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microcontroller fetches the instructions from its program memory one by one, detected their instructions, and then carries act the required operations.

As soon as 5 V dc power supply is applied to the system program displays numbers 0 to 9999 on the display with a one second delay between each output. Modifying the control program the timer can also be used as a two-digit hour-minute digital clock or a stop-watch.

Conclusion

Using microcontroller integrated circuit is saving energy and cost. Since not much external components are needed, the design is relatively compact. By using a microcontroller it can obtain the advantages of light weight, low power consumption, better reliability and precise timing sequence.

Acknowledgements

Firstly, we are deeply grateful to Rector, Dr Tin Maung Hla, Yangon University of Distance Education and Pro Rector Dr Khin Thant Sin, Yangon University of Distance Education, for their kind permission to carry out our research work. We would like to thank Head of Professor Dr Moh Moh, Department of Physics and Professor Dr Marlar Myint, Department of Physics, Yangon University of Distance Education, for their kind permission to carry out this research work.

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STUDY ON CURRENT-VOLTAGE CHARACTERISTICS OF ZnTe ELECTROPLATED FILM UNDER ILLUMINATION

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Abstract

$Zn_{1-x}Te_x$ (x=0.22 mol) electroplated film was grown on stainless steel substrate with different viscosity levels. For more electrical contact, Ni-conductive layers were deposited on both sides of the cell by electroless Ni-plating. I-V characteristics were studied under illumination condition for all fabricated films. The largest value of conversion efficiency (6.908 %) was found at the ZnTe film with kinematic viscosity of 32.22 cP. According to the experimental data resulted from this research, the laboratory-prepared ZnTe film is credible, suitable and appropriate to use for photovoltaic cell application.

Introduction

Amongst the wide band gap II-VI semiconductor materials, Zinc Telluride (ZnTe) is the most attractive material and finds several applications in the field of device electronics. Zinc Telluride, II-VI compound semiconductor, with zinc-blende structure with lattice constant of 6.1037 Å, direct band gap of 2.26 eV at room temperature, and melting point of 1295°C. The II-VI compound semiconductors have considerable potential for integrated-optics applications due to their high electro-optic coefficients, wide transparency range from the

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visible to beyond 10 µm. Zinc Telluride has potential applications in a variety of solid-state devices such as solar cells, photodetectors and light emitting diodes.

It is usually a p-type semiconductor when prepared by electrochemical methods. The composition of Zn-Te electrodeposits was shown to vary depending on applied potentials, concentrations of the reagents, pH, and temperature. Electrochemically prepared semiconductors are amorphous, often requiring further annealing for their better performance. The p-type ZnTe obtained by electrochemical techniques would be more stable than its n-type counterpart for photoelectrochemical applications.

In this research work, ZnTe layers were deposited on stainless steel substrates by electroplating technique with different viscosity levels which is used for photovoltaic cell application. I-V characteristics of all fabricated films were observed under illumination condition. From these characteristics, some photovoltaic 167arameters such as fill-factor, conversion efficiency, quantum yield and series resistance were studied.

Sample Preparation

The first step was to weigh and powder-batch the starting materials of ZnO (1-x) and Te (x). They were mixed by desirable compositions of x = 0.22 mol. Powder in proportion appropriate to get one Te compositions was mixed. The mixed powder was grounded by an agate motor for 10 min to obtain homogeneity. After that ethanol was added to the mixture and stirred 167arameters till the powder became homogeneous.

The ZnTe powder was dried in air for 6 hrs at room temperature, and again ground by agate motor for 30 min. The homogeneous powder was heat treated at 400˚C for 1 hr by convensional furnace annealing (CFA) process. The substrates were used by stainless steel with dimension 0.5 cm x 0.5 cm. The stainless steel substrates were immersed in acetone for 10 min and cleaned to remove organic impurities. They were dried at room temperature.

Measuring Viscosity

ZnTe powder (0.9 g) annealed at 400˚C, 1 hr for two times, was added with ethylene glycol (10 ml) in a beaker and stirred by a glass rod. In this case, the ZnTe powder was used as a solute and ethylene glycol is used as a solvent. Then, the solution poured and recorded the time taken which flow in U-tube viscometer. The duration flowing in U-tube is directly proportional to the viscosity level of the solution. Then, ZnTe (0.3 g) increased into the precursor solution and measured the viscosity level. In the same way, the viscosity of ZnTe precursor solution measured 5 times. They were observed by using U-tube viscometer and shown in Fig.1.

