Oral presentations for Session 3.2.8 | Thursday, 27 October | Room 3812 / 3813

Session Chair:
Edgardo SAUCEDO (Catalonia Institute For Energy Research (IREC), Spain)

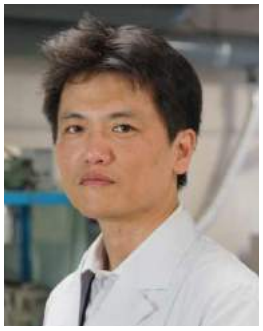
3.2.8a Invited Talk (16:00 – 16:15)
Prof Jinhyeok Kim
Chonnam National University, South Korea

Transparent Conductive Characteristics of Mg and Ga Doped ZnO (MGZO) Thin Film For CZTS Solar Cell With Zn(O,S) Buffer Layer

J. KIM[1]
[1] Chonnam National University, South Korea

Abstract
The fabrication of high-efficiency CZTS thin film solar cell (TFSC) with a structure of Al/MGZO/ ZnO/Zn(O, S)/CZTS/Mo have been demonstrated for the first time. Specifically, n-type Mg and Ga doped ZnO (MGZO) thin films with wide band gap energy (3.8 eV) and low electrical resistivity (3.1×10-4 Ωcm) as an alternative TCO were prepared using sputtering method. The influence of different preparative parameters on the properties of MGZO thin films have been investigated. Further, a comparative study on the electrical properties between Al-doped ZnO (AZO) and MGZO window layer deposited on CZTS TFSCs was performed. The preliminary efficiency of 7.4 % with a Jsc of 14.9 mA/cm2 Voc of 376.9 mV, and a FF of 47 % have been obtained for Al/MGZO/Zn(O,S)/CZTS solar cell, although the processing parameters are not yet optimized. The efficiency can be further improved by optimizing the process parameters and controlling the conduction band alignment.

Biography
Ph. D. material engineering, Korea Advanced Institute of Science and Technology
Post-Doc. UC Santa Babara
Post-Doc. ISIR-Sanken, Osaka university professor Chonnam National University, Korea



3.2.8b (16:15 – 16:30)
Assoc Prof. Yosuke Shimamune
National Institute of Technology (Nagaoka College), Japan

CZTS Formation by Continuous Processing of Coevaporation Followed by Sulfurization Using MBE

Y. SHIMAMUNE[1], K. JIMBO[1], G. NISHIDA[1] et al.
[1] National Institute of Technology (Nagaoka College), Japan

Abstract
CZTS is one of the most promising materials for the next generation photovoltaic material because it is earth abundant and non-toxic. In this report, CZTS formation by continuous processing coevaporation followed by sulfurization within conventional MBE system is investigated to form high quality CZTS. After coevaporation of Cu, Zn, Sn and S on the Mo coated soda lime glass substrate at 320 degree C, the substrate is annealed at 320-450 degree C with sulfur evaporation, then cooled down below 150 degree C. XRD, Raman and AFM analysis showed that sulfurization above 400 degree C contributes to form CZTS films without increasing surface roughness. At 450 degree C, CuxS formation is found to be enhanced. These results suggest that the CZTS formation process of coevaporation followed by sulfurization using MBE system can be a promising process for high quality CZTS formation at temperature of 400-450 degree C.

Biography
April 12, 1974 born in Nanaoka, Niigata March 2002 Ph.D. of Electronic Engineering in Tohoku University April 2002 Joined Fujitsu Limited April 2015 Joined National Institute of Technology, Nagaoka College

Oral presentations for Session 3.2.8 | Thursday, 27 October | Room 3812 / 3813

3.2.8c (16:30 – 16:45)
Dr Kong Fai Tai
Nanyang Technological University, Singapore

Fill Factor Losses in High Performance Cu2ZnSn(SxSe1-x)4 Solar Cells

O. GUNAWAN[1], K. F. TAI[2], S. CHEN[2]
[1] IBM T J Watson Research Center, United States
[2] Nanyang Technological University, Singapore

