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## Optimum chemical composition of antimony sulfide selenide for thin film solar cells

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Abstract: Antimony sulfide ( $\text{Sb}_2\text{S}_3$ ) with an optical bandgap ( $E_g$ ) of 1.88 eV and antimony selenide ( $\text{Sb}_2\text{Se}_3$ ) with  $E_g$  1.1 eV, both of orthorhombic crystalline structure, offer a unique opportunity to prepare solar cell absorbers of  $E_g$ , 1.3 – 1.6 eV poised toward economically viable, non-toxic and ‘earth-abundant’ devices. We prepared chemical precipitates of Sb-S-Se from solutions containing potassium antimony tartrate, thioacetamide and selenosulfate, which were used as sources in vacuum thermal evaporation to produce thin films (280 - 300 nm) of composition,  $\text{Sb}_2\text{S}_x\text{Se}_{3-x}$  ( $x = 0.7 - 2$ ). The  $E_g$  of 1.43 – 1.6 eV and photoconductivity,  $4 \times 10^{-5}$  and  $8 \times 10^{-7} \Omega^{-1} \text{cm}^{-1}$ , respectively of these films help to combine a high open circuit voltage ( $V_{oc}$ ) of 0.609 V with a conversion efficiency ( $\eta$ ) 5.5% or a  $V_{oc}$  of 0.503 V with  $\eta$  of 6.2%. A dual-crucible thermal evaporation system allowed the preparation of absorber films of varying composition ( $x$ ) in the cell structure,  $\text{SnO}_2:\text{F}$  (FTO)/ $\text{CdS}/\text{Sb}_2\text{S}_x\text{Se}_{3-x}/\text{C-Ag}$ . The cell area were, 0.2-0.8  $\text{cm}^2$ . A prototype module of seven series-connected cells of area 1  $\text{cm}^2$  each produced a  $V_{oc}$  of 3.5 V, short circuit current 12 mA at  $\eta$ , 2.4%. Evaluation of the composition of the  $\text{Sb}_2\text{S}_x\text{Se}_{3-x}$  films through grazing incidence x-ray diffraction is illustrated; and device parameters and solar cell perspectives of these materials are presented.

*Key words:* antimony sulfide selenide, thin films, solid solutions; Grazing incidence x-ray diffraction, GIXRD, optical bandgap, photoconductivity; solar cells, thin films photovoltaics, solar cell efficiency; solar energy, renewable energy

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