Effect of Insulator Thickness on the Barrier Height of Thin Film MIS Structure

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Abstract: ***Metal-semiconductor and metal-insulator-semiconductor thin films have been prepared using thermal evaporation technique. The value of the barrier height(Φ_{bn}) which was calculated using; experimental(I-V) measurements and activation energy method showed that(Φ_{bn}) increases with increasing insulator thickness.***

Keywords: effect of insulator thickness on the barrier

1. Introduction

Metal-semiconductor and metal-insulator-semiconductor junctions have been studied extensively because of their importance in many applications such as microelectronic products ; T.V, radio, computers ,detectors , and so on[1]. Rectifying metal –semiconductor contacts form an important constituent of most semiconductor technologies. The Schottky barrier height of such contacts are found to be rather lower than is desirable for most device applications[2]. But the introduction of a thin insulator layer between metal and semiconductor has the result of reducing leakage current and increasing barrier height[2,3]. In this paper we have used thermal evaporation technique to prepare Al/a-Se/n-CdTe junction , the effect of insulator thickness on the barrier height (Φ_{bn}) of this junction are discussed.

2. Sample Preparation and Measurements

The data reported in this paper were taken on Al/a-Se/n-CdTe structure formed by vacuum deposition using Edward (E306)high vacuum coating unit at pressure of less than 10^{-5} mbar on glass substrate. The complete sample which are used in our work have been fabricated by four separate evaporation processes to obtain four different layers. High purity aluminum wire was evaporated from a tungsten spiral as a bottom electrode for electrical connection. Cadmium Telluride films were then deposited by thermal evaporation using molybdenum boat as a semiconductor layer.Amorphous Selenium(a-Se) was then deposited using tungsten boat asa source of evaporation to prepare the insulator layer. Then Aluminum layer was deposited over this structure to prepare the metal layer .It should be pointed out that the materials with purity (99.999%) were supplied from Baizers company. Current –voltage characteristics were recorded at various temperatures in the range of (303-413)°K.

The barrier height is one of the most important factor in determining the electrical properties of MIS diodes . The barrier height of MIS junction is defined as the energy needed for an electron at the Fermi level in the metal to enter the conduction band of the semiconductor[4]. The barrier height is generally a critical parameter for several types of devices and basically ;four methods can be used to measure the barrier height of MIS structures[4,5], the methods are:-

a) Current Voltage measurement.
b) Activation energy measurement.
c) Capacitance –Voltage measurement.
d) Photoelectric effect measurement.

Our work deals with the first and second methods:-

a) Current-Voltage Measurement

For moderately doped semiconductors, the(I-V) characteristics in the forward direction with V> $3k_\beta T/q$ is given by [2,4,6]:

$$I = I_o\left(exp.\left(qV/nk_\beta T - 1\right)\right) \quad .....(1)$$

Where q is the electronic charge , n is a quality factor and I_o is the saturation current , which is given by:-

$$I_o = AA^* T^2 \exp\left(-q\phi_{bn}/k_\beta T \quad ....(2)\right)$$

Where A^* ,A,k_β,T,Φ_{bn} are the Richardson constant, effective area of the junction ,Boltzmann constant ,Temperature and barrier height of the junction respectively .The barrier height,Φ_{bn} can be obtained from eq.(2) as:

$$\phi_{bn} = \frac{k_\beta T}{q}.\ln\left(\frac{AA^* T^2}{I_o}\right) \quad ......(3)$$

b) Activation Energy Measurement

The principle advantage of the barrier height determination by means of activation energy measurement is that no assumption of electrically active area is required .In the case of poorly cleaned or incomplete surface, the electrically active area may be only a small fraction of the geometric area. Now from eq(2), we can obtain[4,7,8]:

$$\ln\left(I_o/T^2\right) = \ln(AA^*) - q\phi_{bn}/k_\beta T \quad ...(4)$$

A graph of ln(I_o/T^2) against (1/T) should then be straight line with slope $\left(-q\phi_{bn}/k_\beta\right)$. The intercept of this line at

(1/T=0) could give the product of the electrically active area(A) and the effective Richardson constant (A^*), such graph is often called a Richardson plot[8].

3. Result and Discussion

The (I-V) characteristics for MS; (Al/n-CdTe) junction and for different MIS; ; (Al/ Se/n-CdTe) junction with different insulator thickness; 250 , 750, 1000 and 2000 A° , measured at an atmospheric pressure and room temperature , under ordinary light (power intensity =1 mW/cm^2) were obtained as in Fig.(1), these characteristics showed that when applying a voltage across the sandwich structure, resulted in a low and a stable current with respect to time . However ; the increase in the voltage tended to vary the current with time to time due to the development of a space charge . For comparison Fig(1) shows that at a fixed voltage, the magnitude of the current(I) decreases with decreasing insulator thickness. As a result the saturation current (I_o) will be smaller due to the effect of the increasing thickness of the insulating layer which compels the electrons to tunnel through the additional barrier . And for more adequate verification for these results the|(I-V) characteristics were re-plotted with semilogarithmic scale for the current (I) as shown in Fig.(2) for different junctions .Thus the value of the barrier height (ϕ_{bn}) can be determined by taking the data that resulted from Fig(2) and using Eq.(3).

