Study of Electrodeposited Cu_2O, $CuInS_2$ and ZnSe for Applications in Thin Film Solar Cells

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Abstract

In this study, preparation of Cu_2O, $CuInS_2$ and ZnSe thin films for fabrication of Cu_2O/Cu_xS and $CuInS_2$/ZnSe heterojunction solar cells are presented. A general discussion of the history and theoretical background of solar cells are also made. The experimental study deals with growth and characterisation of electrodeposited Cu_2O, growth and characterisation of $CuInS_2$, potentiostatic electrodeposition of ZnSe, characterisation of ZnSe and fabrication and characterisation of thin film ITO/Cu_2O/Cu_xS/Metal and Ti/$CuInS_2$/ZnSe/Metal heterostructure solar cells. Cu_2O films of ~0.8 μm thickness were potentiostatically electrodeposited on ITO/glass substrates using previously determined parameters. X-ray diffraction, X-ray fluorescence, scanning electron microscopy, optical absorption and reflectance, C-V measurements were used to study the material. The deposited Cu_2O is of high purity having a polycrystalline structure with a grain size of ~(1-2) μm. It has a direct band gap of 2 eV. As deposited Cu_2O was n-type in conductivity and the doping density of the material was of the order of 10^{18} cm^{-3}. Sulphurisation of Cu-In alloy prepared by one step electrodeposition and sequential electrodeposition was investigated to obtain $CuInS_2$ films. Both methods were successful in producing $CuInS_2$ thin films. Current-potential scan was carried out to establish the deposition parameters for potentiostatic electrodepostion of Cu-In alloy. X-ray diffraction, X-ray fluorescence, scanning electron microscopy, optical reflectance, C-V measurements and photoelectrochemical characterisation were used to study the material. The Cu^{2+} to In^{3+} ionic ratios in the Cu-In alloy deposition bath or the Cu/In atomic ratios of the initial Cu and In layers played a major role in determining the composition of the $CuInS_2$ films. Both methods produced single phase polycrystalline chalcopyrite

structure $CuInS_2$ having a direct band gap of 1.5 eV. As deposited $CuInS_2$ was found to be n-type in conductivity and the doping density of the material was of the order of 10^{17} cm^{-3}. The best $CuInS_2$ films produced V_{oc} of ~300 mV and ~ J_{sc} of 6 mA/cm^2 in a PEC containing polysulphide as the electrolyte. Current-potential scans were determined in an aqueous solution containing $ZnSO_4$ and SeO_2 in order to establish the deposition parameters for potentiostatic electrodepostion of ZnSe. ZnSe films of ~0.4 μm thickness were potentiostatically electrodeposited on glass/ITO substrate. X-ray diffraction, X-ray fluorescence, optical absorption and reflectance, C-V measurements and photoelectrochemical characterisation were used to study the material. The deposited material was amorphous. As deposited ZnSe was found to be p-type in conductivity and the doping density of the material was of the order of 10^{16} cm^{-3}. Antimony was a good p-type dopant for ZnSe and doped ZnSe films exhibited a doping density of the order of 10^{17} cm^{-3}. A glass/ITO/n-Cu_2O/p-Cu_xS/Al heterostructure solar cell was fabricated by partial sulphidation of Cu_2O. Current-voltage characteristics and spectral response of the devices were studied. The spectral response of the cell was observed to be limited to shorter wavelengths. The best Cu_2O/Cu_xS cell exhibited V_{oc} of 255 mV, J_{sc} of 1.62 mA/cm^2 and FF of 0.34 under AM1 artificial illumination. A Ti/$CuInS_2$/ZnSe/ITO heterostructure solar cell was fabricated by electrordepositing very thin (~0.2 μm) p-doped ZnSe film on $CuInS_2$/Ti. Current-voltage and capacitance-voltage characteristics and spectral response of the devices were studied. The best $CuInS_2$/ZnSe cell exhibited V_{oc} of 335 mV, J_{sc} of 2 mA/cm^2 and FF of 0.263 under AM1 artificial illumination. The study reveals the possibility of utilising ITO/Cu_2O/Cu_xS/Metal and Ti/$CuInS_2$/ZnSe/Metal heterostructures in developing low-cost thin film solar cells. Further enhancements of the efficiencies of Cu_2O/Cu_xS and $CuInS_2$/ZnSe solar cells are suggested.