Revealing the low efficiency of tin perovskite solar cells with metal oxide/tin perovskite interface

Ajay Kumar Baranwal,[1]* Shrikant Saini,[2] Tomohide Yabuki,[2] Qing Shen,[3] Koji Miyazaki,[2] Shuzi Hayase[1]

[1] *i-PERC, The University of Electro-Communications, Tokyo, Japan*
[2] *Department of Mechanical Engineering, Kyushu Institute of Technology, Kitakyushu, Fukuoka, Japan*
[3] *Faculty of Informatics and Engineering, The University of Electro-Communications, Tokyo, Japan.*
E-mail: ajaybaranwal@uec.ac.jp

Better optoelectronic properties of Lead-free tin halide perovskite (THP) have shown a ray of hope to compete for toxic lead halide perovskite solar cells. Inorganic metal oxide medium is generally used to assist the perovskite crystal growth and easy charge collection in n-i-p structure solar cells. However, such lead-free THP coated on metal oxide layer generally show poor diode rectification behavior leading to poor solar cell efficiency. We have already reported, carrier density/electrical conductivity was enhanced when THP $CsSnI_3$ was coated on metal oxide Y_2O_3.[1] The reason behind such enhanced carrier concentration was found to be formed Sn(II) vacancies or Sn(IV). This phenomenon of Sn(IV) formation with metal oxide Y_2O_3 is similar to poor rectification behaviour observed in n-i-p solar cells. This finding motivated us to check various metal oxides underneath layers with THP $CsSnI_3$ as atop layer. Interestingly, electrical conductivity values were varied (Table 1). It can be estimated that underneath metal oxide layer can lead to easy Sn(II) to Sn(IV) oxidation. However, reason behind such Sn(II) to Sn(IV) oxidation which can lead to poor rectification behaviour is not yet clear.

Table 1. Electrical conductivity performance of various nanocomposite

	Electrical conductivity/ Scm^{-1}
$CsSnI_3$ film	96±16.52
$CsSnI_3/Al_2O_3$ film	33.66±14.15
$CsSnI_3/SnO_2$ film	192.33±4.04
$CsSnI_3/TiO_2$ film	110.33±9.02
$CsSnI_3$/NiOx film	170±9.01
$CsSnI_3$/ZnO film	49±8.18
$CsSnI_3/ZrO_2$ film	274±21.60

In this work, we study the reason behind such Sn(IV) formation in metal oxide/tin perovskite interface, which significantly raises the carrier concentration and results in poor rectification characteristics. Such Sn(IV) formation has been validated using X-ray photoelectron spectroscopy, Photo yield spectroscopy, and Ultraviolet photoelectron spectroscopy measurements. However, complementarily, Sn(IV) formation in THP films may help to harvest waste heat. Therefore, in this work, we also study the thermoelectric performance of THP films. The further details would be discussed at the conference.

References:

[1] Ajay K. Baranwal, S. Saini, Z. Wang, D. Hirotani, T. Yabuki, S. Iikubo, K. Miyazaki, S. Hayase, Organic Electronics, 76, 105488, 2020