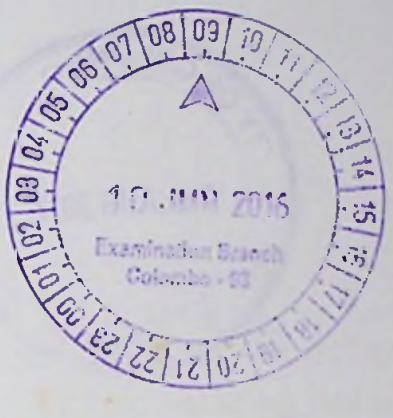

Fabrication and characterization of cuprous oxide solar cells

A thesis submitted to the Faculty of Science,
University of Colombo
for the Degree of Doctor of Philosophy

K.M.D.C. Jayathilaka
July 2015

Abstract

Low cost solar cell devices would play a major role in energy applications in the future. In this aspect, electrodeposited cuprous oxide thin films were studied in this investigation for the development of efficient low cost thin film solar cell devices. Especially, the parameters governing the quality of the thin films and the various combinations of semiconductor thin films were investigated for the fabrication and improving of the devices.

Cuprous oxide thin films were electrodeposited in two different baths one containing an aqueous solution of 0.1 M sodium acetate, 0.01 M cupric acetate (acetate bath) and the other containing aqueous solutions of a mixture of lactic acid (3.25M), cupric sulphate (0.45M) and sodium hydroxide (4M) (lactate bath). Highly photoactive Cl-doped Cu_2O films were electrodeposited potentiostatically on titanium (Ti) substrates. Photosensitive nano cubic cuprous oxide thin films were successfully electrodeposited on Ti substrates in a copper acetate bath without using template or surfactant. The effects of ammonium sulfide surface treatment on the electrodeposited n-type and p-type polycrystalline and nano cubic cuprous oxide thin films deposited on Ti substrates were studied.

Structural and morphological properties of the films were investigated by Scanning electron microscopy (SEM), X-ray diffraction (XRD), High Energy X-ray diffraction (HEXRD), Energy dispersive X-ray spectroscopy (EDS) and X-ray photoelectron spectroscopy (XPS). Both untreated and sulfur treated samples showed XRD patterns consistent with single phase Cu_2O. Cu_xS peaks that were absent in initial XRD spectra were observed using High energy XRD (HEXRD) experiments. The HEXRD analysis revealed that the procedure of sulfur treatment creates Cu_xS in the crystalline form and RDF analysis indicated that the sulfur treatment causes minor structural changes in Cu_2O thin film structures. X- ray photoelectron spectroscopy confirmed the presence of Cl due to doping.

The measurement of the variation of conductivity and photocurrent of the films before and after the sulfur treatment showed reduced resistivity, enhanced spectral photoresponse and enhanced current-voltage (I-V) characteristics in the films which had undergone the sulfur treatment. Results revealed that the peak output photocurrent had increased by ~ 4 times, ~ 50 times ~ 8 times respectively in the sulfur treated films compared to that of untreated p-type, n-type and nano cubic Cu_2O films. Moreover, annealing of sulfur treated cuprous oxide exhibited a good stability against the formation of CuO and enhances the photoactivity of n-type and p-type cuprous oxide thin films.

In this study, sulfur treatment and annealing were successfully used for improving the efficiency of heterojunction and homojunction Cu_2O based thin film solar cells. Fabricated Ti/p-CuO/n-Cu_2O/Au heterojunction and Ti/n-Cu_2O/p-Cu_2O/Au, Ti/p-Cu_2O/n-Cu_2O/Au homojunction solar cell structures resulting efficiencies of 0.64%, 2.14%, 2.6% respectively under AM 1.5 illumination. Alternately, conductivity was increased by chlorine doping of n-Cu_2O films and by partially sulfiding the film using aqueous sodium sulfide and ammonium sulfide vapour. A junction of doped n-Cu_2O/p-Cu_xS produced a Ti/n-Cu_2O/p-Cu_xS/Au structure resulting in efficiency of 1.86 % at an AM1.5 illumination.

Increased effective surface area, increased conductivity and annealing contributed to the improved device parameters. The results obtained from this study are significant because it allows the fabrication of solar cell with a reasonable high conversion efficiency at a very low cost.