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Photovoltaic Parameters of Copper Indium Telluride and Copper Gallium Telluride Films

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Abstract

Copper Indium Telluride Copper Gallium Telluride films were deposited for the first time by the pulse electro-deposition technique at room temperature and at a constant potential of – 0.75 V(SCE)[1,2.3]. The films exhibited single phase. Optical band gap of the films were determined for various duty cycles. Capacitance voltage measurements indicated the films to exhibit p-type behavior. Resistivity was calculated from the resistance values and it was observed that the resistivity increases [4] with increase of indium content. Now in this research paper photovoltaic parameters of CIT and CGT films were studied.

Keywords: Photovoltaic Parameters, Open Circuit, Short Circuit Current, Fill Factor, Efficiency.

Introduction

In the light energy conversion discussed in the following pages, the substance that absorbs the radiant energy and transduces it to an electron hole pair is a semiconductor. The nature and properties of a semiconductor make this possible. The colour of a semiconductor roughly indicates the portion of the solar spectrum that is absorbed by it. The energy gap, therefore, determines the colour of the semiconductor. The visible region of the spectrum extends in the energy from about 1.5 eV to 3.0 eV(red to violet). Silicon, gallium arsenide, Indium phosphide, cadmium telluride and other low band gap materials appear black, since visible light is entirely absorbed by them. Zinc oxide, titanium-di-oxide, tin oxide, strontium titanate, etc., appear white because they absorb only in the ultraviolet region, reflecting the visible spectrum. The energy contained in sunlight is distributed over a wide range of wavelengths and efficient conversion requires a wide spectral response. Wider band gap materials absorb a smaller spectral range of the terrestrial solar radiation producing smaller currents than smaller band gap materials, which absorb more radiation producing larger short circuit current. The basic properties of these junctions are described under the solid-liquid junctions, since this work has a direct bearing on electrochemical conversion of light energy. A short account of the solid state photovoltaics would be in order before going into the wet photovoltaic cells.

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Experiment

Photoelectrochemical (PEC) cells were prepared using the films deposited on titanium substrates heat treated at different temperatures. The films were lacquered with polystyrene in order to prevent the metal substrate portions from being exposed to the redox electrolyte. These films were used as the working electrode. The electrolyte was 1 M polysulphide. The light source used for illumination was an ORIEL 250 W Tungsten halogen lamp. A water filter was introduced between the light source and the PEC cell to cut off the IR portion. The intensity of illumination was measured with a CEL suryamapi, whose readings are directly calibrated in $mWcm^{-2}$. The intensity of illumination was varied changing the distance between the source and the cell. The power output characteristics of the cells were measured by connecting the resistance box and an ammeter in series and the voltage output was measured across the load resistance. The photocurrent, dark current and output voltage were measured with a HIL digital multimeter.

The CIT photoelectrodes were dipped in the electrolyte and allowed to attain equilibrium under dark conditions for about 10 minutes. The dark current and voltage values were noted. The cells were then illuminated by the light source and the current and voltage were measured for each setting of the resistance box. The photocurrent and photovoltage were calculated as the difference between the current under illumination and the dark current, and voltage under illumination and dark voltage respectively.

The films were used as photoelectrodes in photoelectrochemical (PEC) cells. The redox electrolyte was 1M Polysulphide (1M each of Na_2S, S and NaOH). The PEC cells using these films exhibited low

photocurrent and photovoltage. The intensity of the light falling on the films deposited at different duty cycles was kept constant at 60 mW cm^{-2}. Fig.4.10 shows the load characteristics of the as deposited films, deposited at different duty cycles. Films deposited at 50 % duty cycle exhibited maximum photo output. In order to increase the photo outpout, the films deposited at 50 % duty cycle were post heated in argon atmosphere at different temperatures in the range of 400 - 525°C for 15 min

Results

The results for photovoltaic parameters were given. From the table1, it is observed that the PEC output parameters, viz., open circuit voltage and short circuit current were found to increase for the electrodes heat-treated upto a temperature of 500°C. Photoelectrodes heat-treated at temperatures greater than this value exhibited lower open circuit voltage and short circuit current due to the reduction in thickness of the films as well as the slight change in stoichiometry. The photovoltaic parameters are shown in Table 1. Open circuit voltage is found to increase initially and then saturates, the short circuit current density increases linearly with intensity.

