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Defining New Limits in Hybrid Perovskites: Single-Crystal Solar Cells with Exceptional Electron Diffusion Length Reaching Half Millimeters

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Abstract : Exploiting the potential of perovskite single-crystal solar cells in optoelectronic applications necessitates overcoming a significant challenge: the low charge collection efficiency at increased thickness, which has restricted their deployment in radiation detectors and nuclear batteries. Our research details a promising approach to this problem, wherein we have successfully fabricated single-crystal MAPbI3 solar cells employing a space-limited inverse temperature crystallization (ITC) methodology. Remarkably, these cells, up to 400-fold thicker than current-generation perovskite polycrystalline films, maintain a high charge collection efficiency even without external bias. The crux of this achievement lies in the long electron diffusion length within these cells, estimated to be around 0.45 mm. This extended diffusion length ensures the conservation of high charge collection and power conversion efficiencies, even as the thickness of the cells increases. Fabricated cells at 110, 214, and 290 µm thickness manifested power conversion efficiencies (PCEs) of 20.0, 18.4, and 14.7% respectively. The single crystals demonstrated nearly optimal charge collection, even when their thickness exceeded 200 µm. Devices of thickness 108, 214, and 290 µm maintained 98.6, 94.3, and 80.4% of charge collection efficiency relative to their maximum theoretical short-circuit current value, respectively. Additionally, we have proposed an innovative, self-consistent technique for ascertaining the electron-diffusion length in perovskite single crystals under operational conditions. The computed electron-diffusion length approximated 446 µm, significantly surpassing previously reported values for this material. In conclusion, our findings underscore the feasibility of fabricating halide perovskite single-crystal solar cells of hundreds of micrometers in thickness while preserving high charge extraction efficiency and PCE. This advancement paves the way for developing perovskite-based optoelectronics necessitating thicker active layers, such as X-ray detectors and nuclear batteries.

Keywords : perovskite, solar cell, single crystal, diffusion length
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