Sustainable Planar HTM-Free Carbon Electrode-Based Perovskite Solar Cells: Stability Beyond Two Years

Woraprom Passatorntaschakorn[1], Warunee Khampa[2], Wongsathon Musikpan[2], Atcharawon Gardchareon[1], Pipat Ruankham[1, 3, 4], Duangmanee Wongratanaphisan[1, 3, 4, *]

[1]Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand

[2]Materials Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand

[3]Thailand Center of Excellence in Physics (ThEP Center), Ministry of Higher Education, Science, Research and Innovation, Bangkok, Thailand

[4]Research Unit for Development and Utilization of Electron Linear Accelerator and Ultrafast Infrared/Terahertz Laser, Chiang Mai University, Chiang Mai, Thailand

Email address:

woraprom.pa@gmail.com (Woraprom Passatorntaschakorn), warunee_kha@cmu.ac.th (Warunee Khampa), wongsathon_musik@cmu.ac.th (Wongsathon Musikpan), atcharawon.g@cmu.ac.th (Atcharawon Gardchareon), pipat.r@cmu.ac.th (Pipat Ruankham), duangmanee.wong@cmu.ac.th (Duangmanee Wongratanaphisan)

[*]Corresponding author

Abstract

Swift advancement in perovskite solar cell (PSCs) efficiency poses a challenge in maintaining a balance among sustainability, efficiency, and cost for competitive commercialization. Ongoing research is dedicated to effectively addressing these challenges. Traditional PSCs rely on expensive and unstable hole-transporting materials (HTMs) and noble metal electrodes, leading to poor device stability. To overcome these challenges, this study introduces unencapsulated planar HTM-free carbon electrode-based PSCs (C-PSCs) created through an entirely low-temperature process (< 160 ℃) in ambient atmospheric conditions. The approach emphasizes simplicity and cost-effectiveness, incorporating a single electron transporting layer and a one-step perovskite layer ($Cs_{0.17}FA_{0.83}Pb(I_{0.83}Br_{0.17})_3$) fabrication. Carbon films, prepared using an ethanol solvent interlacing method and heat-press transfer, serve as both hole transport layers (HTL) and electrodes. This simplified architecture leverages the properties of carbon materials, achieving the highest power conversion efficiency (PCE) of 11.09% and exceptional shelf-life stability exceeding 2 years (~20,000 hours) without encapsulation. Remarkably, thermal and humidity stability tests under accelerated aging conditions (85% relative humidity, 85 ℃) demonstrated an average 90% efficiency drop after 100 hours. Furthermore, the scalability of the technique is demonstrated in 1.00 cm^2 planar HTM-free C-PSCs on recycled FTO/TiO_2-NPs substrates, exhibiting remarkable performance under both 1 sun and LED illuminations. This approach lowers production costs, making PSCs more renewable and sustainable, paving the way for cost-effective and eco-friendly commercialized PSCs.

Keywords

Carbon Electrode, HTM-free, Low-temperature, Perovskite Solar Cells, Stability, Sustainability