The Alternative Electrical Properties of ($Al-CdSe_{0.8}Te_{0.2}-Al$) Capacitor at Room Temperature

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Abstract

This research aims to prepare an ($Al-CdSe_{0.8}Te_{0.2}-Al$) capacitor and study the alternating electrical properties of it at room temperature, and study the possibility of using these films in electronical applications. The A.C. conductivity of as-deposited films have been measured in the frequency range (f =100Hz-400KHz), and it has shown that A.C. conductivity ($\sigma_{a.c}$) increases with the frequency increasing.

The study of the variation of each of the capacitance and real part of the dielectric constant (ϵ_r) with frequency has shown that their values decrease with frequency increasing.

The study of the variation of each of the imaginary part of dielectric constant (ϵ_i) and the loss factor with frequency has shown that their values decrease with frequency increasing and then they began to increase.

Introduction

A semiconductor material is the one whose electrical properties lie in between those of insulators and good conductors. At 0K, there are no electrons in the conduction band and the valence band is completely filled[1].

The energy gap for semiconductors is less than 2eV [1, 2] and for $CdSe_{1-x}Te_x$ it has been found by many researchers like [3] that E_g=(1.46-1.745)eV for $0\leq x\leq 1$, and another researcher [4] found that E_g=(1.47-1.76)eV for $0\leq x\leq 1$.

Semiconductors are considered as fundamental materials in fabricating electronic devices (diodes, transistors, integrated circuits) which are employed in building all electronic circuits[5].

Data storage with phase change materials like chalcogenide alloys is based upon the reversible switching between the amorphous and the crystalline phase [6, 7].

The reversible phase transition between the amorphous and crystalline states, which is accompanied by a considerable change in electrical resistivity, is exploited as a means to store bits of information[8, 9].

(II-VI) compounds like ($CdSe_{1-x}Te_x$) arouse great practical interest owing to the unique properties including their high photosensitivity to electromagnetic and particular radiation [10], and the main reason of these compounds development is their big direct energy gap, so these compounds could be used in lasers and photo emitting diodes in visible range [11].

Cadmium chalcognides have been known to hold great promise in thin films photo electronic devices and photo electrochemical cells [12]. Sulphides, selenides and tellurides of cadmium find applications as photoconductors and electro optical devices [13].

A.C Electrical conductivity

The electrical properties of semiconductors or insulators in thin layers under metallic electrodes are generally different from the properties of the material itself. The available experimental results about the frequency dependence of A.C. conductivity have revealed a considerable similarity of behavior for a very wide range of materials **[14, 15].**

The frequency dependence of a conductivity can be expressed by the empirical relation (16, 17).

$\sigma_{a.c}(\omega) \sim \omega^{s}$

or $\sigma_{a.c}(\omega)=A_o \omega^{s}$ …………(1)

Where (A_o) is a constant, and (s) is not a constant for all substances, but is a function of temperature.

$S= d[Ln\,\sigma_{a.c}(\omega)] / d[Ln(\omega)]$ ……..(2)

The total conductivity at a certain frequency and temperature is:

$\sigma(\omega) = \sigma_{a.c}(\omega) + \sigma_{d.c}$ ………(3)

Where $\sigma_{d.c}$ is a direct or continuous electrical conductivity.

The preparation of (CdSe0.8Te0.2) alloy

The alloy has been prepared by mixing a certain ratios of Cd, Se and Te (99.999 %) purity elements with their atomic weight 78.96, 112.40 and 127.60 respectively. The weight of each element ratio in the alloy was determined by the equation:

The weight of total alloy = (the ratio of the first element in the alloy * its atomic weight) + (the ratio of the second element in the alloy * its atomic weight) +…… …….. [4].

Then the weight of each element ratio was determined by a sensitive balance (Mettler H 35 AR) and its sensitivity (10^{-4}gm), then these weights have been put in a clean quartz ampoule and it has been closed, the ampoule has been put in a furnace with temperature T=823 K for four hours, then the temperature has been increased to 1023 K for three hours, and finally the temperature has been increased to 1223 K for three hours too, after that the mixed compound has been quenched in a cold water.

(Al-$CdSe_{0.8}Te_{0.2}$-Al) capacitor preparing

A thermal evaporation in high vacuum reaches to (10^{-6} mb) has been used in preparing the capacitor by using an Edward 306 system. The aluminum electrode has been deposited by using a tungsten boat then $CdSe_{0.8}Te_{0.2}$ thin films have been deposited on the Al electrode using a molybdenum (Mo) boat then the other Al electrode has been deposited on them. Thin films have been deposited with substrate temperature of 373 K with (0.3 nm/s) rate of deposition, thin films thickness was (3000±20) nm, the contribute length of electrodes was (0.8cm). A glass substrates have been used with dimensions (2.54*7.62) cm and with (12) cm thickness.

