Lessons Learnt

Acknowledgement: This project received funding from the Australian Government through ARENA, the Australian Renewable Energy Agency.

Lessons Learnt Report: Fabricating Adamantine material solar cell device using $ZnSnP_2$ disk

Project Name: Efficient Adamantine Thin Film on Silicon Tandem Solar Cells

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Solar PV
State/Territory:	NSW

Key learning

ZnSnP2, a non-toxic and cost-effective semiconductor material, was successfully employed to fabricate a functional thin film solar cell device. A series of manufacturing procedures, such as disk thinning and polishing, layer structure depositions, were developed and an operational solar cell device was successfully demonstrated.

Implications for future projects

By further optimizing the device structures, a higher efficiency is expected. Using the preliminary ZnSnP2 devices as prototypes of new Adamantine material PV devices, fabrication experiences in contact/passivation layer selection, band alignment adjustments and thin film preparation are accumulated providing guidance for future projects.

Background

Objectives or project requirements

Making bulk disks into thin film solar cell devices is usually very challenging, considering the difficulties in grinding and polishing the disks into sub-100 µm thick thin films, and in handling and processing of these ultra-thin films during the device fabrication. Development of the optimal device structures also needs a series of studies, such as selection of suitable contact/passivation material, formation of optimal P-N junction based on band alignments.

Process undertaken

Optimization of the grinding and polishing procedures by choosing suitable abrasion media, applied pressure and spinning speed. Different metal contacts (Cu, Ag) and n-type layers (CdS and Zn-Sn-O) were investigated to improve the band alignment and therefore the solar cell performance.

Lessons Learnt Report: Outstanding performance of $ZnIn_2S_4$, a metamaterial with morphology-dependent optical properties

Project Name: Efficient Adamantine Thin Film on Silicon Tandem Solar Cells

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Solar PV
State/Territory:	NSW

Key learning

A ternary ZnIn2S4 compound with different morphologies (nanoribbons, nanosheets and micro flowers) was successfully used as a water splitting catalyst, prior to its application in solar cell devices. The as-synthesized ZnIn2S4 nano sheets showed superb water splitting performance that is comparable with the meticulously processed ZnIn2S4 or some hybrid structures containing ZnIn2S4. Electron paramagnetic resonance (EPR), PL and Raman spectroscopic studies indicated the nano sheets form of this material possess excellent charge separating and transferring properties, making it a strong candidate for water splitting and PV devices.

Implications for future projects

Excellent charge-separating and charge-transfer properties of ZnIn2S4 make it a promising material that can be applied in solar cell devices. By inserting other elements (Cu, Co and Ni et.al.) to ZnIn2S4 base matrix, better water splitting performances and potential PV devices are expected.

Background

Objectives or project requirements

Due to large band gap and poor charge-transfer properties in previously reported spinel (a form of Adamantine) ZnIn2S4 material, extra processing or formation of hybrid structures are required to apply this kind of material in water splitting or PV devices. 2-D materials usually present improved optical/electronic properties compared to their 3-D (bulk), 1-D (nano wires) or 0-D (nano particles) counterparts. Therefore, 2-D nano sheets ZnIn2S4 were successfully synthesized to achieve a suitable optical band gap and improved charge transfer, revealed by a series of characterizations techniques, such as PL, EPR and Raman spectra.

Process undertaken

Ternary ZnIn2S4 compound of different micro morphologies, in the form of powders (20 mg), was directly employed in water splitting tests. Different electrolyte systems were investigated to realize the optimal device performances.

Lessons Learnt Report: $BaZrS_3$ based monograin solar cells

Project Name: Efficient Adamantine Thin Film on Silicon Tandem Solar Cells

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Solar PV
State/Territory:	NSW

Key learning

A type of BaZrS3 monograin was successfully synthesized via a molten salt assisted flux method in quartz ampoule. By adjusting the reaction conditions, like reaction temperature and time, annealing profile and amount of flux, BaZrS3 monograins with different grain sizes and morphologies were obtained. The oxygen contamination for the surface of BaZrS3 monograin was ascribed to the hydrolysis reaction, which could be significantly restrained by an alternative washing solvent of Methanol. A new monograin membrane technical route was also developed which introduces an EVA temporary layer. Compared with the conventional monograin membrane method, this EVA layer is more suitable for smaller monograin and could reduce the capillarity effect of liquid binding agents like epoxy resin.

Implications for future projects

The development of monograin membrane fabrication technique allows new semiconductor materials requiring high synthesizing temperature to be applied for solar cell fabrication. The material synthesis is completely separated from solar cell device fabrication processing, which means monograin technique is feasible for any kind of new materials.

Background

Objectives or project requirements

Fabrication of non-toxic and cost-effective BaZrS3 material based solar cell is a promising route for high-efficient tandem solar cell. However, the high synthesizing temperature for this kind of materials restricts their application in solar cell fabrication via traditional physical or chemical film deposition methods. Therefore, monograin thin film solar cell was developed with completely separated processings of materials synthesis and devices fabrication, making difficultly synthesizing materials based solar cell achievable.

Process undertaken

The annealing temperature, annealing time, annealing profile and amount of flux were adjusted to prepare the BaZrS3 monograins in different grain sizes and morphologies. BaZrS3 monograin membrane fabrication was also investigated via a novel technique route.

Lessons Learnt Report: Colloidal synthesis of metastable nanocrystals

Project Name: Efficient Adamantine Thin Film on Silicon Tandem Solar Cells

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Solar PV
State/Territory:	NSW

Key learning

A ternary Ba-Zr-S nanocrystals was successfully synthesized via heat-up approach. Thorough optimization of different reactions parameters such as precursors, reaction temperature and time, sulfur source etc., a colloidal nanocrystals of metastable Ba-Zr-S phase were obtained. TEM showed nanocrystals sizes in the range of ~ 10 to 12 nm and TEM-EDS elemental mapping showed the uniform distribution of Ba, Zr, and S elements with additional presence of Cl and O in the as-synthesized nanocrystals. PL spectrum showed a broad peak at around 1.6 eV. Since the XRD did not match with the standard JCPDS cards available for BaZrS3, and other ternary Ba-Zr-S phases as well as binary phases of Ba and Zr, we conclude that the formation of metastable Ba-Zr-S phase.

Implications for future projects

Metastable Ba-Zr-S phase with PL peak positioned at ~ 1.6 eV could be further employed as an absorber for thin film solar cells. Since, metastable phase may allow the formation of micron-sized grains (often observed in kesterite nanocrystals-based thin film solar cells), further exploration of different annealing conditions would allow us to fabricate device-grade quality Ba-Zr-S thin films for high efficiency thin film solar cells.

Background

Objectives or project requirements

Chalcogenide perovskite is a promising alternative material to lead halide perovskite overcoming the toxicity and stability issues. However, they require very high formation temperature of ~ 1000 oC. Therefore, colloidal synthesis under non-equilibrium conditions is a good approach to synthesize chalcogenide perovskite at low temperature and with greater control over the composition and optoelectronic properties.

Process undertaken

Different preparative parameters such as precursors, precursors composition, solvent, reaction temperature and time, ramping rate etc. were optimized to prepare the ternary Ba-Zr-S phase. Their basic characterizations such as structural, optical, and morphological were carried out.