Study on Characteristics of CdS/Cu_2S Photovoltaic Cell

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Abstract- In this paper the CdS-Cu_2S photovoltaic cell has been prepared and characteristiced by using evaporation method on glass substrate. CdS film was deposited on the Pyrex glass substrate by evaporation and Cu_2S layer was obtained by electroplating in a dilute acqueous solution of $CusO_4$ at room temperature. Silver electrode was applied to the electroplated surface. The results of electrical and optical characteristics of the CdS-Cu_2S hetrojunction were investigated. The photovoltaic response has been observed under various illuminated intensity for different wavelengths in visible region. It was found to be the photovoltage and photocurrent varying with different light intensities. It can be concluded that formation of a low resistivity CdS film and Cu_2S layer play a big role in obtaining a high efficiency cell.

Keywords: Cds-Cu_2S Photovoltaic Cell, Pyrex Glass, Photovoltage, Electroplating, Light Intensity, Power Conversion Efficiency.

I. INTRODUCTION

Since the photovoltaic effect in a junction made by depositing a thin film of copper on a CdS crystal was first reported by Reynolds [1] and 1972, CdS/Cu2S conversion efficiencies in sunlight of between 5-6 percent were reported by many investigators with a limited number of them reporting efficiencies up to 7 percent [2]. In recent years, efforts on the development of thin film solar cells have been more and more concentrated on Cu2S/CdS cells with a p-n heterojunction. Thin film photovoltaic cell of Cu2S/CdS was the most promising solar energy conversion (optoelectronic) device due to the high conversion efficiency more than 9.1%, easy fabrication and low cost [3]. Cadmium sulphide/copper sulphide cells are clearly heterojunction cell with CdS having energy gap of 2.42 eV in the visible range at room temperature and Cu2S having an energy gap of 1.2 eV. CdS is well known to exhibit high luminescence efficiency, which is II-VI compound semiconductor that has a larger ionic contribution in bonding tends to unipolar. CdS is always n-type because it has an excess of sulphur vacancies, which act as donar , and the small – sized S atoms have smaller binding energies than the larger Cd ions. [4]Cadmium sulphide has a widely used as a window material in heterojunction solar cells with various narrow band – gap semiconductor like Cu_2S mainly because of its favourable optical densities. The main purpose of the window layer is to reduce recombination at the front surface. Surface recombination plays an important role because the window effects allow the junction to place deeper from the surface than homojunction cell, and severely reduce the photocurrent without appropriate surface passivation. The light –generated current and the conversion efficiency for CdS-Cu_2S heterojunction solar cell are increasing function of the sheet resistance of the Cu_2S layer. The diffusion of copper into the CdS would result in an increased carrier concentration in the Cu_2S surface. An increase in the sheet resistance of Cu_2S layer is due primarily to a decrease in the hole concentration, several mechanisms are possible. Considering the nature of sunlight, it is clear that the Cu2S layer is responsible for the bulk of photocurrent generation. The spectral response and photocurrent are limited by high surface recombination velocity, short diffusion length, and high interface recombination [5].

It is desirable to investigate the mechanism of CdS cells to improve the efficiency because of low cost expected to the polycrystalline solar cells. For this purpose, the semiconductor materials used for my research is cadmium sulphide- copper sulphide, a simple structure for the Cu2S/CdS heterojunction based on a range of experiments made on cells has been investigated. This material can be deposited on glass substrates at relatively low processing temperatures and the photovoltaic properties of CdS-Cu2S cell were studied. Compared with the commonly used crystalline photovoltaic devices, the thin film devices offer the advantage of much lower cost and ease of fabrication and are considered a prominent candidate for terrestrial solar energy applications [6].

II. EXPERIMENTAL PROCEDURE

A schematic cross section of CdS-Cu2S photovoltaic cell is shown in Fig.1.Cadmium sulphide layer was deposited onto pyrex glass substrate (2x1.2)cm2 by evaporation method at 600ºC for 3 hours.

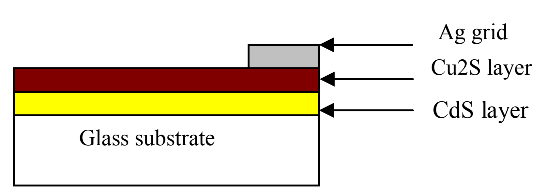

Fig.1. A schematic cross section of CdS-Cu2S photovoltaic cell

The evaporated layer without additional treatment is relatively conducting because of the presence of excess cadmium. The resistivity of these film could be as low as 10Ω /cm to 50 Ω./cm. A Cu2S layer was formed on the CdS layer by electroplating technique. The CdS film and a metallic copper plate were immersed into an acqueous solution of CuSO4. A direct current voltage was supplied between the copper plate (anode) and the CdS film (cathode) within the deposition potential of metallic copper at room temperature for 1 hour. A Cu2S layer was formed on the surface and along the grain boundaries near the surface of the CdS film according to the following reactions:

$$Cu^{++} + CdS = CuS + Cd^{++}$$

$$CuS + Cu^{++} + 2e = Cu_2S$$

After heat treatment at 100ºC for ten minutes in air, a n-CdS / p-Cu2S junction was prepared. Cu2S layer is a critical component of the CdS-Cu2S heterojunction solar cell. It is known that thermal effects play a significant role both in the formation of an efficient photovoltaic device and also in subsequent cell degradation. The heat treatments of various types are used to stabilize and improve the heterojunction response to light. Since the cell is heated when exposed to sunlight, thermally stimulated degradation occurs under certain operating conditions. The thickness of the copper sulphide layer depends on the current density and concentration of the copper sulphate solution. If the thickness of the copper sulphide layer is increased, most of the photocurrent cannot generate in this layer [7].

III. RESULTS AND DISCUSSION

X- ray diffraction analyses are used to study phase formation and the preferred orientation of the CdS-Cu2S photovoltaic cell. XRD measurement was performed with a RIGAKU model RINT 2000 powder diffractometer employing Cu /K-alpha radiation (λ = 1.54056 Aº with 40kV –30mA).

The variation of current and voltage due to a varying load resistor at a constant incident light intensity is shown in Fig 2.If the load resistance is small, the cell acts like a constant current generator with the current output equal to the short circuit current Isc. In this region the current output is approximately proportional to the intensity of radiation incident on the cell. But the load resistance is increased, the cell current decreases and more current flow through the internal diode. For very large value of the resistance, the voltage across the cell terminals approaches the open-circuit voltage. The maximum power that can be extracted from a photovoltaic device is at the point for which the largest rectangle can be inscribed into the current –voltage curve. Under (2klux) illumination, the short-circuit current is 70 µA and the open circuit voltage is 210 mV .The maximum output power is 7.54µW.

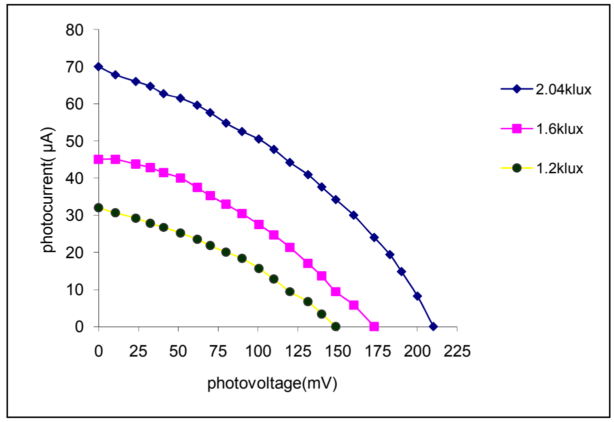

Fig. 2. I-V Characteristics of CdS–Cu2S Cell with Various Light Intensities

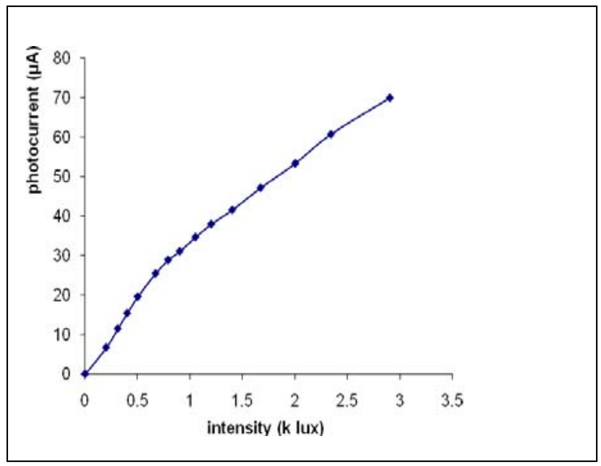

Fig. 3 Photocurrent with various light intensities.

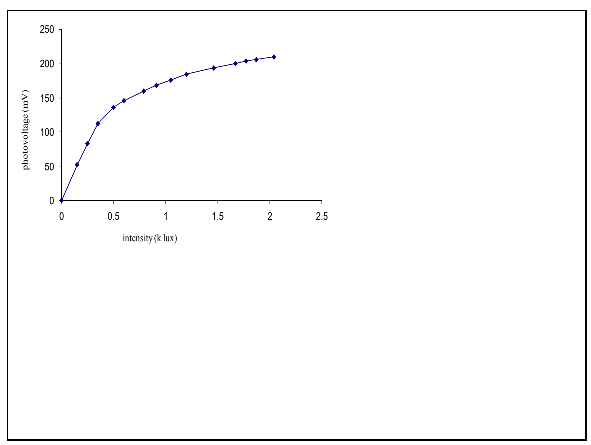

Fig. 4. Photovoltage with various light intensities.

