

MEMORY SWITCHING OF THIN CdS FILMS

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ABSTRACT

Memory switching in thin CdS films has been studied and various switching parameters evaluated. The switching behaviour is attributed to the filling and emptying of barrier-surrounded traps whose existence is well defined.

INTRODUCTION

EXTENSIVE studies have been made on memory switching of wide band-gap polycrystalline^{1,2}, amorphous semiconductor materials^{3,4}, various thin film heterojunctions^{5,7} and other devices^{8,9}. Memory in such a system has been attributed to a non-electronic process of phase transformation¹⁰ or thermal diffusion of electrode metal¹¹. However, these processes appear to be incapable of giving satisfactory explanation to the observed memory switching behaviour of the system. The present investigation has been made with a view to ascertaining the mechanism responsible for the observed behaviour in thin CdS films sandwiched between aluminium electrodes.

EXPERIMENT

Thin films of CdS sandwiched between two aluminium electrodes were fabricated by vacuum evaporation technique on thoroughly cleaned glass slides by suitable masking arrangement. After each deposition, pellets of CdS were made before evaporation in order to avoid spurring of the material. The thickness of the film was monitored by the current through the heating filament and time of evaporation of CdS. Electrical contacts were made by pressure contact.

RESULTS

The study of current voltage characteristic of the system exhibited two irreversible stages of conductivity. Initially a very low conductivity is observed and this is termed as virgin stage. This stage transforms irreversibly to a higher conductivity stage termed as post-breakdown stage, when the voltage across the sandwich exceeds a threshold value of about 7 to 10 volts. This stage exhibits memory switching between its two substrates of conductivity, viz., low and high conductivity states. An explanation to different breakdown potentials for transition has been given in terms of different effective ionized donor densities in the two states. This difficulty can be easily solved, if we know the contact field at breakdown. The contact field is

calculated to be of the order of 10^6 V/cm by using the well known expression¹².

$$E = \left| \frac{2 q N (V + V_b)}{\epsilon \epsilon_0} \right|^{\frac{1}{2}}$$

where E is the contact field, V_b is the diffusion potential, q is the charge, ϵ is the dielectric constant and ϵ_0 is the permittivity of the free space. V is the applied voltage and N is the ionized donor density.

Further, a detailed study of the conduction process of the system revealed that the conduction mechanism in both the stages of conductivity is due to field-induced generation of carriers followed by impact ionization.

The variation of current with voltage at different temperatures has been studied under steady-state conditions. The current decay after thermal stimulation gives the information about the energy and capture cross-section in the polycrystalline thin films. The current is observed to be time dependent and it assumes a steady state value after some time. All, but the shallowest traps are filled at room temperature when a fixed biasing potential is applied across the specimen. The number of majority carriers, i.e., ionized donor density, increases disturbing the equilibrium due to increase in the current. The trapping of excess carriers then takes place predominantly by shallow traps due to elevated temperatures. The decay of current, then starts taking place and after some time an appreciable fall is observed. Based on the above analysis of the current decay, two trap levels at 0.06 eV and 0.08 eV with respective capture cross-section $4 \times 10^{-24}/\text{cm}^2$ and $0.04 \times 10^{-24}/\text{cm}^2$ have been evaluated.

CAPACITANCE STUDY

The study of the space charge capacitance of the diodes exhibited the existence of Schottky type space-charge capacitance due to thin aluminium oxide layer between bottom aluminium electrodes and cadmium sulphide. Further the ionized donor density in the pre-breakdown state is $8.1 \times 10^{17}/\text{cm}^3$.

cm³ and in two reversible states are $8.8 \times 10^{17}/\text{cm}^3$ and $18.8 \times 10^{17}/\text{cm}^3$ respectively¹³. It is thus obvious from these data that the effective ionized donor densities in the pre-breakdown and low conductivity states are almost the same and show a marked variation from this value in the high conductivity stage.