The viscosity of product sol gels was calculated by the following equation.

$$\eta = \frac{\pi P r^4 t}{8 l V}$$

where, η = viscosity of the fluid (cP)

P = pressure difference between the ends of the tube (dynecm^{-2})

r = radius of a tube (cm)

t = time taken (s)

l = length of a tube (cm)

V = volume of fluid passing through a tube (cm^3)

Fig.1 U-tube Viscosmeter

The calculated viscosity value and ZnTe sample content at process temperature 400ºC were collected and listed in Table 1. Fig.2 illustrates the dispersion of viscosity as a function of ZnTe sample content. From the figure, it was clear that the highest viscosity was caused by the ZnTe (1.5g) and the graph nature was bell-shape.

Table 1. Change in viscosity with respect to sample weight

ZnTe (g)	Viscosity (cP)
0.9	23.85
1.2	26.65
1.5	32.22
1.8	30.23
2.1	29.19

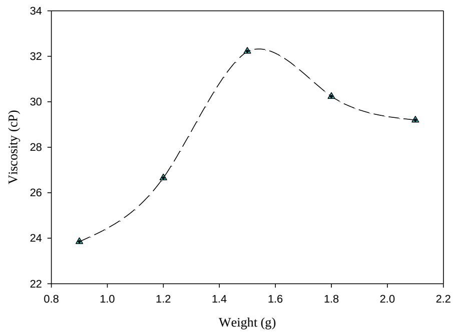


Fig.2 Sample weight dependence of viscosity level

Fabrication of ZnTe Film by Electroplating Method

For each viscosity level, the material was deposited on steel substrates by electroplating technique with a speed of 1000 rpm. First, the solution stirred with magnetic stirrer to reach its colloidal sol (gelly like) for 30 min. The electromagnetic machine with magnetic stirrer is shown in Fig.3. Then, the steel substrates were connected with the electrodes (cathode and anode) in parallel. The distance between cathode and anode is about 0.7 cm. Both components were immersing in the precursor solution and passing a current through the bath.In this process, applied voltage was 26 V and coating time was 30 min. Finally, the source of the materials to be deposited at the cathode and ZnTe flims was achieved. The experimental set up for electroplating system is shown in Fig.4. Then, I-V characteristics of ZnTe fabricated films were observed under illumination condition.

Fig.3 Electromagnetic machine

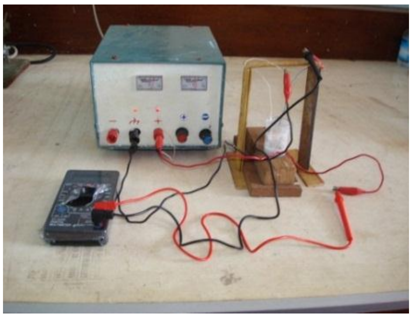


Fig.4 Experimental set up for electroplating system

Nickel-Layer Formation

For more electrical contact, ZnTe electroplated films on steel substrates made by electroless Ni-plating. First, the substrates (0.5cm x 0.5cm) were covered by tape leaving the window layer of (0.3 cm x 0.3 cm) on the front side and the window of (0.4 cm x 0.4 cm) on the back side.Each substrate was dipped in Nickel solution for 5 min to expose Ni on each window layer. Thus, Nickel-layers were formed. They were dried and connected with

Cu-electrodes. Then, samples were measured to current-voltage characteristics by using sodium lamp (500 watt) as a monochromatic light source and digital meter as shown in Fig.5.

Fig.5 The measurement system of I-V characteristics

Results and Discussion

To examine the solar cell 169aramete of fabricated film, I-V characteristics were essentially measured under illumination and recorded in Fig. 6 (a). All films were found to be the same as variation nature and little different in current value. On the 1st quadrant, the current steadily flowed and increased with an increase in forward bias in 4th quadrant of the circle. Fortunately, the negative current flowed due to the forward voltage in 4th quadrant. This result showed the photovoltaic nature of fabricated film for all fabricated films. The positive current was allowed to flow by forward voltage in 1st quadrant of I-V curve.

