13

Layered Ruddlesden Popper Perovskites with Various Thicknesses for Stable Solid-State Solar Cells

© *A.M. Bakhshayesh* [1], *H. Abdizadeh* [1,2,¶], *M. Mirhosseini* [3], *N. Taghavinia* [3]

[1] School of Metallurgy and Materials Engineering, College of Engineering, University of Tehran,
P.O. Box 14395-515, Tehran, Iran
[2] Center of Excellence for High Performance Materials, University of Tehran,
P.O. Box 14395-515, Tehran, Iran
[3] Department of Physics, Sharif University of Technology,
P.O. Box 11155-9161, Tehran, Iran
¶ E-mail: abdizade@ut.ac.ir

Received: November 1, 2019
Revised: November 5, 2019
Accepted: November 8, 2019

The present research comes up with optimizing the layers thickness of a Ruddlesden–Popper perovskite with the general formula of $(S_{0.97}S'_{0.03})_2[Cs_{0.05}(FA_{0.097}MA_{0.03})_{0.95}]_{n-1}Pb_n(I_{0.97}Br_{0.03})_{3n+1}$ for efficient, stable solar cell applications. Such a triple-cation quasi-two-dimensional (2D) structure simultaneously contains two spacers, namely 5-ammonium valeric acid iodide (S) and tetra-*n*-octylammonium bromide (S'). Systematic studies showed that morphology, crystal structure, optical properties, photovoltaic performance, and internal resistances of this compound depended upon the value of the *n* integer. Field emission scanning electron microscopy set forth that the deposited films were composed of various morphologies depending on the *n* value. An increase in the *n* value resulted in improving the light absorption, reducing the band gap energy, and blue-shifting the photoluminescence peak. So as to fabricate solar cells, $CuInS_2$ nanoparticles were employed as a novel hole-transporting material. The device based on the film having $n = 4$ value showed the highest power conversion efficiency of 10.2%. Electrochemical impedance spectroscopy demonstrated that the improved performance of this cell was mainly thanks to its low series resistance (11.68 Ω), high charge recombination resistance (922.35 Ω), and long electron lifetime (8.05 μs) as compared to all the fabricated cells. Moreover, this cell displayed a maximum external quantum efficiency of 82% among all the devices. The un-encapsulated solar cells showed that the output reduction directly depended on the n value so that the cell based on the $n = 4$ reached 82% of its initial power over 2500 h in ambient conditions.

Keywords: ruddlesden Popper structure, 2D triple-cation perovskite, solar cells, tetra-*n*-octylammonium bromide.