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**Influence of dipping cycles on physical, optical, and electrical properties of  $\text{Cu}_2\text{NiSnS}_4$ :  
Direct solution dip coating for photovoltaic applications**

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**Abstract:** Direct solution coating technique has emerged as a promising economically viable process for earth abundant chalcogenide absorber materials for photovoltaic applications. Here, direct ethanol based dip coating of earth abundant  $\text{Cu}_2\text{NiSnS}_4$  (CNTS) films on soda lime glass (SLG), molybdenum coated glass (Mo), and fluorine doped tin oxide coated glass (FTO) substrates is investigated. The structural and morphological properties of pre-annealed and sulfurized CNTS films coated on SLG, FTO, and Mo substrates are reported. The influence of dipping cycles on composition and optoelectronic properties of pre-annealed and sulfurized CNTS films deposited on SLG substrate is presented. Energy dispersive spectroscopy (EDS) and X-ray fluorescence (XRF) analysis reveal how changes in thickness and elemental composition affect morphology and optoelectronic properties. The obtained absorption coefficient, optical bandgap, resistivity and mobility of pre - annealed and sulfurized films are found to be  $10^4 \text{ cm}^{-1}$ , 1.5 eV,  $0.48 \text{ } \Omega\text{cm}$ ,  $3.4 \text{ cm}^2/\text{Vs}$  and  $10^4 \text{ cm}^{-1}$ , 1.29 eV,  $0.14 \text{ } \Omega\text{cm}$ ,  $11.0 \text{ cm}^2/\text{Vs}$ , respectively. These properties are well suited for photovoltaic applications and lead to the conclusion that the direct ethanol based dip coating can be an alternative economically viable process for the fabrication of earth abundant CNTS absorber layers for thin film solar cells.

**Keywords:** dip coating; dipping cycles;  $\text{Cu}_2\text{NiSnS}_4$ ; annealing; optoelectronic properties; photo response

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