To identify the performance 169arameters of solar cell, I_{sc}-V_{oc} (short-circuit current and open-circuit voltage) variation was also investigated and shown in Fig.6(b). The maximum current and maximum voltage (I_m& V_m) were recognized on I_{sc}-V_{oc} curve. The maximum power delivery (P_m) was the product of I_m and V_m. V_{oc} is the maximum voltage obtainable at the load under open-circuit condition of the diode and I_{sc} is the maximum current through the load under short-circuit condition. V_{oc} was the applied voltage relative to an open circuit where no current flowed through the device.

$$V_{OC} = V_m \text{ at } I = 0$$

The short circuit current (I_{sc}) represents to the maximum current that passes through the cell that corresponds to the short circuit condition when the impedance is low. It occurs at the beginning of the sweep when the voltage is zero. In an ideal cell, this maximum current value is the total current produced in the solar cell by the photon excitation.

$$I_{SC} = I_m \text{ at } V = 0$$

This maximum power point is denoted by

$$P_m = V_m I_m$$

The fundamental parameters, maximum current (I_m), maximum voltage (V_m), maximum power (P_m), short circuit current (I_{sc}) and open circuit voltage (V_{oc}) for all fabricated films are listed in Table 2.

The variation of maximum power as a function of viscosity level of ZnTe film is shown in Fig.7(a). From the figure, the maximum power was found that $7.11\text{x}10^{-3}$ W at 32.22 cP. The short circuit current (I_{sc}) was measured from V_{oc}-I_{sc} curve, and these values were $1.10\text{x}10^{-2}$ A, $1.14\text{x}10^{-2}$ A, $1.16\text{x}10^{-2}$ A, $0.49\text{x}10^{-2}$ A and $0.44\text{x}10^{-2}$ A. The short circuit current-viscosity level for all films was described in Fig.7(b). The open circuit voltage and viscosity level of ZnTe film is illustrated in Fig.7(c). The open circuit voltage were 1.854 V, 1.938 V, 1.995 V, 1.781 V and 1.906 V at 23.85 cP, 26.65 cP, 32.22 cP, 30.23 cP and 29.19 cP, respectively.

For device performance, conversion efficiency (η_{con}) was evaluated. The conversion efficiency of a solar cell was defined as the ratio of the output electrical power (electricity) to the input optical power. When the solar cell was operating under maximum power conditions, the conversion efficiency was

$$\eta_{con} = \frac{P_m}{P_{in}} \times 100\% = \frac{I_m V_m}{P_{in}} \times 100\%$$

where, P_{in}= input power, P_m= maximum power point (W)

The fill-factor (F_f) is essentially a measure of quality of the solar cell. It is calculated by comparing the maximum power to the theoretical power (P_T) that would be output at the both the open circuit voltage and short circuit together. The fill-factor (F_f) was obtained by the equation,

$$F_f = \frac{P_m}{P_T} = \frac{I_m V_m}{I_{sc} V_{oc}}$$

The quantum yield of a radiation-induced process was the number of times that a defined event occurred per photon absorbed by the system. Thus, the quantum yield was a measure of the efficiency with which absorbed light produces some effect.

The quantum yield (Y) was obtained by the equation,

$$Y = \frac{1.32x10^3}{\lambda_{(nm)}} x \frac{J_{sc}}{P_{in}}$$

where, J_{SC}= the short-circuit current density

λ= the wavelength of incident monochromatic light

The internal series resistance (R_s) was calculated by the equation, $R_S = \frac{V - V_{OC}}{I_{SC}}$.

The photovoltaic 170arameters calculated from I-V illumination, conversion efficiency (η_{con}), fill-factor (F_f), quantum yield (Y) and series resistance (R_s) are listed in Table 3.

The various viscosity level of ZnTe film dependence of conversion efficiency (η_{con}) is represented in Fig.8(a). From the figure, it was observed that the maximum efficiency occurred to cell at 32.22 cP viscosity level. The viscosity level dependence of the fill factor of ZnTe film was calculated and described in Fig.8(b). The maximum fill factor was 0.309 at viscosity level of 26.65 cP. Fig .8(c) Shows the quantum yield and ZnTe viscosity level plot for all ZnTe films. The maximum value of quantum yield occurred at 32.22 cP.