The temperature variation of capacitance at low fixed bias voltage is shown in Fig. 1. This figure

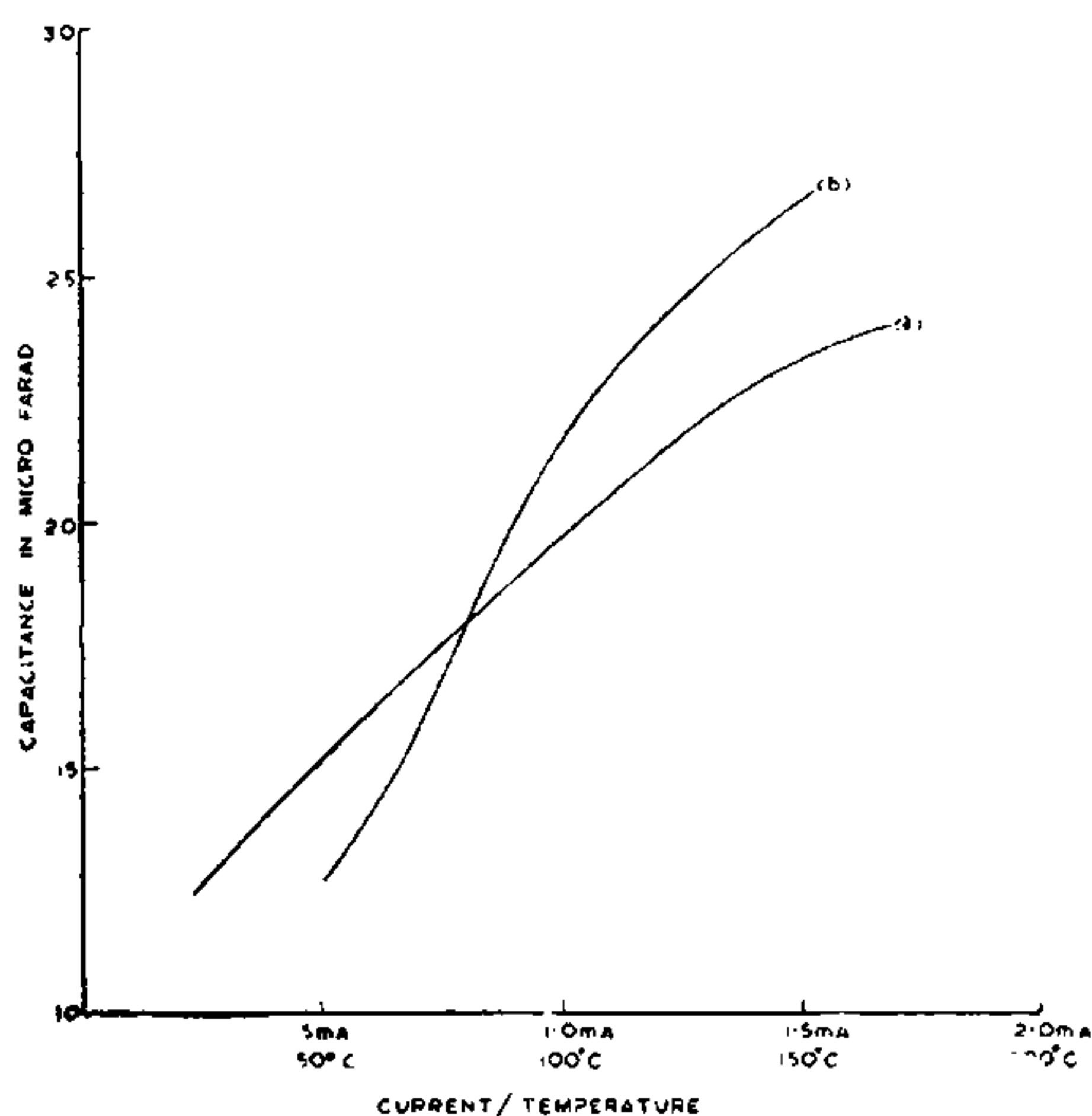


FIG. 1. Variation of capacitance with (a) current and (b) Temperature (at 2 volts).