Abstract
Fill factor (FF) is the second most significant parameter deficit for Cu2ZnSn(SxSe1-x)4 (CZTSSe) solar cell. Various pathways for FF loss were investigated and high series resistance was found to be a major contributing factors. We perform electrical and physical characterizations of the full-range of bandgap (Eg = 1.0- 1.5 eV) CZTSSe devices, as well as bare- and exfoliated-films with various S/(S+Se) ratios. High intensity Suns-VOC measurement indicates a non-ohmic junction developing in S-rich CZTSSe. Physical characterizations indicate the formation of Sn(S,Se)2, Mo(S,Se)2 and Zn(S,Se) at the high S-rich CZTSSe/Mo interface, contributing to the increased series resistance (RS) and non-ohmic back contact characteristics.

3.2.8d (16:45 – 17:00)
Dr Hitoshi Tampo
National Institute of Advanced Industrial Science and Technology, Japan

Efficiency Improvement of Cu2ZnSnSe4 Solar Cell with 10.7% by Na Incorporation

H. TAMPO[1]
[1] National Institute of Advanced Industrial Science and Technology, Japan

Abstract
Conversion efficiency of Cu2ZnSnSe4 (CZTSe) solar cells was improved by Na corporation, and the Na effects were investigated. CZTSe thin films were grown by coevaporation method. Change of carrier concentration and suppression of non-radiative recombination were observed with Na incorporation, and it was concluded that the Na incorporation affected both shallow and deep energy levels in CZTSe. The non-radiative recombination center was evaluated by time resolved photoluminescence measurements, and the minority carrier lifetime monotonically increased from 2 to 15 nm with increasing Na incorporation. The drastic morphological change with Na incorporation, larger grain size and flatter surface of CZTSe, was also observed, which imply grain growth mode with a liquid phase by Na related compounds. These Na effect led to efficiency improvement of CZTSe cells, which is mainly due to improvement of short circuit current density and fill factor; conversion efficiency of 10.7% was obtained with Na incorporation.

Biography
2002 - 2010: research on ZnO-related materials and devices (epitaxial thin film)
2011 - present: research on kesterite materials and solar cells

Oral presentations for Session 3.2.8 | Thursday, 27 October | Room 3812 / 3813

3.2.8e (17:00 – 17:15)
Mr Ying Fan Tay
Nanyang Technological University, Singapore

Solution Processed AgxCu1-xZnSnS4 with Efficiency >6.5%

Y. F. TAY[1], A. GUCHHAIT[1], Z. SU[1] et al.
[1] Nanyang Technological University, Singapore

Abstract
Copper Zinc Tin Sulphide (CZTS) cells suffer from low efficiencies compared to their Copper Indium Gallium Selenide (CIGSe) counterparts with the peak efficiency of CZTS solar cells remaining at 12.7% since 2014 as compared to CIGSe of 22.3%. These low efficiencies are due to the low open circuit voltage (Voc) of CZTS cells where only about 60% of its theoretical Voc is achieved. This Voc deficit is determined to be caused by bulk defects and band tailing, with Cu/Zn antisite defect being the most prevalent of all due to the similarity in charge and sizes of the two cations. In this study, we have fabricated a solution processed (AgxCu1-x)2ZnSnS4 for the first time and have demonstrated that with the incorporation of the larger cation Ag+, the Voc deficit is reduced and the efficiency of CZTS can be improved from 5.48% to 6.57% at an optimal ratio of Ag.

Biography
He is currently a postgraduate student studying PhD in Materials Science and Engineering at Nanyang Technological University and has achieved his Bachelors in Materials Science and Engineering with Second Upper Honors in Nanyang Technological University. His research interests include: photoelectrodes for water splitting and copper chalcogenide solar cells.

