**Effect of RF power on the properties of Al-doped ZnO (AZO) thin films and their application to Cu$_2$ZnSn(S, Se)$_4$ thin film solar cells**

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Cu$_2$ZnSn(S,Se)$_4$(CZTSSe) has been emerged as an attractive candidate to replace CdTe, CIGS, silicon based thin film solar cells (TFSCs). In a present study, Al doped ZnO (AZO) thin films as a window layer in CZTSSe TFSCs were optimized to improve a device efficiency. AZO thin films are deposited on soda lime glass (SLG) substrate by radio frequency (RF) magnetron sputtering by varying the RF sputtering power during the deposition. The influence of different RF power on the structural, optical and electrical properties of AZO thin films as well as on the CZTSSe TFSCs efficiency were investigated. All the deposited thin films showed a uniform microstructure with transmittance of over 90% in visible region though it possesses comparable band gap and resistivity differences. Especially, AZO thin films deposited at 50 W and 70 W showed high optical band gap energies of ~ 3.67 eV with transmittance of ~ 90% in visible region. On the other hand, the AZO thin film deposited at 50 W showed improved electrical properties having lowest resistivity of 4.36 x 10$^{-4}$ Ωcm, higher carrier concentration of 5.95 x 10$^{20}$ cm$^{-3}$, high mobility of 24.06 cm$^2$V$^{-1}$s$^{-1}$ and lower sheet resistance of 6.4 Ω/SQ respectively. This led to the enhanced device efficiency in CZTSSe TFSCs with AZO window layer deposited at 50 W owing to its outstanding optoelectronic properties. Specifically, improved open-circuit voltage ($V_{OC}$) has resulted in high efficiency (PCE) of 5.53% for CZTSSe TFSCs. This signifies the effectiveness of AZO as a highly promising TCO for TFSCs application.

**Keywords:** Al-doped ZnO (AZO), CZTSSe, Sputtering, Thin film solar cells.