Understanding and Mitigating Atomic Oxygen-Induced Degradation of Perovskite Solar Cells for Near-Earth Space Applications

Biruk Alebachew Seid[1], Sema Sarisozen[1], Francisco Peña-Camargo[1], Sercan Ozen[1], Emilio Gutierrez-Partida[1], Eduardo Solano[2], Julian A. Steele[2, 3], Martin Stolterfoht[1], Dieter Neher[1], Felix Lang[1, *]

[1]Institute of Physics and Astronomy, University of Potsdam, D-14476 Potsdam-Golm, Germany

[2]NCD-SWEET Beamline, ALBA Synchrotron Light Source, Cerdanyola del Vallès, Barcelona, Spain

[3]Australian Institute for Bioengineering and Nanotechnology, The University of Queensland, Brisbane, QLD, Australia

Email address:

seid@uni-potsdam.de (Biruk Alebachew Seid), felix.lang.1@uni-potsdam.de (Felix Lang), sema.sarisoezen@uni-potsdam.de (Sema Sarisoezen), carlos.francisco.pena.camargo@uni-potsdam.de (Francisco Peña-Camargo), sercan.oezen@uni-potsdam.de (Sercan Ozen), emiliogp93@gmail.com (Emilio Gutierrez-Partida), esolano@cells.es (Eduardo Solano), julian.steele@uq.edu.au (Julian A. Steele), stolterf@uni-potsdam.de (Martin Stolterfoht), neher@uni-potsdam.de (Dieter Neher)

[*]Corresponding author

Abstract

Metal halide perovskites have aroused burgeoning interest in the field of space photovoltaics owing to their versatile optoelectronic properties, high specific power potential, and extraordinary radiation tolerance. Despite the encouraging breakthroughs and extraordinary potential, the practical application of PSCs still faces the bottleneck due to different extreme conditions in space. For instance, atomic oxygen (AtOx) in low-Earth orbit is known to etch, corrode, and form metal oxide on the metal contact with PSC devices. To mitigate this issue, we report the applicability of thermally evaporated 0.7 µm silicon oxide (SiOx) encapsulation as an AtOx barrier for triple cation PSC. Moreover, the AtOx-induced degradation mechanism of phenethylammonium iodide (PEAI)-passivated and non-passivated devices are discussed and analyzed. We found that after a total exposure duration of 120 minutes, the SiOx-encapsulated cells maintained over 97% of their initial power conversion efficiency (PCE), regardless of the device type (passivated or non-passivated). In contrast, in the case of unencapsulated devices, PCEs for non-passivated and PEAI-passivated devices the PCE declined to a maximum value of 43% and 62%, respectively. In non-passivated and unencapsulated devices, AtOx has no impact on the short-circuit current density (J_{SC}) but degrades the fill factor (FF) and open circuit voltage (V_{OC}). In PEAI-passivated devices, the J_{SC} additionally degrades by almost 35%. Injection-current-dependent electroluminescence (EL) and intensity-dependent photoluminescence quantum yield (IPLQY) measurements ruled out the perovskite as the origin of PCE degradation. Instead, inefficient charge extraction and mobile ions, due to a swiftly degrading PEAI interlayer, are the primary causes of AtOx-induced device performance degradation in passivated devices, whereas a large ionic FF loss limits non-passivated devices with no change in transit time.

Keywords

2D Passivation, Atomic Oxygen, Degradation, Encapsulation, Perovskite Solar Cells