3.2.8f (17:15 – 17:30)
Mr Wei-Chih Huang
National Tsing Hua University, Taiwan

Ag-alloyed (Ag, Cu)2ZnSn(S, Se)4 Kesterite Solar Cells Fabricated by Spray Pyrolysis

W. HUANG[1], S. WEI[1], X. ZENG[1], et al.
[1] National Tsing Hua University, Taiwan

Abstract
(Ag, Cu)2ZnSn(S, Se)4 kesterite solid solution thin film solar cells were fabricated by environmental friendly chemical spray pyrolysis of aqueous solution followed by selenization. For kesterite with high Ag content, aggregation of grain and formation of second phases occurred at elevated temperature, but can be solved when being annealed at relatively low temperature. Enhancement of grain size at lower process temperature is fulfilled by Ag incorporation. With 20% Ag addition, efficiency of the kesterite increased from 5.3% to 6.8% with the improvement of VOC from 388 mV to 444 mV. Bandgap of ACZTSSe can be controlled from 1.06 to 1.2 eV with Ag content varied from 0~50% and the tailing energy was reduced by Ag alloying.

Biography
I am a Ph.D. candidate at Department of Materials Science and Engineering, National Tsing Hua University. My research involves CZTSSe and Ag-alloyed kesterite solar cells fabricated through spray pyrolysis, and scanning probe mocroscopy for the chalcogenide solar cells.

Oral presentations for Session 3.2.8 | Thursday, 27 October | Room 3812 / 3813

3.2.8g (17:30 – 17:45)
Mr Chung-Hao Cai
National Tsing Hua University, Taiwan

The effect of Sulfurization Time on Cu2ZnSn(S,Se)4 Solar Cells Fabricated by Sulfurization After Selenization of Precursors

C. CAI[1]
[1] National Tsing Hua University, Taiwan

Abstract
It well-known that Cu(In,Ga)(S,Se)2 (CIGSSe) solar cells fabricated by sulfurization after selenization (SAS) of metallic precursor can reach the efficiency of 22.3%. SAS is widened-used in CIGS-based solar cells. However, the annealing process of kesterite Cu2ZnSn(S,Se)4 (CZTSSe) is still based on selenization. The study of SAS process on CZTSSe solar cells is few so far. In this work, we fabricated the CZTSSe solar cells by using SAS process of sputtered precursors. The effects of sulfurization time (second step) on composition, morphology, electrical property of CZTSSe solar cells are investigated. S/(S+Se) ratio can be controlled simply by tuning the sulfurization time. Longer sulfurization time also promotes the grain growth of CZTSSe absorber. The CZTSSe solar cell efficiency of 7.8% can be achieved by this method.

Biography
Chung-Hao Cai received his M.S. degree from Department of Materials Science and Engineering, National Tsing Hua University, Taiwan in 2014. Now he is a Ph.D. candidate at Department of Materials Science and Engineering, National Tsing Hua University.

3.2.8h (17:45 – 18:00)
Dr Marc D. Heinemann
PVcomB - Helmholtz Zentrum Berlin, Germany

Evolution Of Optical And Structural Properties during Cu(In,Ga)Se2 Thin Film Growth

M. D. HEINEMANN[1], R. MAINZ[2], D. GREINER[1]
[1] PVcomB - Helmholtz Zentrum Berlin, Germany
[2] Helmholtz Zentrum Berlin, Germany

Abstract
We present an optical technique, based on White Light Reflectometry, which is capable of providing in-situ data about deposition rate, roughness, band gap, presence of secondary phases as well as Urbach energy of CIGS thin films during three-stage co-evaporation. Additionally we used real-time energy dispersive X-ray diffraction and fluorescence to correlate the obtained optical properties to the structural properties of the growing film. The work gives new insight into the film formation during the co-evaporation of CIGS thin films, as for the first time it is shown how the band gap energy, Urbach energy and roughness develops during the process. The analysis opens new easy-access pathways for process and quality control of the CIGS deposition process. For example the course of surface roughness during the deposition can be correlated with the crystalline phases in the film and the Urbach Energy can be correlated with the chemical composition of the film.

Biography
Following the master thesis about photo-physics of nanoparticle/polymer hybrid blends, Marc D. Heinemann started his research on solar cells in 2009 at the Solar Energy Research Institute of Singapore. In 2011 he switched to the Helmholtz Zentrum Berlin to do his PhD on CIGS superstrate solar cells and since 2015 he is post-doc at the PVcomB leading a project on high mobility TCOs for CIGS solar cells.