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# STUDIES ON BARRIER CHARACTERISTICS OF THIN FILM Al/CdS SCHOTTKY JUNCTIONS BY I-V-T MEASUREMENTS OVER A WIDE TEMPERATURE RANGE

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## ABSTRACT

**Cadmium sulphide (CdS), a member of group II-VI semiconductors is one of the promising materials from its applications point of view. The present investigations are about the preparation and electrical characterization of CdS thin films. CdS thin films with thickness around 700nm have been deposited by vacuum evaporation technique keeping substrates at 400K. Characteristic parameters of Schottky junctions formed by a thermal-vapor-deposition of 500nm Al films on pre-coated CdS glass substrates were obtained experimentally from the I-V characteristics in the temperature range of 40-300 K. Diode parameters, such as the zero bias barrier height $\phi_{b0}$, the flat band barrier height $\phi_{bf}$ and the ideality factor $\eta$, calculated using thermionic emission theory were found to be strongly temperature dependent. It is found that as the temperature decreases the rectification properties of Al/CdS deteriorates, may be due to increasingly dominant role played by interfacial states and inhomogenities.**

***Key words:*** *Al/CdS, Low Temperature I-V, Barrier characteristics, Schottky junction*

## INTRODUCTION

Due to their excellent electronic and optical properties, II-VI compounds have been utilized for many opto-electronic devices such as LEDs, radiation detector etc. [1, 2]. Due to very good interface properties CdS and CdSe were used extensively in bulk crystalline and in thin film forms for device applications in association with varieties of substrates and contact materials. A clear understanding of the physical principles underlying the properties of these interfaces is therefore essential in order to develop more refined practical devices based on this material. Various efforts have been made to study the properties of the interfaces through the measurements of I-V characteristics in Au/CdS junction by Chavez *et al* [2] and by Patel *et al* [3]. Studies of electrical properties have also been made by Gupta *et al* [1] for Cu/CdS and Zn/CdS Schottky junctions by determining various junction parameters. However, very little efforts have been made to study the properties of interfaces in the case of Al/CdS junctions. The present paper reports results of investigations on Al/CdS schottky interfaces carried over a wide temperature range.

## EXPERIMENTAL DETAILS

CdS thin films were prepared by thermal evaporation of a stoichiometric powdered compound (99.995% pure, from ALDRICH Co.) in a residual pressure of $10^{-6}$ torr. Cleaned glass slides were used as substrate and molybdenum as a boat. Glass substrates were first cleaned with detergent solution and then with distilled water. After that the dried substrates were again cleaned with acetone and then finally air dried. The films were grown by maintaining the substrates at 400K to ensure absence of contaminations on the surface for film deposition. The rate of evaporation was kept at 1Å/Sec. and the thickness of the films deposited was around 700nm, (both controlled by Sigma SQC 310 deposition controller under the vacuum better than $10^{-6}$ torr). Chemical composition of the deposited films was analyzed by Energy dispersive analysis of X-Rays (EDAX). In order to obtainn the schottky barrier structure Al films of 500nm were deposited through suitable metal mask ($1cm^2$) on CdS films. Ohmic contacts for external circuit connection to CdS and Al films were taken using an adhesive and conductive silver paste (Elteck corporation-Bangalore, 1228).

## RESULTS AND DISCUSSION

### EDAX STUDIES

The EDAX of prepared films was carried out using the electron microscope at SICART, V. V. Nagar. The result of EDAX is shown in Fig. 1. The stoichiometric proportion of the constituent elements obtained from EDAX and expected values are nearly matching as given in Table 1. Thus the prepared films have been found to be impurity free and stoichiometric in nature.

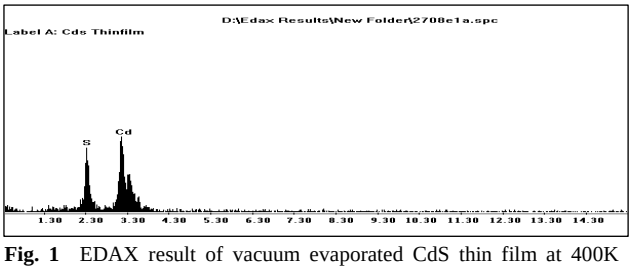


**Fig. 1** EDAX result of vacuum evaporated CdS thin film at 400K substrate temperature.

**Table - 1** Elemental proportion of Cd and S in CdS thin films done by EDAX.

| Elements | Wt (%) obtain from EDAX | Wt (%) calculated by theoretical |
|---|---|---|
| Cd | 77.03 | 77.80 |
| S | 22.97 | 22.19 |

### I-V CHARACTERISTICS STUDIES.

The I-V-T data were acquired using Keithley 4200 semiconductor characterization system along with Lakeshore Closed Cycle Refrigerator (CCR 75014). The temperature was monitored and controlled by Lakeshore temperature controller (Model 340) with an accuracy of ±0.1K. I-V data were taken

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from 300 K down to 40 K at an interval of 20 K. The measured I-V characteristics in the temperature range 300-40 K are shown in Fig. 2.