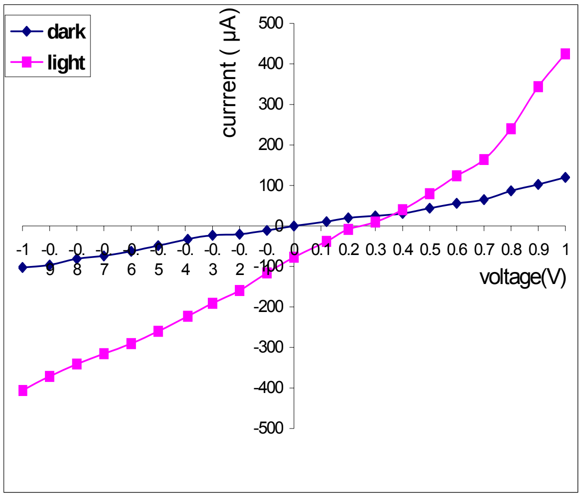

Fig.5. I-V Characteristics of CdS–Cu2S Cell

Fig.3 and Fig.4 represents photovoltage (Voc) and photocurrent (Isc) of the cell under various light intensity .It can be seen that the short- circuit current rises linearly increasing with light intensity. The variation of photocurrent with light intensity indicates that it is affected by an exponential trap distribution .This is due to the increase in the number of photons generating the photocurrent in addition to the perceptible improvement in Isc with increase in temperature, which is the consequence of the improvement in the diffusion length and due to the shift of the absorption edge to lower energies. Open circuit voltage rises linearly at low light intensity and then tapers off, increasing slightly for large increase in illumination. The larger gap material produces the largest open-circuit voltage, while the lowest – gap material which absorbs a greater portion of the incident spectrum, generates the largest short-circuit current On the other hand, a large energy gap can give a higher photovoltage and a lower photocurrent. This is a fact that the efficiency is lower [8].

The current–voltage characteristics of the cell under illumination intensity were investigated by biasing the device with stabilized power supply and drift current was measured. It can be seen from Fig 5., the bias voltage and the current depend upon incident light intensity. In the forward - bias direction, there are both photogenerated carriers and thermally injected holes from the Ag electrode. For reverse- bias condition, all the carriers are photogeneated. It is investigated that the device operated in the fourth quadrant under illumination will deliver power to an external load. The majority carrier concentration at the junction is so high that the series resistance is not influence by the photoconduction process. In third quadrant, junction is reversed biased and the device carries a reverse current. This indicates that the transport of photo-generated carriers in the cell is mainly based on the drift effect by an electric field since the mobility of photogenerated carriers in this cell is very small[9].

There are two ways of light incidence in the cell: one is incidence from the glass side and the other from the Ag electrode side. The efficiency in the former case was higher than that in the latter case, because light shading occurred due to the Ag electrode. Table shows the change in photovoltaic characteristics by changing the light incidence. The fill factor in the former case is also larger than that in the latter case. This may be interpreted by the decrease of series resistance of the cell due to the photoconductivity of the CdS film [10]. The maximum efficiency was 1.67 % under the tungsten lamp light equivalent to 301 mW/cm2.The difference between η under the tungsten lamp light and that under the sunlight must be due to the differences in the spectra and intensity of the illuminators. The degradation in the cell is caused by ionic conductivity of Cu2S.[11].

The experimental results of CdS/Cu2S photovoltaic cell can be summarized in Table.

Incident light intensity	Voc (mV)	Isc (μA)	Pm (mV)	Rs (kΩ)	FF (%)	η (%)
3.01 klux	210	70	7.54	1.35	51.3	1.67
1.6 klux	170	45	2.90	2.07	37.9	0.73
1.2 klux	130	32	1.56	1.87	36.7	0.39

IV. CONCLUSION

A simple technique based entirely on evaporation method and electroplating was used to fabricate Cu2S/CdS solar cell. CdS film with low resistivity was obtained on the glass substrate .It was necessary to decrease the resistance of CdS film in order to increase its efficiency. The glass substrate provides protection and ease of cleaning. Silver electrode was applied to the Cu2S layer. The electrical and optical characteristic of the cell was measured under illumination including dark and different wavelengths in the visible region. The efficiency was higher in the light incident from the glass side than in the light incident from the Ag electrode .The maximum efficiency was 1.67%. Further investigation is necessary to improve the cell life. High resistivity of CdS thin film, high series resistance and the poor design of the grid have lead to low efficiency. Stability is another important factor together with conversion efficiency in this cell. Much effort has to be made for improvement in life characteristics and efficiency of the cell.

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