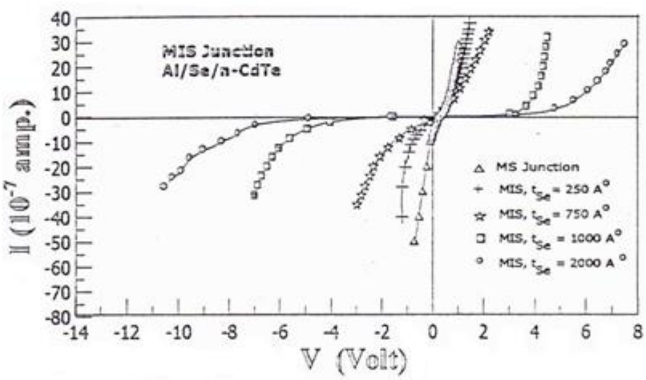

Figure 1: Current-Voltage characteristics of AI/Se/n-CdTe junctions of different thicknesses at room temperature

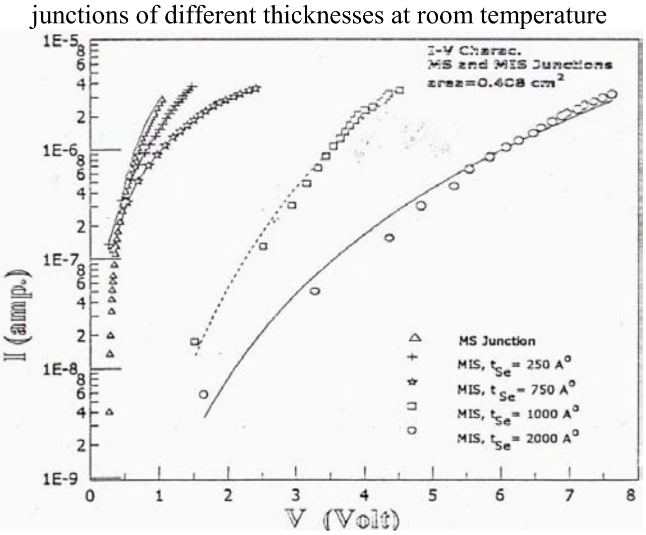

Figure 2: Log I-V characteristics for a forward biased AI/Se.n-CdTe junctions of different thicknesses

Measurement of the temperature dependence of the current-voltage characteristics (activation energy method are make in the dark in the range of(303-413)K°, Figs(3),(4) shows that the current increases with increasing temperature ,which is attributed to a dominant thermionic emission controlling the current flow at elevated temperature , and also can be attributed to the lowering of the junction resistance . this can be further confirmed by the linearity of ln(I_o/T^2) against (1000/T) graph as in Figs(5) ,(6). The graph has a slope (-$q\Phi_{bn}/k_\beta$) ; such a graph is often called a Richardson plot.From these Figs.(5) ,(6) the values of (Φ_{bn}) were calculated.

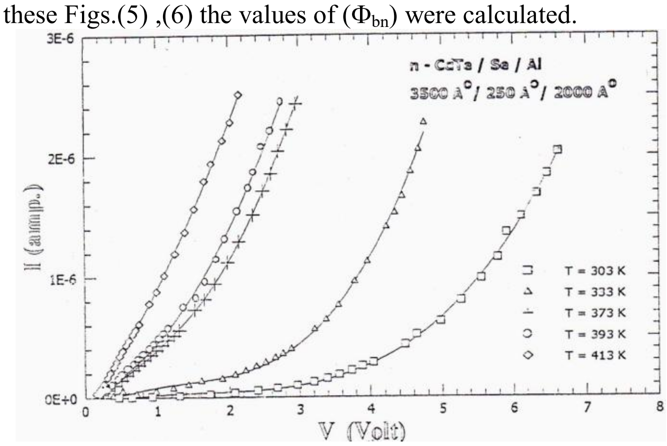

Figure 3: Current-Voltage characteristics of a forward biased AI/Se/n-CdTe junctions at different temperature, insulator thicknesses 250A°.

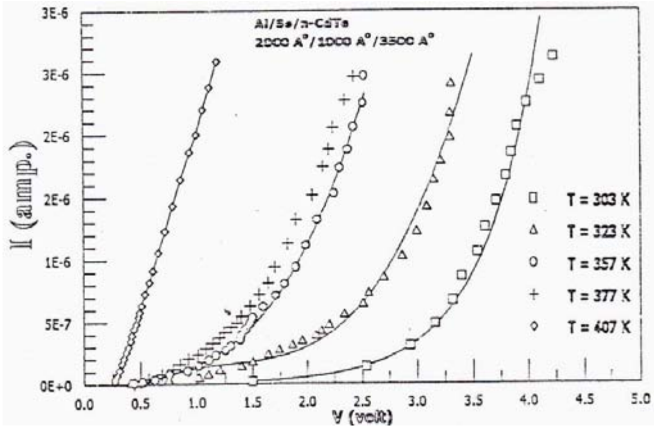

Figure 4: Current-Voltage characteristics of a forward biased AI/Se/n-CdTe junctions at different temperature, insulator thicknesses 1000A°.