A.C Conductivity measurements

The (Al -$CdSe_{0.8}Te_{0.2}$-Al) capacitor has been connected to the electrical circuit as shown in figure (2) and the measurements of capacitance (C) and resistance (R) have been done by a General Radio Capacitance Bridge type (42748 Multifrequency LCR Meter Hewlet Packard). These instruments permitted measurements in the frequency range (f = 100Hz-400kHz). During the measurements the voltage on the specimen was kept at (1 volt), and all measurements were taken at room temperature.

The following equations have been used to compute the alternating electrical properties[1,5,16,17]

$\sigma_{a.c} = t / R.A$ ……… (5)

Where t: film thickness, R: film resistance, A: effective area of the capacitor $=0.5cm^2$

$\epsilon_r = C.t / \epsilon_o .A$ ………. (6)

Where C: the capacitance of the capacitor, ϵ_o: permittivity of the space

$\epsilon_i = t / \omega \epsilon_o R A$ ………. (7)

Where ω: the angular frequency =2 π f, f: the frequency

$\tan\delta = \epsilon_i / \epsilon_r$

$= 1 / \omega R C$ ………(8)

$S= d[Ln\,\sigma_{a.c}(\omega)] / d[Ln(\omega)]$ this equation has mentioned before equation (2) [16, 17, 18]

Results and Discussion

Figure (3) shows the frequency dependence of electrical conductivity (Ln $\sigma_{a.c}$ vs Ln ω) ,there is an increase in $\sigma_{a.c}$ values with the increase of frequency values, and it is found from

this figure that alternative electrical conductivity nearly or approximately follows a power law of equation [1], with the exponential S < 1, where(S) has been computed (S = 0.9257). S is a variable depends on the temperature and its value arises in the range (1>S >0.5), the alternative electrical conductivity depends on ω at this range.

Figure (4) shows the variation of capacitance with the frequency, it has shown that capacitance values decrease with the frequency increase and at the last points in the figure, the change is very small.

Figure (5) shows the variation of the real part of dielectric constant (ϵ_r) with frequency, the values of ϵ_r decrease with frequency increase till f = 100 kHz, where at the last points the change is very small and the points try to be nearly constant.

Figures (6 and 7) show the variation of imaginary part of dielectric constant (ϵ_i) and the loss factor (Tan δ) with frequency, the values of (ϵ_i) and (Tan δ) decrease with frequency increase till f = 20kHz where the last points begun to increase, the behavior of (ϵ_i and Tan δ) with frequency are similar to each other and that's clear if we see the equation (8) where the proportion between them is direct, and the behavior of (ϵ_r and C) with frequency are similar to each other and that's clear if we see the equation (6) where the proportion between them is direct too.

Generally, crystallization occurs by a mechanism of nucleation and growth. In such a mechanism, small crystalline nuclei form initially, which subsequently grow. The formation of nuclei can proceed at the surface / interface and / or the bulk of the material. To understand the kinetics of crystallization, the activation energy for nucleation needs to be considered first. The net change in free energy is the sum of the decrease in volume free energy due to crystallization and the increase in free energy due to the surface energy [19]. This volume change upon crystallization causes changes in the film capacitance.

Depending on the equation (3) $\sigma_{a.c}$ will ascendant at high frequencies and with low temperatures, whereas $\sigma_{d.c}$ will ascendant at low frequencies and with high temperatures.

Conclusions

The (ω^{s}) dependence of conductivity can be considered as an indication of the existence of a wide distribution of transition probabilities for charge carriers. Carriers transfer through interfaces either between the specimen and electrodes or between grain boundaries also contribute to (ω^{s}) dependence [16].

- Successive layers of (Al -$CdSe_{0.8}Te_{0.2}$-Al) structure can be obtained by vacuum evaporation in the range of frequency (100Hz-400kHz).
- At the range f = (100Hz-20kHz) where the values of loss factor decrease with frequency the material shows a good insulating properties because when Tan δ decrease the capacitor would be near to the ideal state(5)
- This capacitor can be used in engineering applications as insulators of field effect transistor, JFET amplifier, in applying alternative current (AC) to direct current (DC) in biased transistor circuit[1].

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b-The mask used for Al -electrodes deposition

a-The mask used for film deposition.

