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Process Optimization of Copper Antimony Sulfide Thin Films via Chemical Bath Deposition for High-Performance Photovoltaic Applications.

PAIS Abejeewa[1,2], EVA Premalal[2] , HNM Sarangika[2] , KR Koswattage[2] ,Lakshan Priyankara[2] , Lasitha Madhusanka[2]

Faculty of Graduate Studies, Sabaragamuwa University of Sri Lanka, Belihuloya, Sri Lanka[1].

Center for Nanodevice Fabrication & Characterization , Faculty of Technology , Sabaragamuwa University of Sri Lanka[2].

INTRODUCTION & AIM

Key Advantages

- Direct band gap 1.5 eV (ideal for solar spectrum absorption)
- High absorption coefficient > 10^5 cm^{-1} in the visible range
- Non-toxic and environmentally friendly

Current Challenges

- Poor charge carrier transport
- High defect density
- Rapid electron-hole recombination

Research Approach

Various strategies have been explored to address these limitations

This study

- Uses Chemical Bath Deposition (CBD) technique
- Focus on optimization of the deposition bath parameters
- Aimed at achieving the best film quality and device performance

METHOD

Stage 01

Substrate Cleaning

TiO_2 Layer Coating

Chemical Bath Preparation of $CuSbS_2$

Stage 02

Dipping Process Optimalization Process

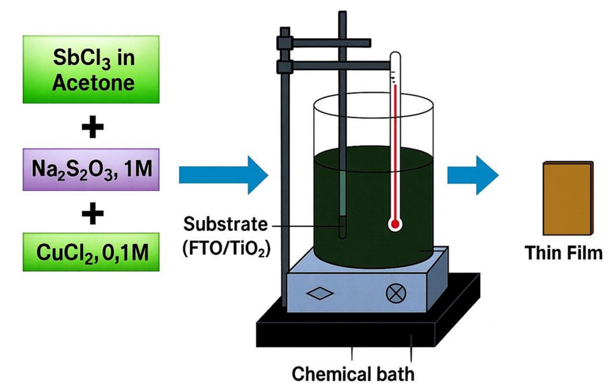

Figure 01 *: Chemical Bath Process*

RESULTS & DISCUSSION

Fixed Conditions

Bath temperature kept constant

$CuCl_2$ concentration kept constant

Variable Parameter

Only the dipping time was changed during the experiment

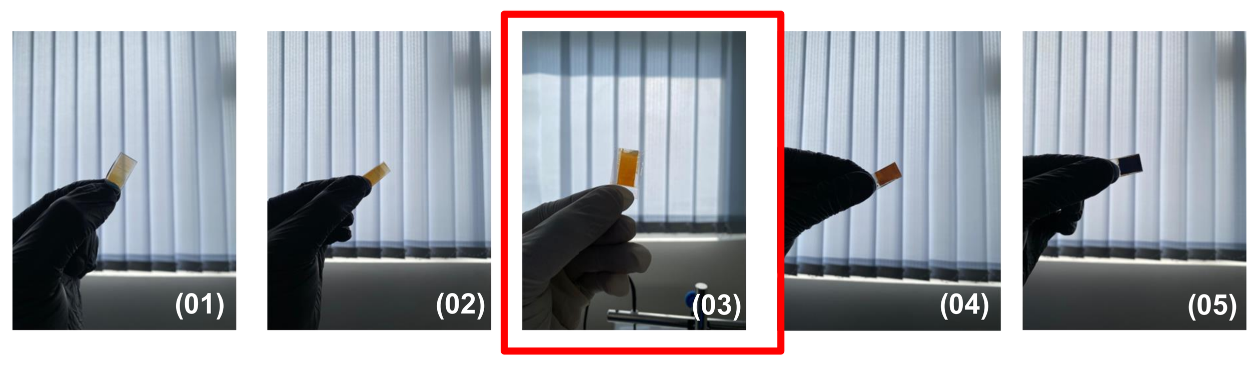

Figure 02 *: Tested Dipping times of Solar Cells :* ***(01)*** *1 hour ,* ***(02)*** *2 hours ,* ***(03)*** *3 hours ,* ***(04)*** *4 hours ,* ***(05)*** *5 hours*

FTO / TiO_2 / $CuSbS_2$

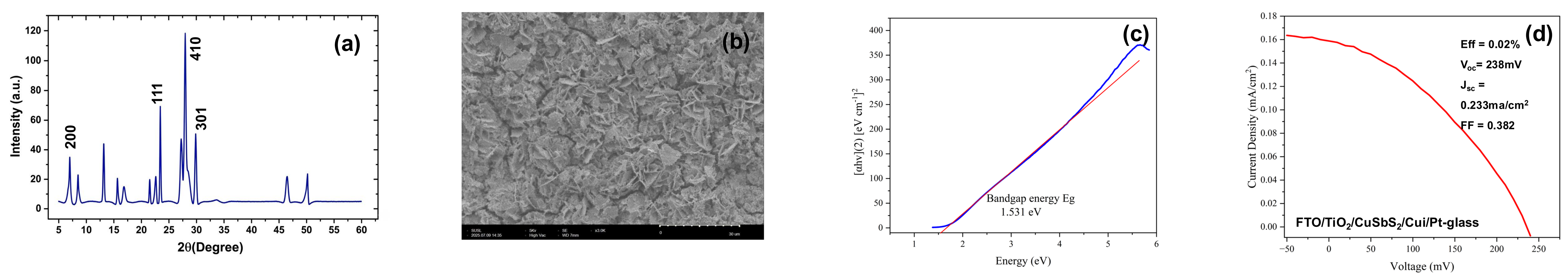

Table 01

Solar Cell	J_{sc} (mA cm^{-2})	V_{oc}	FF	η (%)
(01)	0	0	0	0
(02)	0.017	0.100	0.265	4.5×10^{-4}
(03)	**0.168**	**0.247**	**0.398**	**169×10^{-4}**
(04)	0.016	0.042	0.260	1.72×10^{-4}
(05)	0.002	0.001	0.130	2.6×10^{-7}

Figure (a) shows the XRD pattern of the synthesized material, confirming its successful formation through well-defined peaks that match the standard JCPDS card. **Figure (b)** presents the SEM image of the thin film prepared by 3-hour dipping for the solar cell, clearly demonstrating uniform and successful coating of the film. **Figure (c)** displays the Tauc plot used to determine the optical bandgap of the material, calculated to be 1.53 eV. **Figure (d)** illustrates the current-voltage (I-V) characteristics of the optimized solar cell. Additionally, the ***Table 01*** summarizes the overall photovoltaic performance parameters for devices fabricated at different dipping times.

CONCLUSIONS

- $CuSbS_2$ thin films were successfully deposited on FTO glass via optimized CBD method.
- XRD patterns show the orthorhombic structure films in polycrystalline nature.
- According to Tauc plots, optical band gaps of $CuSbS_2$ films are estimated to be 1.5 eV.
- The solar cell immersed for 3 hours exhibited the best photovoltaic performance.
- The best deposition time for the $CuSbS_2$ thin film is 3 h by the optimized chemical bath deposition method.

FUTURE WORKS

- Future research will focus on enhancing the efficiency of $CuSbS_2$ thin-film solar cells through systematic doping with d-block elements (Fe, Co, Ni, Mn).
- In addition to elemental doping, further studies will investigate interface engineering between the TiO_2 electron transport layer and the $CuSbS_2$ absorber layer to reduce charge recombination losses.

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