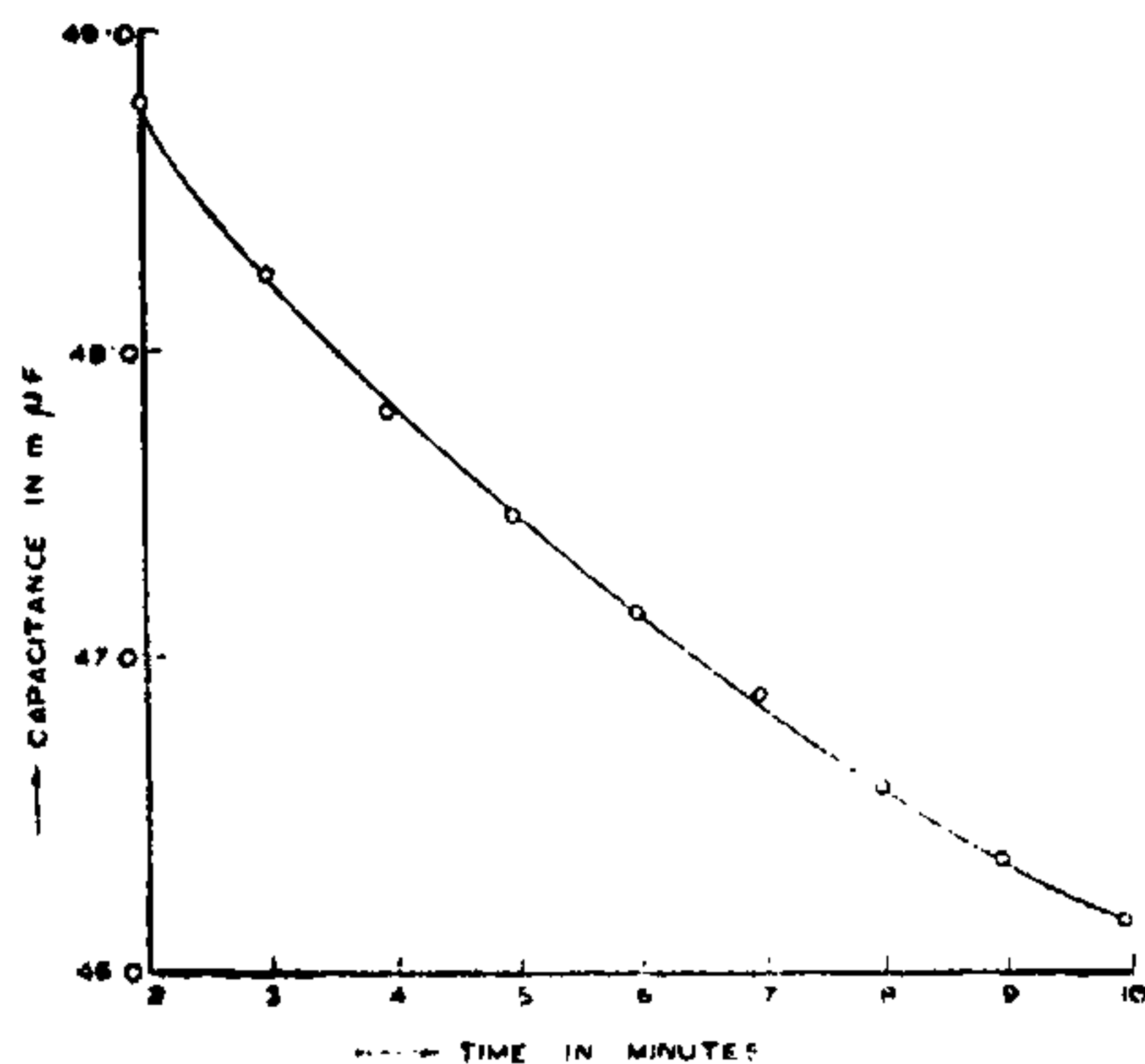


FIG. 2. The variation of capacitance with time (at 2 volts).

also shows the variation of capacitance with current at a constant voltage, current being changed by increasing the temperature. It is evident from this, that the capacitance and current

increase with temperature. The capacitance will increase only if trap ionization is the cause for increased current. Thus, it may be concluded that the major increase of the current with rising temperature is due to impact ionization of traps.