Fig. (1) The masks used in preparing the capacitor

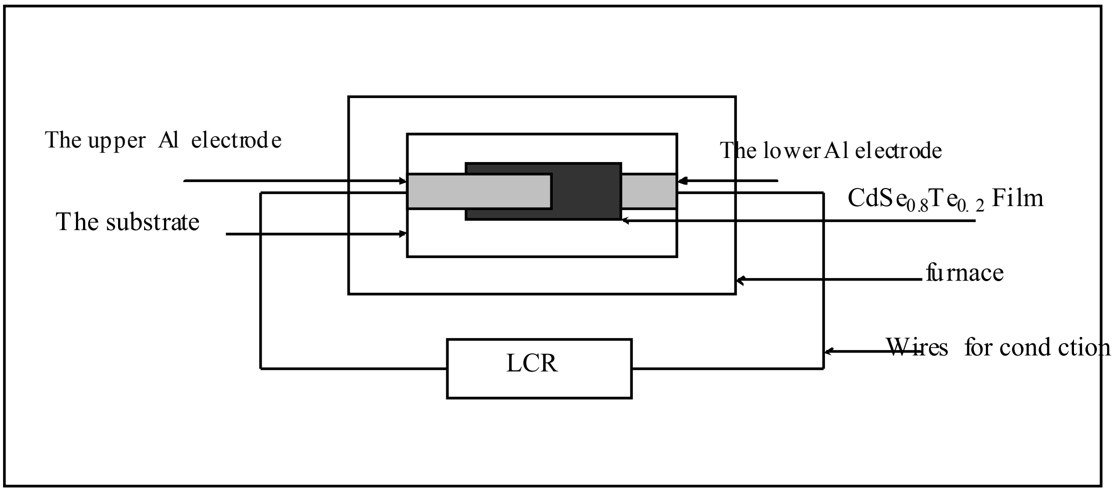

Fig. (2) Shows the circuit diagram of alternative conductivity measurements

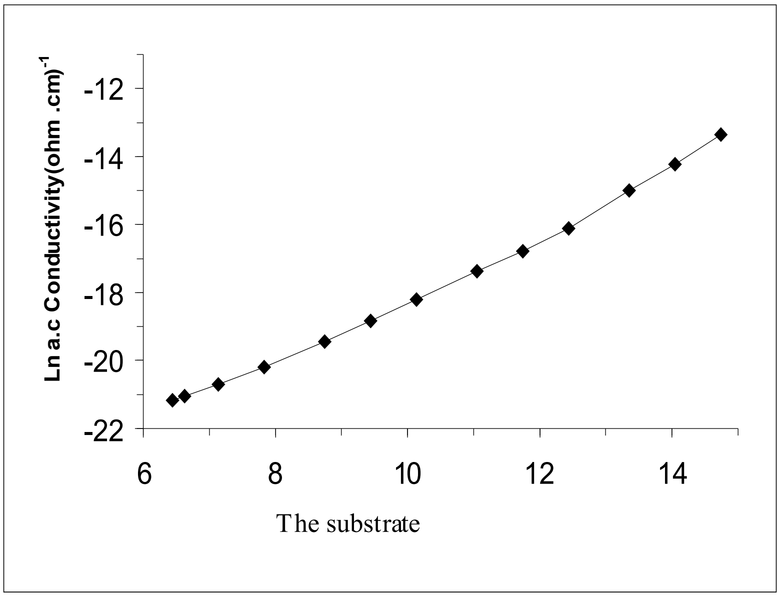

Fig. (3) Shows the frequency dependence of alternative electrical conductivity

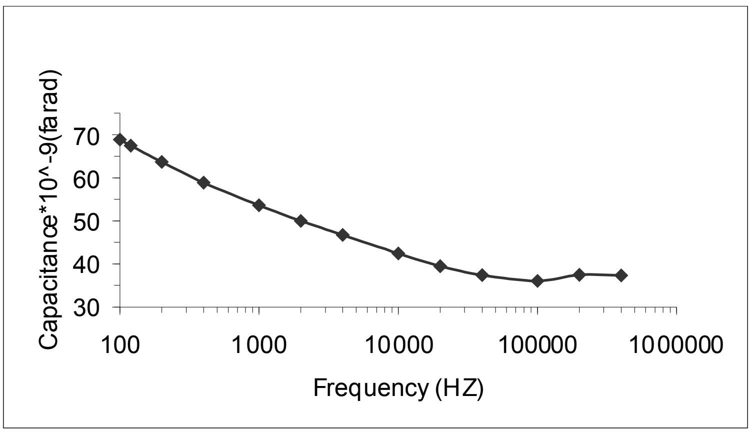

Fig. (4) Shows the variation of capacitance with frequency

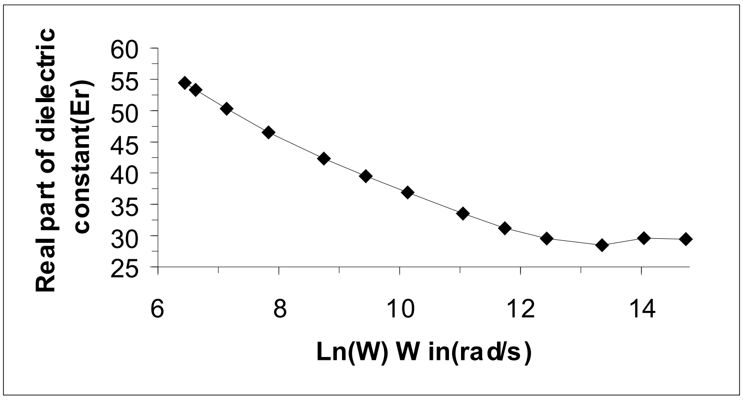

Fig. (5) Shows the variation of real part of dielectric constant ϵ_r with frequency

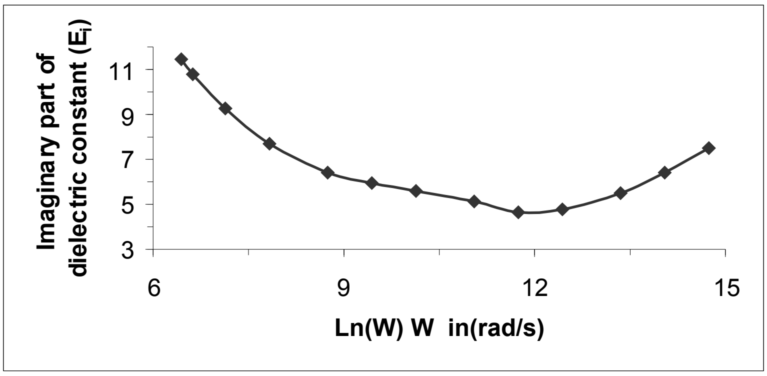

Fig. (6) Shows the variation of imaginary part of dielectric constant ϵ_i with frequency

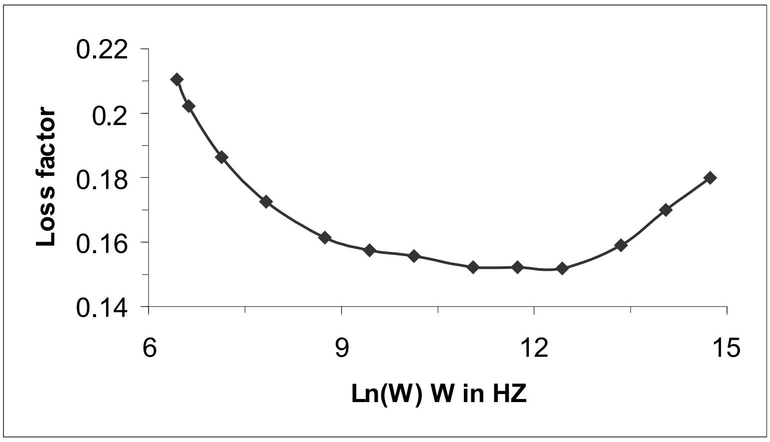

Fig. (7) Shows the variation of loss factor tan δ with frequency

الخواص الكهربائية المتناوبة للمتسعة ($Al-CdSe_{0.8}Te_{0.2}-Al$) عند درجة حرارة الغرفة

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الخلاصة

يهدف هذا البحث إلى تحضير المتسعة ($Al-CdSe_{0.8}Te_{0.2}-Al$)، ودراسة الخواص الكهربائية المتناوبة لها عند درجة حرارة الغرفة، ودراسة إمكانية استخدام هذه الأغشية في التطبيقات الألكترونية.

قيست التوصيلية الكهربائية المتناوبة في مدى الترددات ($f=100Hz-400KHz$) ولوحظ أنها تزداد بزيادة التردد .

وأظهرت دراسة تغير كل من السعة والجزء الحقيقي من ثابت العزل الكهربائي مع التردد أن قيمها تنخفض بزيادة التردد. وأظهرت دراسة تغير كل من عامل الفقد والجزء الخيالي من ثابت العزل الكهربائي مع التردد أن قيمها تنخفض بزيادة التردد ثم تبدأ بالزيادة.