The Effects Of Ga-Doped CdSe Thin Films On The Electrical Properties Prepared By Thermal Evaporation Technique

Ibrahim R. Agool , Hamza M. Mahdi , Nadheer J. Mohammed
Department of physics, Science faculty, University of Al-Mustansiriyah, Baghdad, Iraq.

***Abstract*—This paper reports electrical properties study of thermal evaporation CdSe:Ga thin films on glass substrate and with Ga Concertino (1,3and5) % wt of thickness(400±20)nm. The effect of Ga concentration on some of the electrical properties such as D.C conductivity and Hall Effect has been studied. It has been found that the increase in Ga concentration caused an increase in d.c conductivity at R.T .All films have shown two activation energies, where these values decreases with increasing doping ratio. The maximum value of activation energy was (0.2990) eV for pure CdSe film in the thermal range (25-30) C , Also the charge carrier concentration increases with increasing Ga concentration, and it varies between 94.07×10^{+18}cm^{-3} for pure films and 245.45×10^{+18}cm^{-3} for doping films with 5wt%Ga. The Hall mobility at laboratory temperature has been calculated, and it is decreased exponentially from 91.34cm^2/V.sec for the pure film to 47.59 cm^2/V.sec for doped films with 5wt% Ga.**

Keywords—CdSe; thin films; electrical properties$\sigma_{d.c}$; Hall Effect

Introduction

Cadmium Selenide (CdSe) has received considerable attention because of its importantproperties. It is direct band gap energy with 1.72 eV at R.T [1].Cadmium selenide (CdSe) is an important material for the development of various modern technologies of solid-state devices such as solar cells, high-efficiency thin-film transistors, etc[2] .A survey of literature reveals that revealed methods ware employed on the preparation and characterization of CdSe thin films grown by pulsed laser deposition, spray pyrolysis technique, and Chemical bath deposition method [3-10].The electrical properties of CdSe films depends on the method of preparation and deposition parameters as consequence of variationstoichimetry and micro-structure, so that the predominate scattering mechanism has been attributed to potential carrier scattering [11],combination of both inte rcrystalline [12] or potential scattering[13]. CdSe have high absorption coefficient (10^{+5}cm^{-1}) for important electromagnetic spectrum (IR-Vis) [14] . In this work, have Ga doped CdSe films prepared by thermal evaporation technique. The effects of Ga doping on the electrical properties of Ga-doped CdSe films were investigated.

Experimental

Cadmium Selenide (CdSe) pure and doped with Gallium (1,3and 5)% thin films by thermal vacuum evaporation using (Edwards- Unit 306) system in prepared vacuum about 2.3 x10^{-5} Torr at room temperature deposited on a glass substrate with a thickness (400±20)nm which measure by weighting method. The electrical resistance has been measured as a function of the temperature (T) using the circuit diagram shown in Fig.(1) and Study of Hall measurements the variation of Hall voltage as a function of currents for pure CdSe and doping with Ga at the concentration(1,3and5)% Gallium has been studied as shown in Fig.(2).