Table I. Photovoltaic parameters of CIT photoelectrodes deposited at different duty cycles and post heat treated at 500˚C (Int : 60 mW cm^{-2})

Duty cycle(%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	ff	η (%)	R_s (ohms)	R_{sh} (Kilo ohms)
6	0.33	1.60	0.50	0.44	26	2.8
9	0.39	1.95	0.55	0.70	22	2.6
15	0.41	2.40	0.63	1.04	19	2.8
33	0.46	2.80	0.63	1.34	14	2.5
50	0.53	3.50	0.52	1.60	10	2.5
50	0.75	5.50	0.72	4.96	7	2.4

The value of the ideality factor was calculated from the slope of the straight line and it was found to be 2.05. The reverse saturation current density, J_o, was 2.5 x 10^{-7} A cm^{-2}. The effect of photoetching on the PEC performance was studied by shorting the photoelectrode and the graphite counter electrode under an illumination of 80 mWcm^{-2} in 1**:**100 HCl for different durations in the range 0 – 100 s. Both the photocurrent and photovoltage are found to increase upto 60 s photoetch, beyond which they begin to decrease (Table 1). Photoetching leads to selective attack of surface defects not accessible to chemical etchants. It is observed that during photoetching the V_{oc} increased from 0.53 V to 0.75 V and J_{sc} increased from 4.5 mAcm^{-2} to 5.5 mAcm^{-2}. The decrease in photocurrent and photovoltage beyond 60 s photoetching can be attributed to increase in surface area due to prolonged photoetching . The power output characteristics after 80 s photoetching indicates a V_{oc} of 0.75 V, J_{sc} of 5.50 mAcm^{-2}, ff of 0.72, η of 4.96 % for 60 mW cm^{-2} illumination. The photovoltaic parameters of the electrodes deposited at 50 % duty cycle and post annealed at different temperatures are shown in Table 1.

Table II. Photovoltaic parameters of CGT films deposited at different duty cycles and post heat treated at 500˚C (Int : 60 mW cm^{-2})

Duty cycle(%)	V_{oc} (V)	J_{sc} (mA cm^{-2})	ff	η (%)	R_s (ohms)	R_{sh} (Kilo ohms)
6	0.33	1.80	0.59	0.58	17	2.6
9	0.35	2.00	0.64	0.75	14	2.6
15	0.40	2.12	0.55	0.77	12	2.5
33	0.40	2.50	0.56	0.89	9	2.6
50	0.43	4.50	0.53	1.71	6	2.5
50	0.48	5.80	0.68	3.13	4	2.6

From Table 2, copper Gallium Telluride films shows followind photovoltaic parameters.Both the photocurrent and photovoltage are found to increase upto 60 s photoetch, beyond which they begin to decrease .Photoetching leads to selective attack of surface defects not accessible to chemical etchants. It is observed that during photoetching the V_{oc} increased from 0.43 V to 0.48 V and J_{sc} increased from 4.5 mAcm^{-2} to 5.8 mAcm^{-2}. The decrease in photocurrent and photovoltage beyond 60 s photoetching can be attributed to increase in surface area due to prolonged photoetching [8]. The power output characteristics after 80 s photoetching indicates a V_{oc} of 0.48 V, J_{sc} of 5.80 mAcm^{-2}, ff of 0.68, η of 3.13 % for 60 mW cm^{-2} illumination. The photovoltaic parameters of the electrodes deposited at 50 % duty cycle and post annealed at different temperatures are shown in Table 2.

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