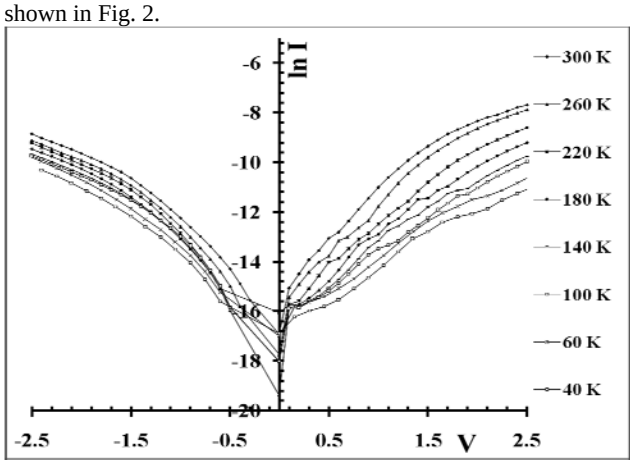


**Fig. 2** lnI-V characteristic of Al/CdS Schottky barrier in the temperature range 300-40K.

From Fig. 2 it is seen that the current under forward bias is relatively high. These junctions also show a reduced rectification ratio 31 (V=2.5V) at 300 K, a consequence of the unsaturated current under reverse bias [4]. The diodes show an abnormal inversion of their rectification properties and the reverse-bias current is higher than the forward-bias current below 200K.

Current transport through the Schottky barrier diode is mainly due to majority carriers and obeying the thermionic emission model [5, 6] at low forward biases V. The current in such cases can be expressed as

$$I = I_0 \left[ \exp\left( \frac{qV}{\eta k T} \right) - 1 \right] \quad (1)$$

where q is the electron charge, η is the ideality factor, k is the Boltzmann constant, T is the absolute temperature, $I_o$ is the reverse saturation current. The values of $I_0$ were obtained by extrapolation of the low forward bias linear region of lnI-V curves to zero applied voltage and were used to calculate the zero bias barrier height $\phi_{b0}$ from Eq. 2.

$$\phi_{b0} = \frac{kT}{q} \ln\left( \frac{A A^* T^2}{I_0} \right) \quad (2)$$

Where A is the diode area (1 $cm^2$), A* is the Richardson constant (23.4 $A/K^2cm^2$) [6]. The ideality factor is given by

$$\eta = \frac{q}{kT} \left( \frac{dV}{d(\ln I)} \right) \quad (3)$$

The ideality factor was calculated from the slope of the linear region of the forward lnI-V characteristics (fig.2.). The flat band barrier height $\phi_{bf}$ is given by

$$\phi_{bf} = \eta \phi_{b0} - \left[ (\eta - 1) \frac{kT}{q} \ln\left( \frac{N_A}{N_C} \right) \right] \quad (4)$$

Where $N_A$ is effective density of state and $N_C$ is carrier concentration.

The zero-bias barrier height $\phi_{b0}$ decreased with decreasing temperature and flat band barrier height $\phi_{bf}$ increased with decreasing temperature as shown in Fig. 3. Various factors can contribute to a reduction in zero bias barrier height at lower temperatures such as non homogeneity present at Al/CdS interface, generation and recombination currents in the space charge region, the effect of the image force, and, at low temperatures, tunneling processes and thermally assisted tunneling processes from states in the forbidden gap. The ideality factor η tends to decrease showing decreasing non-ideal behavior with increasing temperature as shown in Fig 3. This behavior may be due to current transport across the Al/CdS interface as a result of a thermally activated process because at low temperatures the electrons are able to surmount the lower barriers.[7] Therefore, current transport will be dominated by current flowing through patches with a lower Schottky barrier height and a greater ideality factor. The value of ideality factor greater than unity is also associated with Fermi-level pinning at the interface [8-10] or relatively large voltage drops in interface region. Interfacial oxide layer may also be the possible cause for higher value of ideality factor [11].

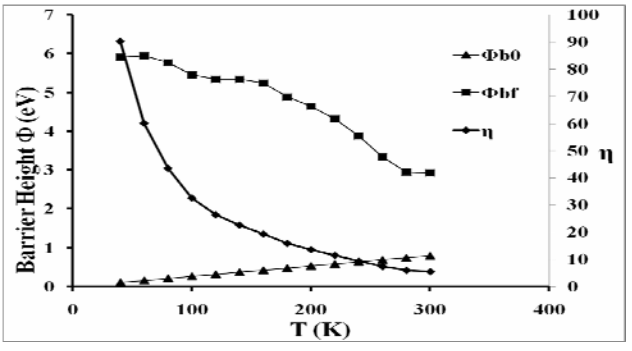


**Fig. 3**Variation of η, $\phi_{b0}$ and $\phi_{bf}$ with a temperature.

## CONCLUSIONS

Measurement of I–V characteristics of Al/CdS Schottky barriers in the temperature range 40–300K shows that low voltage I-V characteristics follow a thermionic emission mechanism under both forward and the reverse bias conditions. The diodes show an abnormal inversion of their rectification properties below 200K and the reverse-bias current is higher than the forward-bias current. The zero-bias barrier height $\phi_{b0}$ decreases, ideality factor η increases with decrease in temperature. The changes are quite significant at lower temperatures as reflected in the flat-band barrier height $\phi_{bf}$ which is always larger than zero-bias barrier height $\phi_{b0}$. The deviation from thermionic emission model at lower temperatures seems to be related to various kind of mechanisms e. g. inhomogenities, thermally assisted tunneling etc.

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