

Electrical study of Cu-CdS and Zn-CdS Schottky junctions

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Schottky junctions (Cu-CdS and Zn-CdS) have been formed by vacuum evaporation of Cu and Zn on to cadmium sulfide (CdS) thin films. I-V Characteristics of these junctions have been recorded at room temperature using Keithley Electrometer. I-V Curves of these junctions show rectifying behaviour with low forward voltage drop. The other junction parameters such as barrier height, ideality factor, series resistance and saturation current have also been calculated, which are in good agreement with the results obtained by other workers. The Cu-CdS and Zn-CdS junctions have also been fabricated by screen-printing technique and electrical study has been done on these junctions to obtain the junction parameters.

(Received March 17, 2008; accepted April 2, 2008)

Keywords: Cadmium sulfide, I-V characteristics, Schottky junction, Series resistance

1. Introduction

Schottky diodes consist of a metal layer that contacts a semiconductor element. The metal/semiconductor junctions exhibit rectifying behaviour [1-3], allowing the current to pass through the structure more readily with one polarity than the other. Schottky diode shows high-speed response to bias because it does not rely on holes or electrons recombining when they enter the opposite type of region as in the case of a conventional diode. By making the device small the normal RC type time constants can be reduced, making these diodes an order of magnitude faster than the conventional PN diodes. Due to this reason Schottky diodes are very popular in fast-switching digital circuits. The forward voltage drop is lower making the Schottky diode ideal for use in power rectification applications. Most Schottky diodes are used in high frequency application as a mixer or detector diode [4].

In metal-semiconductor junctions, most representative of these semiconductors are CdS, CdSe, which exhibit interface behaviour midway between those of covalent and ionic semiconductors [5]. Cadmium sulfide (CdS) is very popular in opto-electronic devices due to their good optical and electrical properties [6,7]. The usual materials and techniques for making electrical contacts to CdS film are not satisfactory. The I-V characteristics are erratic and nonlinear, the photocurrent noise is excessive and there is a spurious photovoltaic effect, all associated with poor, high-resistance contacts [8]. It has been found that CdS has ability to make both ohmic and Schottky contacts with the metals [9]. A lot of work has been done on the study of ohmic contact on CdS but no study so far has been done on Schottky contacts on CdS films for electronic applications. Most of the monovalent elements like Ag, Cu, Zn etc. make Schottky contact with CdS because the work function of these elements are greater than work function of CdS.

In this present work Cu-CdS and Zn-CdS junctions have been formed by vacuum evaporation of Cu and Zn on to cadmium sulfide (CdS) thin films. I-V Characteristics of these junctions have been recorded at room temperature using Keithley Electrometer. The barrier height, ideality factor, series resistance and saturation current have also been calculated. Cu-CdS and Zn-CdS junctions have also been prepared by screen-printing technique as well and electrical measurements have also been done to see the effect of different preparation technique.

2. Sample preparation

2.1 Material preparation

CdS has been prepared by chemical method using CdCl₂ and H₂S. In this method an appropriate ratio of cadmium chloride is taken in solution form. This solution is mixed thoroughly using magnetic stirrer for 20 minutes. H₂S gas produced by heating thiourea was then passed through this solution. The yellow precipitate obtained in the above process was filtered. This precipitate was then dried in open atmosphere. When precipitate was completely dried, it was then crushed to fine powder by grinding process [10-12].

2.2 Junction preparation

Above obtained powder of CdS is now used to prepare junctions of Cu-CdS and Zn-CdS by vacuum evaporation and screen-printing methods. Initially chemically prepared cadmium sulfide (CdS) was deposited on glass substrate by thermal vacuum evaporation method. Thickness of CdS coating was 0.55 μm. After that Cu and Zn metals were evaporated on CdS films to make Cu-CdS and Zn-CdS junctions respectively. Thicknesses of Cu and Zn metal films were 0.5 μm and 0.53 μm respectively.

Commercially available copper strip of thickness 0.05mm has been used as substrate for Cu-CdS junction and CdS has been printed on Cu-strip using screen-printing technique. The paste of CdS for screen-printing was prepared by using cadmium chloride as an adhesive source and ethylene glycol as a binder. The weight of cadmium chloride was only 10% of the weight of CdS. The paste was then screen-printed on Cu-strip. CdS printed Cu-strip was then sintered in an oven at 300 °C for 15 minutes for ensuring a good adhesion. Thickness of CdS film is 0.05 mm. Now Zn metal film was further screen-printed on CdS film and the so prepared sample was again sintered at 300 °C for 15 minutes. Thickness of Zn metal film was 0.05mm.

