Sb2S3-based extremely thin absorber solar cell

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Sb_2S_3-based Extremely Thin Absorber Solar Cell

Introduction

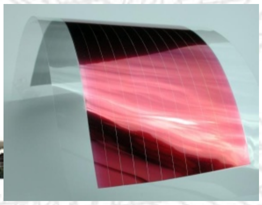
Semiconductor-sensitised nanoporous solar cells are a derivative of dye-sensitised solar cells (DSSC) where a solid-state semiconductor absorber is used in place of the molecular dye of DSSC. In particular, solid-state cells have been drawing much attention recently due to its high light-harvesting capability, tunable band gap over a wide range and a large intrinsic dipole moment. Such solid-state cells are fabricated where the semiconductor absorber is being sandwiched between interpenetrating electron and hole conductors. The typical thickness of the absorbers ranges from several nanometers to several tens of nanometers, also known as Extremely Thin Absorbers (ETA) cells.

Motivation

Solar cells have evolved through 3 generations (from silicon-based, to thin film solar cells and to the latest organic and nanomaterial solar cells). However, much research efforts are still invested in search of new materials and fabrication process. We report the fabrication of ETA cells that incorporate the advantages of both stability of thin film solar cells and printability and flexibility of organic solar cells.

1st Generation – Crystalline Silicon
High cost
Rigid substrate
Rooftop

2nd Generation – Thin Film
Lower cost
Flexible substrate
Building façade, window coating



3rd Generation – Organic PV and DSSC
Extremely thin
Printable
Portable applications

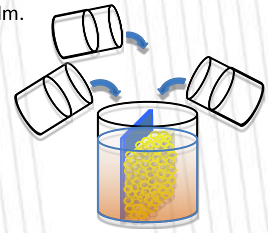
Table 1. Tested absorber materials on structured TiO_2 with deposition methods (ECD – electrochemical deposition, ALD – atomic layer deposition, CBD – chemical bath deposition, SILAR – successive ion layer gas reaction) and solar cell parameters.

Absorber on TiO_2	Deposition	V_{OC} (V)	J_{SC} (mA/cm²)	PCE (%)
Cd_xHg_yTe	ECD	0.6	15	1.9
$CuInS_2$	ALD	0.49	18	4
CdS	CBD	0.85	2.3	1.3
$In(OH)_xS_y/In_xPb_yS$	SILAR	0.72	9	2.9
CuS_x	CBD+ion exchange	0.24	0.05	0.06
In_2S_3/CuSCN	SILAR	0.47	8	2.3
Sb_2S_3	CBD	0.61	10.62	3.1

T. Dittrich, et al., Sol. Energy Mater. Sol. Cells (2011), doi:10.1016/j.solmat.2010.12.034

Methodology

Except for the commercially purchased transparent conducting glass and metal electrode, the cell is solution processed with variable parameters to control the film formation. Mesoporous TiO_2 is formed by doctor blading while chemical bath deposition (CBD) is used to form the In(OH)S and Sb_2S_3 film.



Important Parameters for CBD
•Concentration
•pH
•Temperature

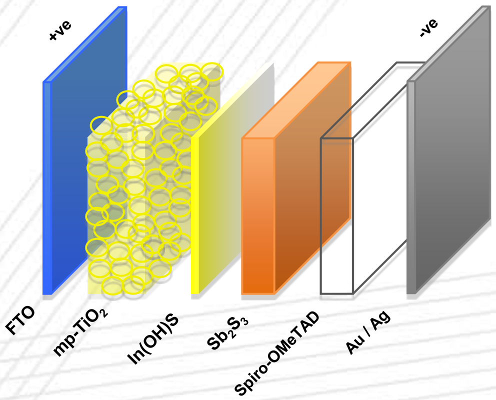


Figure 1. Schematic of Sb_2S_3-based ETA Solar Cell

Findings

•In(OH)S is essential as a barrier layer against recombination and also serve to stabilise the formation of Sb_2S_3 above the TiO_2 layer which would otherwise, catalyse the formation of Sb_2O_3 instead of Sb_2S_3
•Optimal thickness of Sb_2S_3 is found to be around 10-20nm
•Decylphosphonic acid treatment improves pore filling of hole conductor

Future Work

- Replace the mesoporous TiO_2 with titania nanotubes array
- Study the effect of using Al_2O_3 in place of In(OH)S as a recombination barrier
- Use of other hole conductors such as P3HT and PEDOT

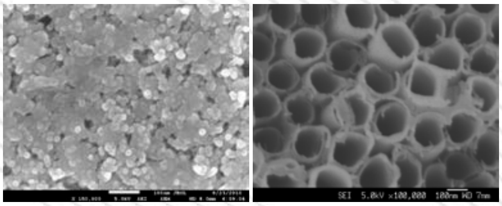


Figure 2. a) Morphology of S_b2S_3 film in mp-TiO_2
b) FESEM image of titania nanotubes

Conclusion

Sb_2S_3 has shown to be a promising semiconducting absorber material for new solar cell devices with good stability in air. Nonetheless, more study on its combination with other materials is required to optimise its performance and fabrication process.

Project Title: Nanonets: New Materials & Devices for Solar Cell Applications
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