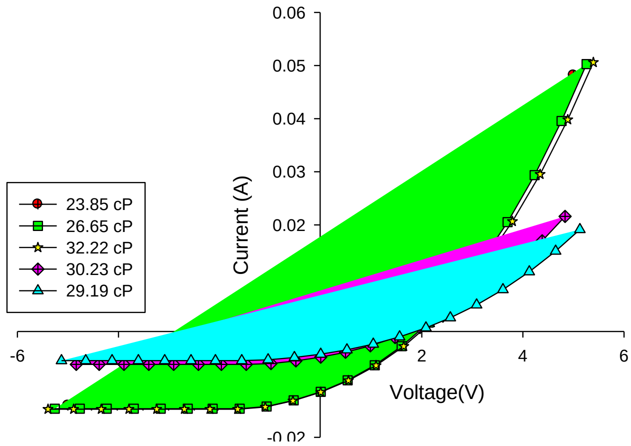


Fig.6(a) I-V characteristics of ZnTe films at different viscosity levels under illumination

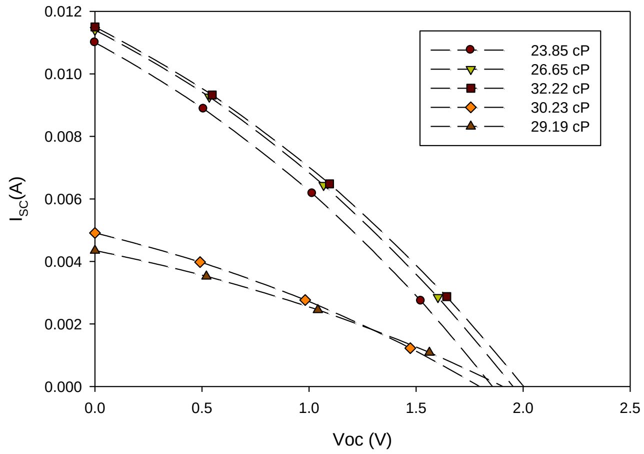


Fig.6(b) I_{sc}-V_{oc} characteristics of ZnTe films at different viscosity levels under illumination

Table 2 I_m, V_m, P_m, I_{sc} and V_{oc} at different viscosity levels

Viscosity (cP)	I_m(A)	V_m(V)	P_m(W)	I_{sc}(A)	V_{oc}(V)
23.85	6.18×10^{-3}	1.005	6.21×10^{-3}	1.10×10^{-2}	1.854
26.65	6.43×10^{-3}	1.063	6.83×10^{-3}	1.14×10^{-2}	1.938
32.22	6.50×10^{-3}	1.094	7.11×10^{-3}	1.16×10^{-2}	1.995
30.23	2.74×10^{-3}	0.985	2.69×10^{-3}	0.49×10^{-2}	1.781
29.19	2.42×10^{-3}	1.037	2.50×10^{-3}	0.44×10^{-2}	1.906

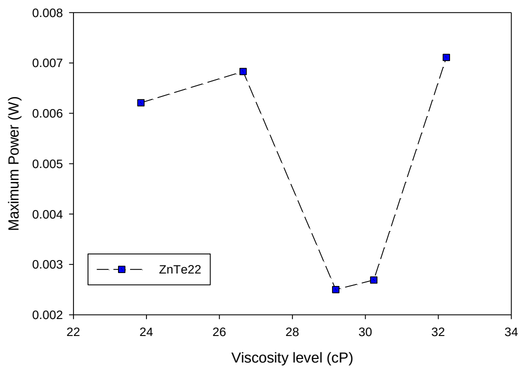
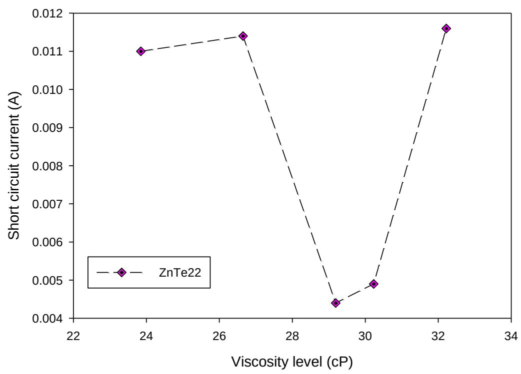