3. Results and discussion

The current-voltage characteristics of Cu-CdS and Zn-CdS junctions made by both techniques were determined using Keithley Electrometer/High Resistance meter 6517 A at room temperature. The electrical contacts were made by silver paste on samples. Keithley Electrometer has an in built capacity of output independent voltage source of ± 1000 volt. The voltage is applied across the sample to measure the current through the sample.

The I-V characteristics of these junctions show the rectification behaviour, which indicates the formation of the barrier at the Cu-CdS and Zn-CdS interfaces. The Schottky equation, which describes the evaluation of current as a function of the applied voltage is given below:

$$I = I_s [\exp (eV/nk_B T) - 1] \quad (1)$$

and

$$I_s = A^* T^2 \exp (-e\Phi_b/k_B T) \quad (2)$$

Where e is the charge on electron, V is the applied voltage, n is the diode ideality factor, k_B is the Boltzmann constant, T is the temperature, Φ_b is effective barrier height, A^* is effective Richardson constant and I_s is the reverse saturation current.

The Current-Voltage characteristics of Cu-CdS and Zn-CdS junctions made by vacuum evaporation technique are shown in Figs. 1&2.

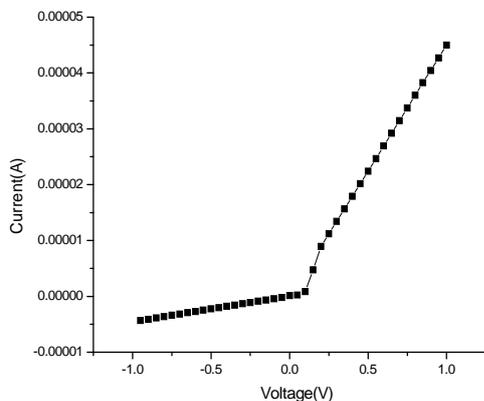


Fig. 1. I-V characteristics of Cu-CdS junction.

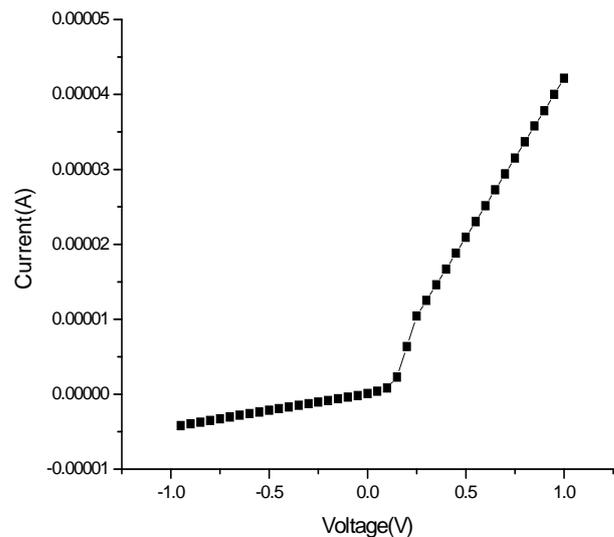


Fig. 2. I-V characteristics of Zn-CdS junction.

A space charge layer is created at the Cu-CdS and Zn-CdS interface. The I-V characteristic of Cu-CdS and Zn-CdS junctions under the forward bias condition shows the exponential behaviour in very low voltage range (0.0-0.2 volt). This is due to decrease in the width of depletion region at the junction. Beyond this voltage the I-V dependence is almost linear because the depletion layer is minimized at the interface and Cu film behave as series resistance in the Cu-CdS junction. Similarly Zn film behaves as series resistance in Zn-CdS junction at high voltage.

In the reverse bias the depletion layer increases due to introduction of high barrier potential and almost all current is just because of minority charge carriers of CdS. This produces fairly small current in the junction. The reverse saturation current (I_s) is determined by interpolation of exponential slope of I at $V=0$ and the value of diode ideality factor has been calculated using equation (1). It has been found that the reverse saturation current (I_s) and barrier height (Φ_b) of Cu-CdS and Zn-CdS junctions are 4.52×10^{-7} A and 0.72V and 4.786×10^{-7} A and 0.73V respectively. The diode ideality factor is 1.35 and 1.37 for Cu-CdS and Zn-CdS junctions respectively, which is in good agreement as obtained by other workers [13]. The ideality factor of an ideal Schottky junction is unity. The value of ideality factor greater than unity is associated with Fermi-level pinning at the interface [14-18] or relatively large voltage drops in interface region. Surface defects produce electronic energy levels in the band gaps of CdS semiconductor. These levels can pin the Fermi energy at metal-semiconductor interfaces and cause Schottky-barrier formation. The value of series resistance (R_s) has also been calculated, which is 0.153 K Ω and 0.165 K Ω for Cu-CdS and Zn-CdS junctions respectively. These junction parameters are helpful in the fabrication of

Cu-CdS and Zn-CdS Schottky barrier diodes. The electrical measurements have also been done on Cu-CdS and Zn-CdS junctions made by screen-printing method. The I-V characteristics of these junctions are shown in figures 3&4.

