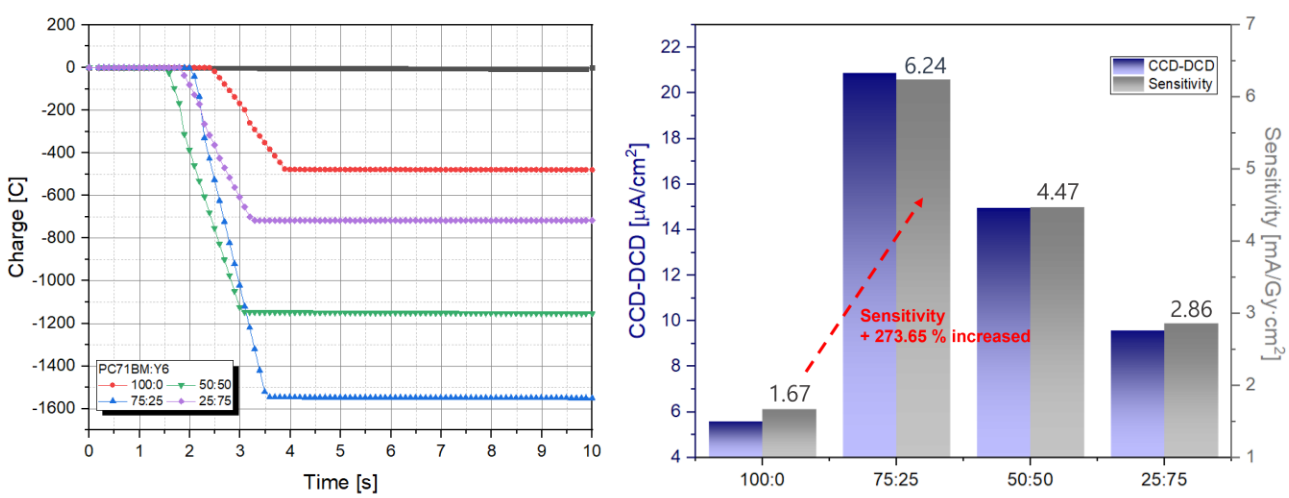

Figure 2. (a) Charge-time plot and (b) Radiation parameters (CCD − DCD and sensitivity) of the X-ray detectors based on the $PC_{71}BM:Y_6$ ETL with addition of various amounts of $MAPbI_3$

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