Radiation Resistance of Organic and Perovskite Solar Cells for Space Applications

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Abstract:
We report a comparative study of the radiation tolerance of organic and quasi-2D perovskite solar cells (PSCs) under particle irradiation conditions relevant to space environments.
For organic solar cells (OSCs), short-pulsed (150 ns) 140 keV proton irradiation was applied to devices based on donor–acceptor systems with different bandgaps (Eg) ranging from 1.17 to 1.65 eV to assess the influence of E_g on radiation stability. Power conversion efficiency, open-circuit voltage, short-circuit current, and fill factor were measured before and after irradiation, complemented by spectroscopic and morphological analyses. The results reveal a clear E_g-dependent degradation trend and provide guidelines for designing OSCs with improved resilience to high-dose proton exposure.
Quasi-2D PSCs based on $GA(MA)_5Pb_5I_{16}$ with different electron transport layers (ETLs) were tested for UV stability, electron irradiation, and proton irradiation. Under continuous UV illumination at 310 and 350 nm, SnO_2-based devices maintained performance with minimal photodegradation, while TiO_2-based counterparts showed much faster bleach amplitude decay. Under 30 keV electron irradiation up to $1\cdot10^{15}$ e/cm^2, SnO_2-based devices retained a higher fraction of their initial PCE, indicating better resistance to electron-induced damage. Under low-energy pulsed (150 ns) 170 keV proton irradiation with fluences up to $1\cdot10^{13}$ p/cm^2, simulating ~30 years in low Earth orbit, quasi-2D PSCs showed moderate degradation (8% at $2\cdot10^{12}$ p/cm^2 and 43% at $1\cdot10^{13}$ p/cm^2) and ~10% higher stability than previously studied 3D triple-cation devices. The enhanced resilience is attributed to suppressed non-radiative recombination and optimized device architecture.
These findings deepen the understanding of degradation mechanisms in OSCs and PSCs under space-relevant radiation and support the development of material and structural strategies for next-generation radiation-hard photovoltaics.

Conflicts of Interest
The authors declare no conflict of interest.

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