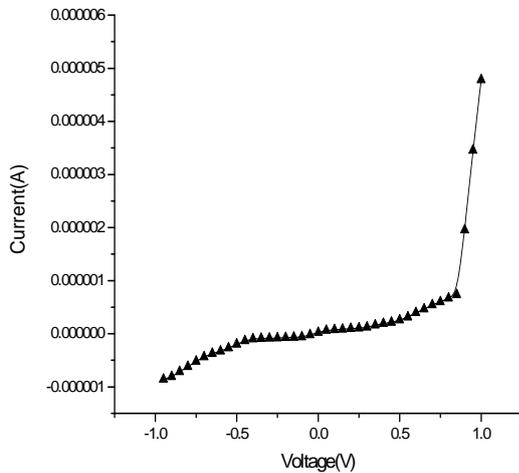


Fig. 3. I-V characteristics of Cu-CdS junction.

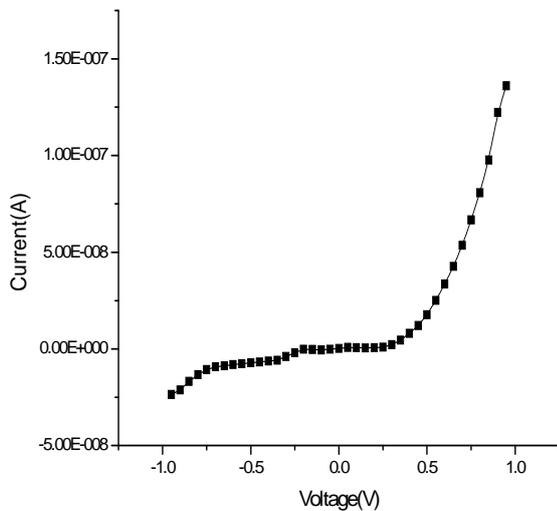


Fig. 4. I-V characteristics of Zn-CdS junction.

The I-V characteristics of these junctions also show the rectification behaviour. The I-V characteristics of Cu-CdS and Zn-CdS junctions under the forward bias condition show the exponential behaviour in low voltage range (0.0-0.75 volt). This was again due to decrease in the width of depletion region at the junction. After this voltage the I-V dependence is again almost linear because the depletion layer is minimized at the interface and Cu strip behave as series resistance in the Cu-CdS junction. Similarly Zn film behaves as series resistance in Zn-CdS junction at high voltage. It was found that in the reverse

bias the current becomes saturated at 1.73×10^{-7} A and 1.0425×10^{-8} A for Cu-CdS and Zn-CdS junctions respectively. The values of barrier height (Φ_b) and series resistance (R_s) are 0.82 V and 4.347 K Ω and 0.89 V and 5.02 K Ω for Cu-CdS and Zn-CdS junctions respectively. The diode ideality factor is 2.78 and 3.51 for Cu-CdS and Zn-CdS junctions respectively.

The difference of values of junction parameters of Cu-CdS and Zn-CdS junctions made by both techniques is attributed to the roughness of the surface of film. The surface of thick films made by screen-printing technique is not uniform over the whole area. By vacuum evaporation method more uniform surface of thin films could be obtained with the help of vacuum of the order of 2×10^{-5} Torr. By using this technique, compactness of materials increases due to the decrease in surface imperfection. This brings out a decrease in barrier potential and hence an increase in electrical conduction.

Since the screen-printed films were very thick the probability of surface imperfection is greater. Hence surface defects can be minimized by reducing the thickness of films and better junctions can be prepared by this cheaper technique than the vacuum evaporation technique.

4. Conclusion

The Schottky junctions (Cu-CdS, Zn-CdS) have been fabricated using vacuum evaporation and screen-printing methods. The I-V characteristics of these junctions show a rectifying behaviour. The junction parameters such as barrier height, ideality factor, series resistance and saturation current of junctions prepared by vacuum evaporation method were in good agreement with those obtained by other workers. The junctions prepared by screen-printing method show junction parameters, which are quite different from ideal behaviour. This departure from the ideal behaviour is explained on the basis of surface imperfection. By reducing the thicknesses of screen-printed films, surface defects can be minimized hence a good junction can be obtained by this cheaper technique.

Acknowledgments

Authors are thankful to Ms. Vinodini Shaktawat, Ms. Manasvi Dixit, Ms. Deepika Chaudhary, Mrs. Rashmi Saxena, Mr. Kuldeep S. Rathore, and Mr. Praveen Kumar Jain for their helps in various ways during the course of this work.

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