Fig.7(a) Variation of maximum power and viscosity levels of ZnTe film



Fi.7(b) Variation of short circuit current and viscosity levels of ZnTe film

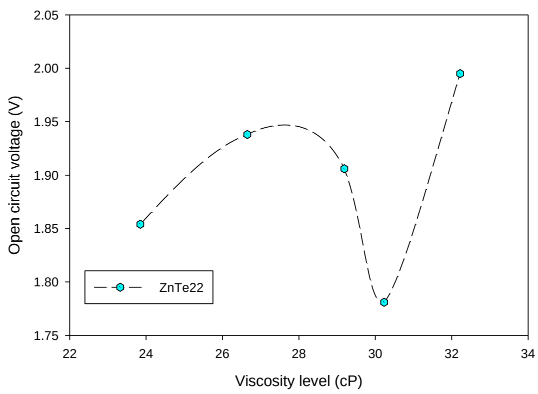


Fig.7I Variation of open circuit voltage and viscosity levels of ZnTe film

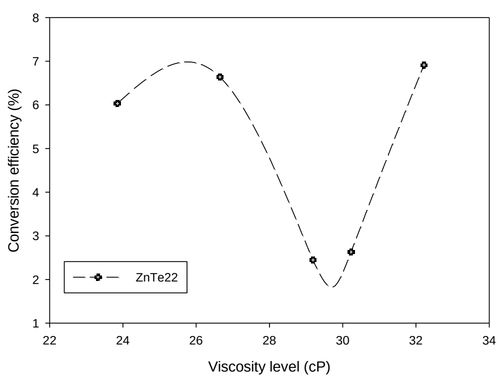


Fig .8(a) Variation of conversion efficiency and viscosity levels of ZnTe film

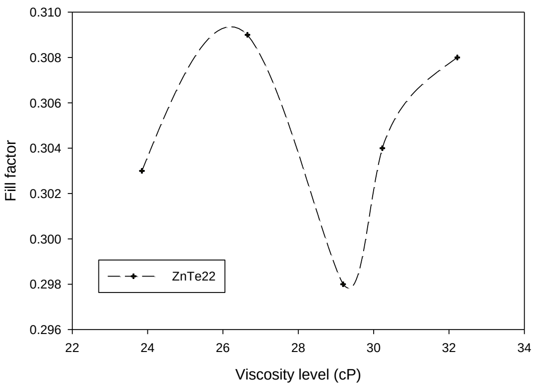


Fig.8(b) Variation of fill factor and viscosity levels of ZnTe film

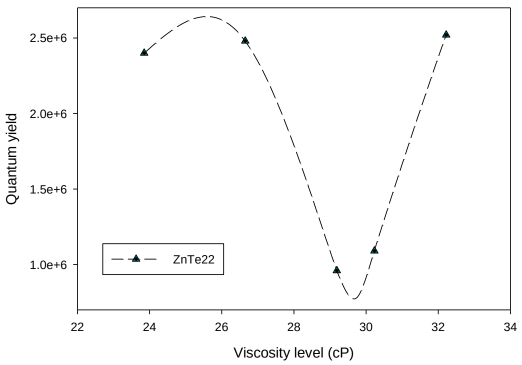


Fig.8(c) Variation of quantity yield and viscosity levels of ZnTe film

Table 3 The photovoltaic parameters calculated from I-V characteristics

Viscosity (cP)	η_{con} (%)	F_f	Y	$R_s(\Omega)$
23.85	6.034	0.303	$2.40x10^6$	285.00
26.65	6.638	0.309	$2.48x10^6$	268.75
32.22	6.908	0.308	$2.52x10^6$	259.69
30.23	2.631	0.304	$1.09x10^6$	643.84
29.19	2.445	0.298	$0.96x10^6$	698.35

Conclusion

The ZnTe electroplated films with Ni conductive layers in different viscosity levels were studied for current–voltage characteristics under illumination. The conversion efficiency, fill factor, quantum yield and series resistance of these films were determined by the analysis of I-V curves under illumination. The largest value of conversion efficiency (6.908 %) was found at the ZnTe film with kinematic viscosity of 32.22cP. The quality of the grown ZnTe film on stainless steel substrate is good, based on the results of the electrical characterization. Hence, the ZnTe electroplated film can be used in photovoltaic application.

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