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Screen Printing On Cu₂ZnSnS₄Se₁₋ₓ Thin Film For Photovoltaic Application

INTRODUCTION

Screen Printing

The main fabrication method of solar cell is done by vacuum deposition. Screen printing, a common T-shirt patterning process, can be used as direct liquid coating for thin film solar cell. Beside saving equipment cost for vacuum setup, screen printing has larger deposition area and is compatible with roll-to-roll process.

Motivation of CZTS Solar Cell

Cu(In,Ga)S₂ (CIGS) solar cell is one of the few successful commercialized solar cells other than silicon-based solar cell. However In and Ga, used in CIGS are scarce elements and in future, this will limit its production volume.

Cu₂ZnSnS₄ (CZTS) solar cell, having similar material structure of CIGS, replaces scarce In and Ga with abundant and non-toxic Zn and Sn. Current researches focus on improving efficiency and cost reduction.

Figure 2 shows a typical device structure of CZTS solar cell.

Overview of CZTS

Derivation from CIGS

The binary II-IV semiconductor exhibits hexagonal wurzite structure. CIGS ternary I-II-III-V₂ semiconductor formed by mutating group II atoms into pairs of group I and III atoms. Further derivation into CZTS, quaternary I-II-IV-V₂ semiconductor, requires replacing two group III atoms by one group I atom and one group IV atom.

Crystal Structure

Figure 4 compares CIGS and CZTS crystal structure. The binary II-IV semiconductor exhibits hexagonal wurzite structure. CIGS ternary I-II-III-V₂ semiconductor formed by mutating group II atoms into pairs of group I and III atoms. Further derivation into CZTS, quaternary I-II-IV-V₂ semiconductor, requires replacing two group III atoms by one group I atom and one group IV atom.

EXPERIMENTAL SECTION

1. Objective: Reduce Binder For CZTS Grain Growth Enhancement

Binder, an organic compound, is commonly used in direct liquid coating of CZTS film. It prevents cracking and contraction of CZTS film during drying process. Upon heating, some binder decomposes into carbon dioxide, while some of it remains in film as carbon residue which impedes grain growth of CZTS.

2. Overview of Sample Fabrication

A) Ball Milling Solid Precursor

B) Liquid Phase Precursor (Ink)

C) Screen Printing

D) Annealing

3. Result

The X-Ray Diffraction (XRD) peak pattern found in Figure 5 shows that CZTS was successfully formed in all 3 samples containing standard binder, low binder and very low binder. An unknown XRD peak was found in very low binder sample, indicating formation of secondary phase.

Crystal Structure

Figure 4 compares CIGS and CZTS crystal structure. The binary II-IV semiconductor exhibits hexagonal wurzite structure. CIGS ternary I-II-III-V₂ semiconductor formed by mutating group II atoms into pairs of group I and III atoms. Further derivation into CZTS, quaternary I-II-IV-V₂ semiconductor, requires replacing two group III atoms by one group I atom and one group IV atom.

Scanning Electron Microscopy (SEM) pictures in Figure 6 shows that standard binder sample contained some CZTS crystals but majority was incomplete transformed grains which gives rough surface and rounded edges. When the binder was reduced, crystal became larger and it appeared that many small crystals were growing on the incomplete transformed grains. Beside these, all films were porous and were not suitable for making solar cell for efficiency testing.

4. Conclusion & Recommendation

Screen print CZTS thin film with low binder was fabricated and the grain size was slightly improve. Porous film structure was observed and the porosity can cause short circuit after chemical bath deposition of CdS. Reducing the porosity will be the main focus of next stage of research and changing the metal ratio and annealing condition may further increase the grain size.

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Project Title: Cu-chalcopyrite Solar Cell from Nanoparticle Ink

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