The capacitance of the system was also found to change its value with time immediately after a low bias was applied as shown in Fig. 2 which attains a steady value after about 25 minutes. The capacitance at fixed bias increases with time in the forward bias and decreases in the reverse bias operation. Furthermore this fall in capacitance was not observed when the sandwich was in the high conductivity state. It may, therefore, be concluded that the origin for both the phenomena, *i.e.*, change in capacitance and current with temperature are associated with ionization of slow traps.

DISCUSSION

The inferences drawn from these experiments are used as a probe to explain the mechanism responsible for the observed memory switching behaviour of the system. The switching behaviour is attributed to either electrode metal diffusion, phase transformation or filling and emptying of barrier surrounded traps. The former alternatives, *i.e.*, electrode metal diffusion and phase transformation, do not yield satisfactory explanation to the change of donor density by a factor of two in different states of post-breakdown stage. The rapidity of the switching behaviour of the system also does not favour the idea of phase transformation. Cadmium sulphide in contact with aluminium oxide forms a depletion type of contact as shown in Fig. 3. Cadmium sulphide is an N-type semi-

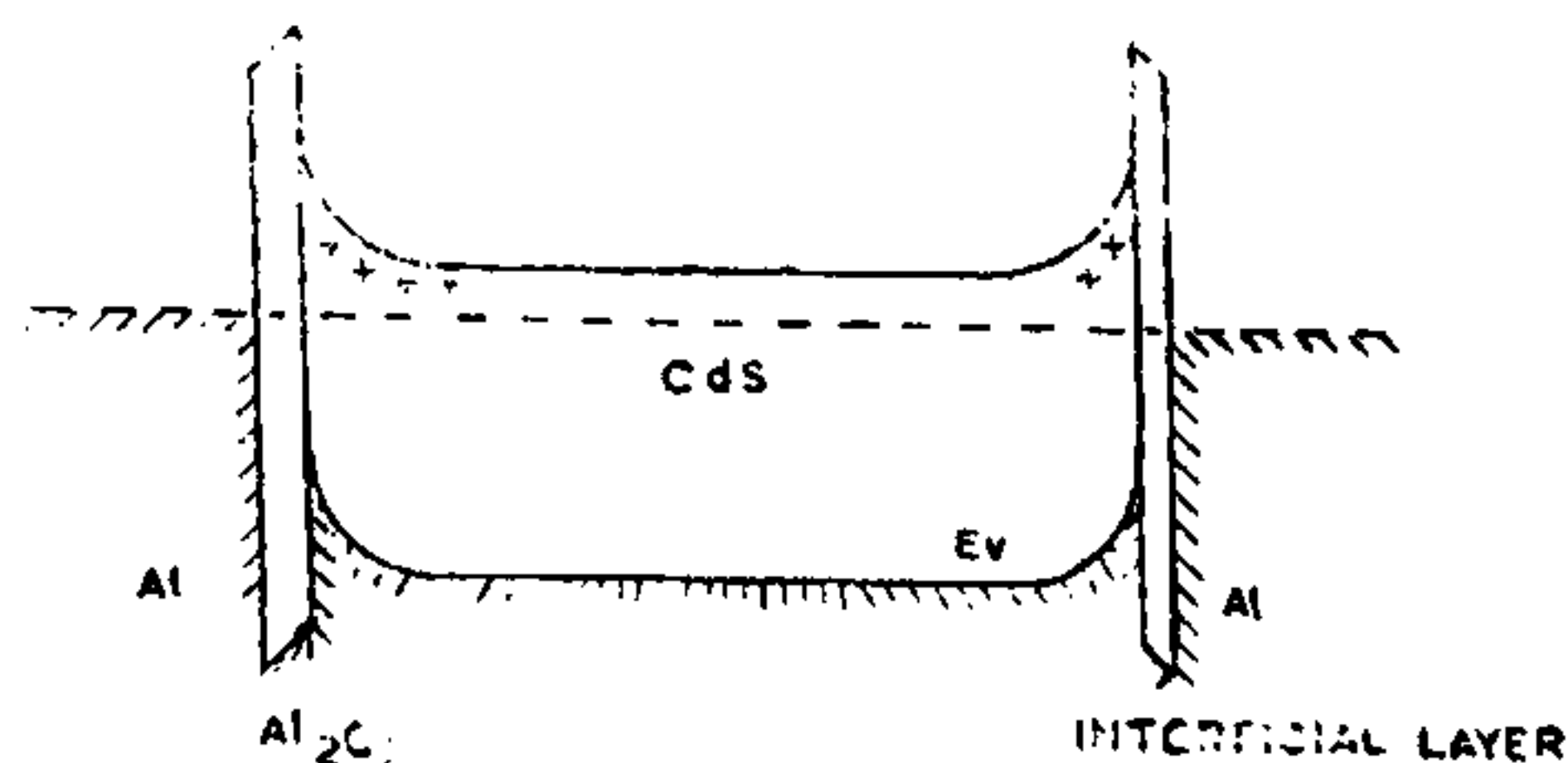


FIG. 3. Energy Band diagram of Al-Al₂O₃-CdS Film.

conductor and hence electrons are depleted from aluminium oxide cadmium sulphide interface when positive voltage is applied to the top electrode of the sandwich. For larger voltage, impact ionization dominates field ionization. Thus by Avalanche process, trapping centres which are in excess near aluminium oxide-cadmium sulphide interface are emptied out. This causes an increase in the effective

ionized donor density and hence an increase in the field for the same voltage is achieved. The increase in the field will further enhance impact ionization and donor density further increases and the entire process becomes cumulative and instantaneous till all the traps are ionized and switching takes place. The transition from high to low conductivity state can be explained on similar lines. In this case negative bias is applied to the upper electrode (*i.e.*, the direction of the bias is reversed). The reverse bias increases the width of the depletion region near cadmium sulphide aluminium interface and for large applied voltage, impact ionization supercedes field ionization. Thus warm electrons are generated near cadmium sulphide aluminium interface which are trapped by barrier surrounded trapping centres near oxide semiconductor interface. This reduces the effective ionized donor density thereby resulting in a decrease of conductivity.