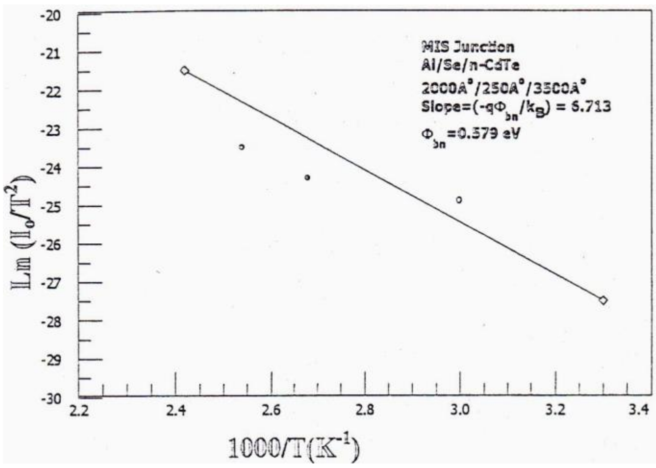

Figure 5: Richardson-plot for AI/Se/n-CdTe junctions for insulator thicknesses 250A°

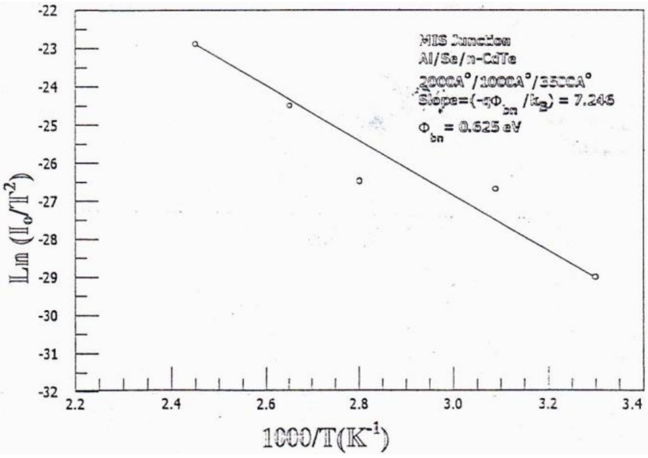

Figure 6: Richardson-plot for AI/Se/n-CdTe junctions for insulator thicknesses 1000A°

From these different techniques of measuring($\emptyset_{bn}$) , it was found to be in the rang (0.544-0.792)eV, which is in agreement with researchers [2,4,9,10], the general behavior of ($\emptyset_1 bn$) was almost the same , where it increased with increasing insulator thickness Fig.(7), this may be attributed to majority carrier electrons as being blocked by the increase in the thickness and decreasing the tunneling probability of electrons through the insulator.

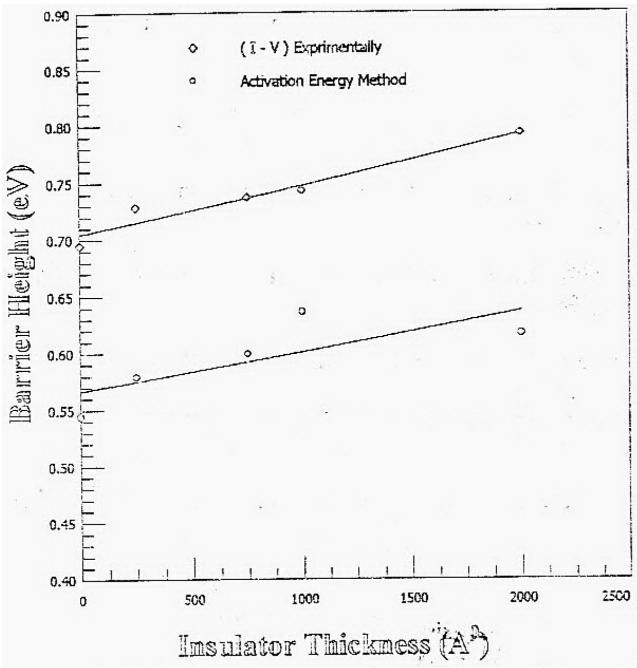

Figure 7: Barrier height variation with insulator thickness for AL/Se/n-CdTe junctions.

4. Conclusion

1) The (I-V) measurements indicated a marked effect of the presence of insulator film on the junction current.
2) The barrier height ($\emptyset_{bn}$) measurement showed that the barrier consists of two parts; the first results from the space charge in the depletion region of the semiconductor ; and the second from the presence of the insulator.
3) Maked difference in the barrier height have been resulted from the two measurement techniques ;(I-V) measurement and activation energy measurements , our interpretation is that, the difference in ($\emptyset_{bn}$)values are due to the increase in the mobility of the majority carriers with increasing temperature in the case of activation energy measurements.

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