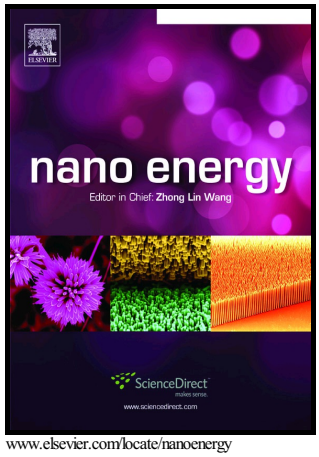

www.elsevier.com/locate/nanoenergy

Band bending near grain boundaries of $Cu_2ZnSn(S,Se)_4$ thin films and its effect on photovoltaic performance

Yaping Ma, Wenjie Li, Ye Feng, Zhaohui Li, Xuhang Ma, Xiaoru Liu, Xuefeng Wu, Yi Zhang, Chunlei Yang, Xinhui Lu, Kedong Wang, Xudong Xiao

PII: S2211-2855(18)30425-7
DOI: https://doi.org/10.1016/j.nanoen.2018.06.032
Reference: NANOEN2813

To appear in: *Nano Energy*

Received date: 11 April 2018
Revised date: 8 June 2018
Accepted date: 8 June 2018

Cite this article as: Yaping Ma, Wenjie Li, Ye Feng, Zhaohui Li, Xuhang Ma, Xiaoru Liu, Xuefeng Wu, Yi Zhang, Chunlei Yang, Xinhui Lu, Kedong Wang and Xudong Xiao, Band bending near grain boundaries of $Cu_2ZnSn(S,Se)_4$ thin films and its effect on photovoltaic performance, *Nano Energy,* https://doi.org/10.1016/j.nanoen.2018.06.032

Band bending near grain boundaries of $Cu_2ZnSn(S,Se)_4$ thin films and its effect on photovoltaic performance

Yaping Ma[a], Wenjie Li[b], Ye Feng[b], Zhaohui Li[b], Xuhang Ma[c], Xiaoru Liu[d], Xuefeng Wu[c], Yi Zhang[d], Chunlei Yang[b], Xinhui Lu[a], Kedong Wang[c*], Xudong Xiao[a*]

[a]Department of Physics, The Chinese University of Hong Kong, New Territories, Hong Kong
[b]Centre for Photovoltaic Solar Cells, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen, China
[c]Department of Physics, Southern University of Science and Technology, Shenzhen, China
[d]Institute of Photoelectronic Thin Film Devices and Technology, Nankai University, Tianjin, China

xdxiao@phy
cuhk.edu.hk
wangkd@sustc.edu.cn

Abstract

Although the family of polycrystalline $Cu_2ZnSn(S,Se)_4$ (CZTSSe) thin films are well-known light absorber materials for photovoltaic solar cells and have been studied extensively in the past, the behaviors of their grain boundary (GB) still remain elusive. By using a combination of experimental techniques, we have systematically investigated the compositions and electronic structures of the grain interior (GI) and GB of the polycrystalline CZTS, CZTSe and CZTSSe films at nanometer scales. In particular, we have for the first time independently determined the band edge positions for both the conduction band and the valence band using scanning tunneling spectroscopy. While the composition of GB was nearly the same as that of GI for both CZTS and CZTSe films, opposite band bending behaviors near GBs were discovered for them. For CZTS, both the conduction band and valence band were found to bend