CONCLUSION

It is thus concluded that the memory switching in the system considered is due to filling and emptying of barrier-surrounded traps, which change its occupancy and hence the conductivity at threshold voltage when switching takes place.

ACKNOWLEDGEMENT

The authors wish to record their sincere gratitudes to Dr. S. S. Banerjee, UGC Professor, for his encouragement throughout the course of the investigation. Thanks are also due to CSIR, India, for supporting the project.

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MAGNETIC PROPERTIES OF COPPER (II) COMPLEXES OF SCHIFF BASES DERIVED FROM PYRROLE-2-ALDEHYDE AND ISOPROPANOLAMINE/2-AMINO-2-METHYLPROPANOL

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ABSTRACT

The synthesis of new copper(II) complexes of Schiff bases derived from pyrrole-2-aldehyde and isopropanolamine or 2-amino-2-methylpropanol is described. The Schiff bases coordinate through O, N and N as tridentate dibasic ligands. The complexes are characterised by magnetic susceptibility (84–294° K), infrared and electronic spectral studies. The magnetic moment of the copper (II) complex of pyrrole-isopropanolamine increases as the temperature is lowered indicating ferromagnetic nature of the complex while that of the copper(II) complex of pyrrole-2-amino-2-methylpropanol decreases with lowering of temperature indicating antiferromagnetic nature of the complex. The difference in magnetic properties has been attributed to the presence of steric hindrance arising out of two methyl groups in the latter complex.

INTRODUCTION

TRIDENTATE dibasic ligands yield metal complexes which frequently exhibit novel structural and magnetic properties¹⁻³. The dibasic character of these ligands force the metal (II) ions to dimerise or polymerise leading to metal complexes with unusual magnetic properties. The size of the chelate rings influence the magnetic properties of the copper (II) complexes⁴. We now report the effect of steric hindrance on the magnetic behaviour

of the copper (II) complexes of Schiff bases. We have prepared new copper (II) complexes with the tridentate dibasic ONN donor ligands I and II and studied the magnetic properties of the complexes from 84 to 294° K.

EXPERIMENTAL

Pyrrole-2-aldehyde (0.02 M) was dissolved in 40 ml ethanol and isopropanolamine (0.02 M) was mixed with 10 ml ethanol. These solutions were