Strain-Induced Effects in Perovskite Thin Films due to Orbit-Like Thermal Cycling

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Abstract:

Perovskite solar cells hold significant promise as a power source in space due to their exceptional properties. Their high absorbance in the visible spectrum allows the active layer thickness to be reduced to just a few hundred nanometers. Combined with efficiencies comparable to state-of-the-art silicon devices, this results in an outstanding power-to-weight ratio. Additionally, their solution processability reduces both launch and manufacturing costs, making them a cost-effective alternative to current multi-junction gallium arsenide cells. Besides, first tests have already proved that perovskite devices can be operated in space [1].
However, several challenges must be addressed to make perovskite solar cells viable in harsh space conditions, including high vacuum, extreme temperatures, and radiation. Our study focuses on the extreme temperature fluctuations experienced in low Earth orbit, between the illuminated and eclipse phases, and their impact on the solar cell performance. Operando grazing-incidence wide-angle X-ray scattering (GIWAXS) provides insights into the crystal structure of perovskite active layers while the solar cell is simultaneously illuminated and subjected to temperature changes. Synchrotron radiation sources, with their high X-ray intensities, offer the time resolution needed for these studies. The experiments aim to understand the complex system of the full solar cell assembly, consisting of multiple layers and interfaces with varying thicknesses, elastic moduli, and thermal expansion coefficients. Photoluminescence (PL) measurements further reveal information about the solar cells' electrical and optical properties. This comprehensive investigation of the mechanical, optical, and electrical behavior under temperature fluctuations from -125°C to +100°C enables a deeper understanding of device interactions. This insight is crucial for optimizing the solar cells for space environments. The results show significant changes in nearly all properties of the perovskite, including crystal phase and anisotropic strain. As the lattice structure evolves, the optoelectronic properties also change markedly, as observed in the PL measurements. Based on these findings, our research aims to enhance the durability and performance of perovskite solar cells in space, ultimately advancing their viability for space applications.

Conflicts of Interest

The authors declare no conflicts of interest.

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