# DEVELOPMENT OF COPPER OXIDES AND COPPER INDIUM DISULPHIDE BASED SOLAR CELLS USING ELECTRODEPOSITION TECHNIQUE



Submitted by

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# Abstract

Cuprous Oxide ($Cu_2O$) is a highly researched material in the field of semiconducting devices. It is naturally abundant, non-toxic, low cost material having a high absorption coefficient and favorable spectral response in the visible range, which is suitable as a window material for solar cells. In this study, preparation of $Cu_2O$, $(Cu_2O)_{1-x}(CuO)_x$, CuO and $CuInS_2$ for fabrication of $(Cu_2O)_{1-x}(CuO)_x/Cu_2O$, $CuO/Cu_2O$ and $CuInS_2/Cu_2O$ heterojunction solar cells are presented. X-ray diffraction, scanning electron microscopy, optical absorption and mott-schottky plot were used to study the material. Photoresponse measurements, dark and light current-voltage measurements and spectral response measurements were used to study the optical behavior of material and junction devices. $(Cu_2O)_{1-x}(CuO)_x/Cu_2O$ and $CuO/Cu_2O$ solar cell devices are very limited and $CuInS_2/Cu_2O$ device has not been reported in the literature. $Cu_2O$ films were electrodeposited in acetate bath at potential -200 mV Vs SCE. $Cu_2O$ deposited in acetate bath exhibits existence of both n-type and p-type conductivity in photoelectrochemical cell (PEC) and this p-type behavior causes the reduction of overall performance of the devices. This effect can be minimized by introducing Cu layer prior to the deposition of $Cu_2O$. Deposition duration of the Cu layer improves the n-type conductivity and the highest improvement was observed at the Cu deposition duration of 5 min. The p-type $Cu_2O$ were electrodeposited in lactate bath at the pH around 12 and the potential of -450 mV Vs SCE.

The $(Cu_2O)_{1-x}(CuO)_x$ composite thin films were grown by annealing the $Cu_2O$ thin film in air at 400 °C for 15 min. It shows the band gap energy value of 1.8 eV and has the p-type conductivity. The p-$(Cu_2O)_{1-x}(CuO)_x$/n-$Cu_2O$ heterojunction solar cell was successfully fabricated by subsequently electrodeposition of $Cu_2O$ thin film on $(Cu_2O)_{1-x}(CuO)_x$ composite thin film at the potential -500 mV Vs SCE in acetate bath. The Ti/p-$(Cu_2O)_{1-x}(CuO)_x$/n-$Cu_2O$/Au solar cell device was fabricated by sputtering a Au grid on top of $Cu_2O$. Resulting solar cell outputs are $V_{OC}$ of 340 mV and $J_{SC}$ of 1.52 mA/cm$^2$ under the AM 1.5 artificial illumination. The device had a fill factor of 0.247 and an efficiency of 0.127 %.

Anodic electrodeposition of p-type CuO on Ti substrate was potentiostatically carried out in lactate. Deposition potential of 700 mV and bath pH of 12.5 was found by employing the linear sweep voltammetry curves. The p-CuO/n-$Cu_2O$ heterostructure were successfully fabricated by electrodepositing n-type $Cu_2O$ on Ti/CuO electrode in acetate bath at the potential -200 mV Vs SCE. Ti/p-CuO/n-$Cu_2O$/Au structure was fabricated by sputtering Au grid on the Ti/p-CuO/n-$Cu_2O$ surface. The best Ti/p-CuO/n-$Cu_2O$/Au heterojunction solar cell produced $V_{OC}$ of 300 mV and $J_{SC}$ of 2.63 mA/cm$^2$ under AM 1.5 artificial illumination. The cell had a fill factor of 0.166 and an efficiency of 0.131%.

The $CuInS_2$ thin films were prepared by sulphurisation of Cu-In alloy on Ti substrate. Single-phase polycrystalline $CuInS_2$ can be obtained by optimizing the Cu/In ratio in the Cu-In alloy films. The best n-type photoactivity was obtained when the atomic ratio of Cu/In at 0.7. The Ti/Cu/In films were annealed at 130 °C for 4 hours in air to form Cu-In alloy. Sulphurisation of Cu-In alloy was carried out at 500 °C for 30 min in 100% $H_2S$ gas with a constant flow rate. The n-type $CuInS_2$/p-type $Cu_2O$ heterojunction was fabricated by electrodepositing p-$Cu_2O$ on Ti/$CuInS_2$ electrode in lactate bath at the potential -450 mV Vs SCE. Au was sputtered on Ti/$CuInS_2$/$Cu_2O$ thin film to fabricate the Ti/n-$CuInS_2$/p-$Cu_2O$/Au device. But device characteristic was not obtained due to the poor photoactive property. Therefore this will be subjected to future studies. This study shows the possibility of fabricating low cost environment friendly p-$(Cu_2O)_{1-x}(CuO)_x$/n-$Cu_2O$, p-CuO/n-$Cu_2O$ and n-$CuInS_2$/p-$Cu_2O$ heterojunction solar cell devices for photovoltaic applications.

*Keywords:* Cuprous Oxide; Electrodeposition; Thin film; Spectral Response; Sulphurisation