Research Center for Photovoltaics

Comparison study of wide bandgap CIGS prepared from Cu-rich and Cu-poor metal precursor

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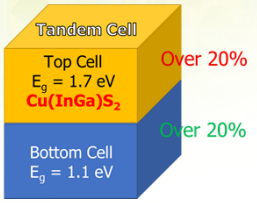
Introduction

Wide bandgap chalcopyrite thin-film solar cell for tandem solar cell application

For the high efficient solar cell beyond 30%!!



Pure sulfide chalcopyrite, wide bandgap $Cu(InGa)S_2$ (CIGS) has been reported to be a promising absorber material for the top cell application. Recently, solar cell prepared using CIGS absorber has reached a conversion efficiency of 16.9% [1].

Comparison study of CIGS prepared using Cu-rich and Cu-poor metal precursor

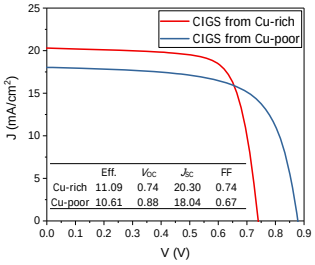
Cu/III = ~1.6, GGI = ~0.3 → Cu/III = ~0.93, GGI = ~0.3 (After sulfurization and KCN etching)

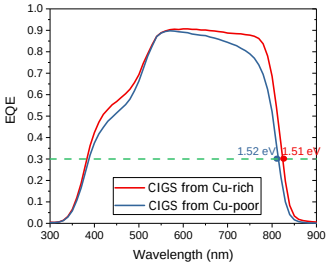
Cu/III = ~0.94, GGI = ~0.3

- In this study, CIGS was prepared using Cu-rich and Cu-poor metal precursor (MP).
- A comparison study was performed to investigate the photovoltaic properties with different Cu contents of MPs.

Results and discussion

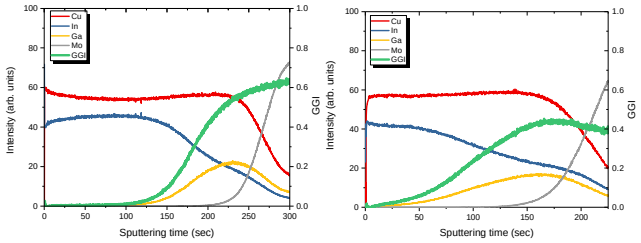
J-V and EQE results





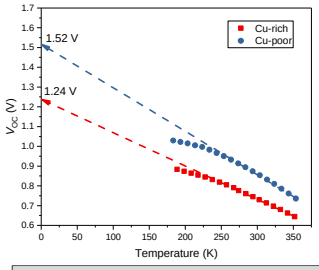
- ✓ CIGS from Cu-rich shows larger J_{SC} and FF.
  - ✓ J_{SC} – steep GGI profile
  - ✓ FF – small shunt resistance effect; 1.1 (Cu-rich MP) and 2.7 (Cu-poor MP) ohm·cm².
- ✓ V_{OC}-deficit = 0.77 and 0.64 V for CIGS from Cu-rich and Cu-poor, respectively.

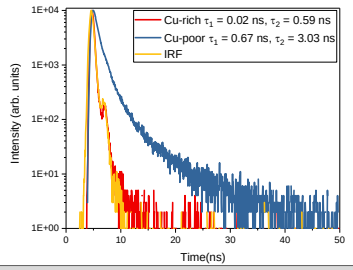
Depth profile results – GD-OES



- ✓ CIGS from Cu-rich MP exhibits steep Ga/(Ga+In) (GGI) profile, which leads to steeper back-graded-bandgap.
  → Improved longer wavelength response in EQE results.

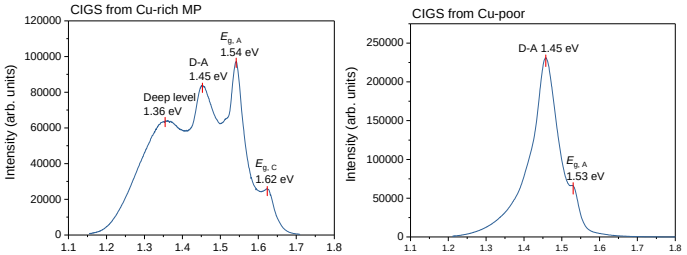
Recombination properties of CIGS cells





- ✓ CIGS using Cu-rich MP shows larger recombination properties.
- ✓ Large difference between E_a (1.24 eV) and $E_{g,EQE}$ (1.51 eV)
  cf. E_a (1.52 eV) = ~$E_{g,EQE}$ in CIGS using Cu-poor MP
- ✓ Very small carrier lifetime in TRPL results

Defect analysis –photoluminescence method



- ✓ CIGS prepared using Cu-rich MP exhibited strong deep emissions at 1.36 eV.
  → the reason for the large recombination limiting V_{OC} of the device.
- ✓ Cu_{In} or V_{In} is known to be easily formed in the Cu-rich $CuInS_2$.
  → Deep levels are caused by Cu-excess growth condition.

Summary

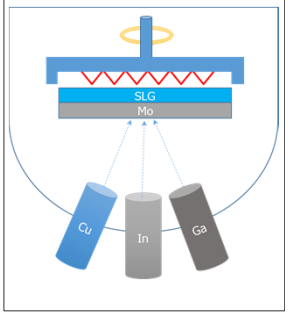
- ➢ CIGS using Cu-rich MP
  - ➢ Good crystallinity and morphology
  - ➢ Better J_{SC} and FF
  - ➢ Large V_{OC} loss due to large recombination
  - ➢ Deep level acceptor (Cu_{In} or V_{In}) caused by Cu-excess growth condition
- ➢ CIGS using Cu-poor MP
  - ➢ Poor crystallinity and morphology
  - ➢ Large open-circuit voltage (V_{OC}) boosting
  - ➢ Reduced recombination
  - ➢ PL emission characteristics without deep level transition

References

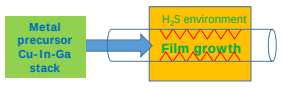
[1] H. Sugimoto *et al.*, PVSEC-27, Otsu, Japan (2017).

Experimental Conditions

Metal precursor deposition via using co-evaporation



Sulfurization



CIGS device structure