Improved performance of single crystal-based X-ray detector via 2D layer formation

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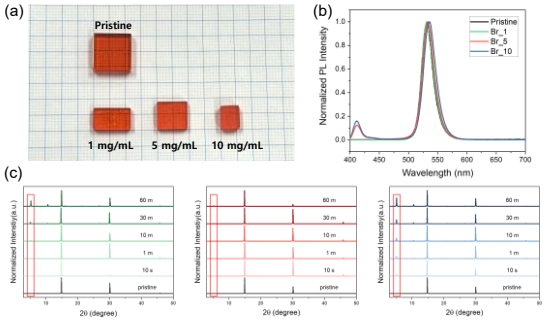
Methylammonium lead tribromide (MPB, $MAPbBr_3$) single crystals are representative halide perovskites that possess excellent charge transport properties and have recently attracted significant attention as key materials for radiation detection and optoelectronic device research. Due to the high mobility–lifetime product and long carrier diffusion length, efficient charge collection is possible even under low bias conditions. In addition, low-temperature growth and low-cost processing make MPB single crystals suitable candidates for next-generation semiconductor detectors.[1] However, for radiation detector device applications, surface defects remain a critical issue, which leads to current instability and reduced sensitivity caused by ion migration.

In this study, MPB single crystals were grown, surface-treated using a two-dimensional (2D) organic–inorganic layer via a dipping process and then characterized by X-ray diffraction (XRD) to confirm their crystallinity. XRD patterns of MPB single crystals with different 2D treatment times are presented. The (100), (200), and (300) diffraction peaks are preserved for all samples, confirming that the fundamental 3D perovskite crystal structure is maintained. A new diffraction peak appears at around 5–6°(marked by red boxes), which means to diffraction from the 2D layer. As the treatment time increases, the intensity of the 2D-related peak gradually increases.



(a) Photographs of 2D-treated MPB single crystals. (b) Normalized steady-state photoluminescence (PL) spectra and (c) X-ray diffraction (XRD) patterns of pristine and Br-based 2D-treated MPB single crystals with concentrations of 1, 5, and 10 mg/mL.

Optical analysis – steady-state photoluminescence (PL) – measurements after 2D dipping treatment revealed changes in the normalized PL spectra, with distinct spectral behaviors depending on the halide composition of the introduced 2D layer, indicating modified surface-related optical responses. Based on this established mechanism, the introduction of a 2D organic–inorganic layer through surface treatment is expected to be an effective strategy for improving charge collection efficiency and mitigating ion-migration-related effects in MPB single-crystal detector applications.[2] Future work will include X-ray photoelectron spectroscopy (XPS) analysis to investigate surface chemical states related to the 2D layer treatment and the observed optical property changes.

1. Wei, Haotong, and Jinsong Huang. "Halide lead perovskites for ionizing radiation detection." *Nature communications* 10.1 (2019): 1066.
2. Ko, Juyoung, et al. "High-performance 110 kVp hard x-ray detector based on all-crystalline-surface passivated perovskite single crystals." *InfoMat* 6.8 (2024): e12560.

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