Effect of dopant in hole transport materials on the stability and recoverability of perovskite solar cells on very thin substrates after 7 MeV proton irradiation

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Introduction

The emergence of "commercial" space activities has been driven by a dramatic reduction in launch cost and manufacturing cost of space hardware. New space solar cell technologies that are low cost are important as costs of current solar cell technology are prohibitive for such "commercial" space activities. Organometal halide perovskite solar cells (PSCs) are promising due to their high efficiencies especially when implemented in multi-junction tandems, low manufacturing cost for space applications and radiation hardness [1]. To fully take advantage of their high power to weight ratios, PSCs must be fabricated on thin substrates. Proton radiation tests on such PSCs have not been previously reported [1]. Herein, we report results of proton irradiations on PSCs with high power to weight ratios on thin 175-μm sapphire substrates and compare their radiation hardness when different types of hole transport materials (HTM's) are used. For the radiation tests, protons at 7 MeV are chosen for sufficient substrate penetration and accumulated fluences at 1011, 1012, and 1013 protons/cm2 were irradiated to emulate conditions experienced on low earth orbit (LEO). While all cells retained more than 90% of their initial PCE's after radiation with accumulated fluences of 1011 protons/cm2, certain type of HTM in PSCs result in better radiation stablity to higher fluence levels. Reasons for more severe proton-induced-damage in the latter will be presented in the conference. This is the first report of defect analysis on proton-irradiated-perovskite cells using thermal admittance spectroscopy (TAS) and deep-level transient spectroscopy (DLTS). Interestingly, proton-induced-degradation in power conversion efficiency is irreversible by thermal vacuum anneal confirmed by TAS and DLTS. Recovery is particularly strong (100%) in PSCs with more proton-radiation tolerant HTM's. This work provides insights into the development low-cost light-weight PSCs for space application.

Result

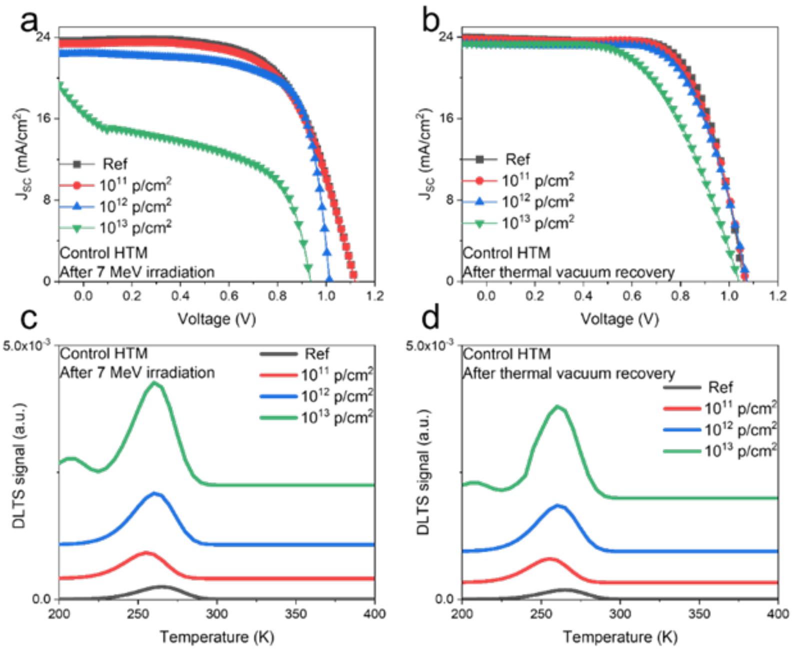

Figure 1. (a, b) Current-density voltage characteristic and (c, d) Deep-level transient spectroscopy (DLTS) spectra of perovskite solar cells with control HTM after (a, c) 7 MeV proton irradiation and (b,d) after additional thermal vacuum recovery.

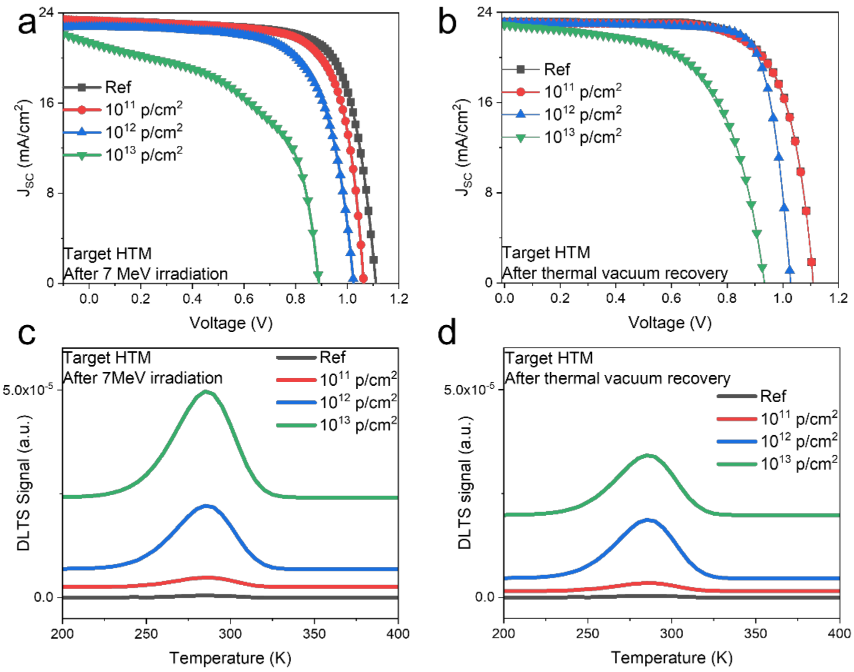

Figure 2. (a, b) Current-density voltage characteristic and (c, d) DLTS spectra of perovskite solar cells with target hole transport layer after (a, c) 7 MeV proton irradiation and after (b,d) additional thermal vacuum recovery.

References

1. Ho-Baillie, A. W. Y.; Sullivan, H. G. J.; Bannerman, T. A.; Talathi, H. P.; Bing, J.; Tang, S.; Xu, A.; Bhattacharyya, D.; Cairns, I. H.; McKenzie, D. R., Deployment Opportunities for Space Photovoltaics and the Prospects for Perovskite Solar Cells. *Advanced Materials Technologies* **2022,** *7* (3), 2101059.