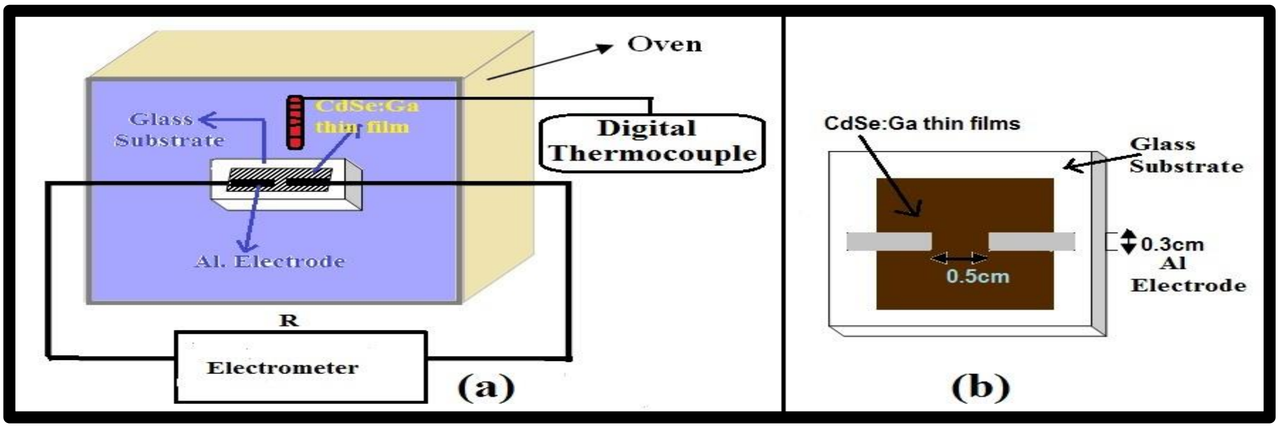

Fig (1)) a- Electrical circuit diagram used to measure the Continuous electrical conductivity b- The mask used in measuring σd.c after depositionof electrode conductivity on them.

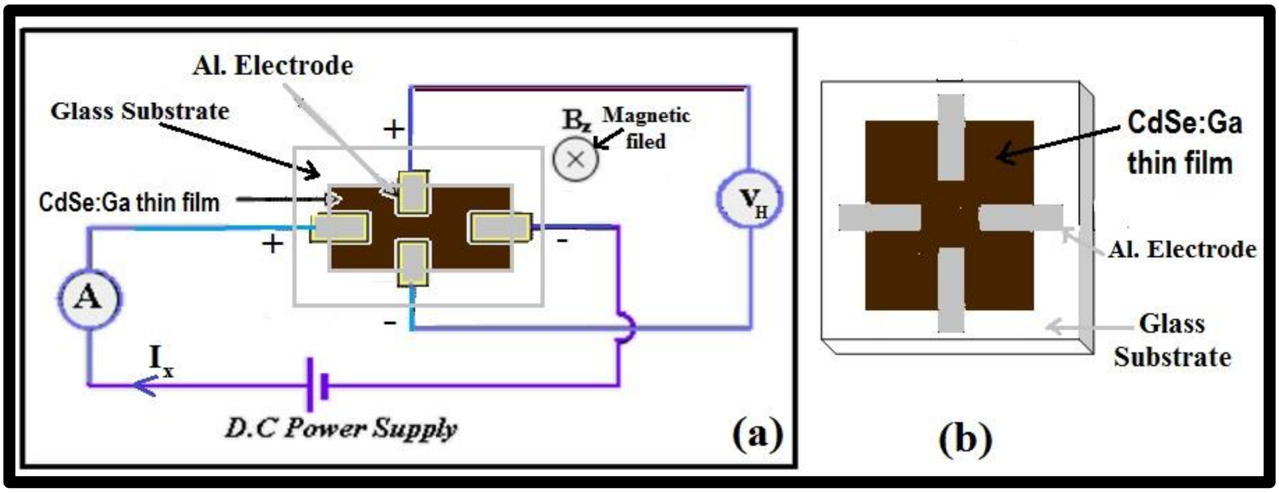

Fig.2 a- Electrical circuit diagram used for measuring the Hall Effect b- The mask used in measuring Hell effect after deposition of electrode on them.

Results and Discussion

1) D.C. Conductivity

The D.c. conductivity for the deposited thin films was calculated after measuring the resistivity (ρ) as a function of temperature within the range (25-200) ^{o}C by using equations (1) and (2). It has been noticed that in general all films that the d.c conductivity (σ) increases with increasing the temperature and that is the natural state which means normal properties of semiconductors that have a resistance of negative thermal coefficient, whereas the concentration of carriers increase with increasing the temperature [15].

$$\boldsymbol{\sigma_{dc}} = \frac{\mathbf{1}}{\boldsymbol{\rho}} \quad (1)$$

$$\boldsymbol{\rho} = \boldsymbol{R}\frac{\mathring{A}}{\boldsymbol{L}} \quad \{\mathring{A} = \boldsymbol{b}\,.\boldsymbol{t}\} \qquad (\mathbf{2})$$

Where

$\boldsymbol{\sigma_{dc}}$: Electrical conductivity

$\boldsymbol{\rho}$: Theelectrical resistivity

R :The electrical resistance of the films

L: The distance between of aluminum electrode

Ą: cross-sectional area of the movement of electrons through the films.

b: Width of electrode.

t: thickness of films

Fig. (3) shows that the electrical conductivity increasing with increasing ratio of doped Gallium , because the atoms of Gallium was led to induce of donor levels within the energy gap near the conduction band and this lead to stimulate a larger number of electrons with small energies which therefore decreasing the energy gap this is agreement with the researchers [15,18]

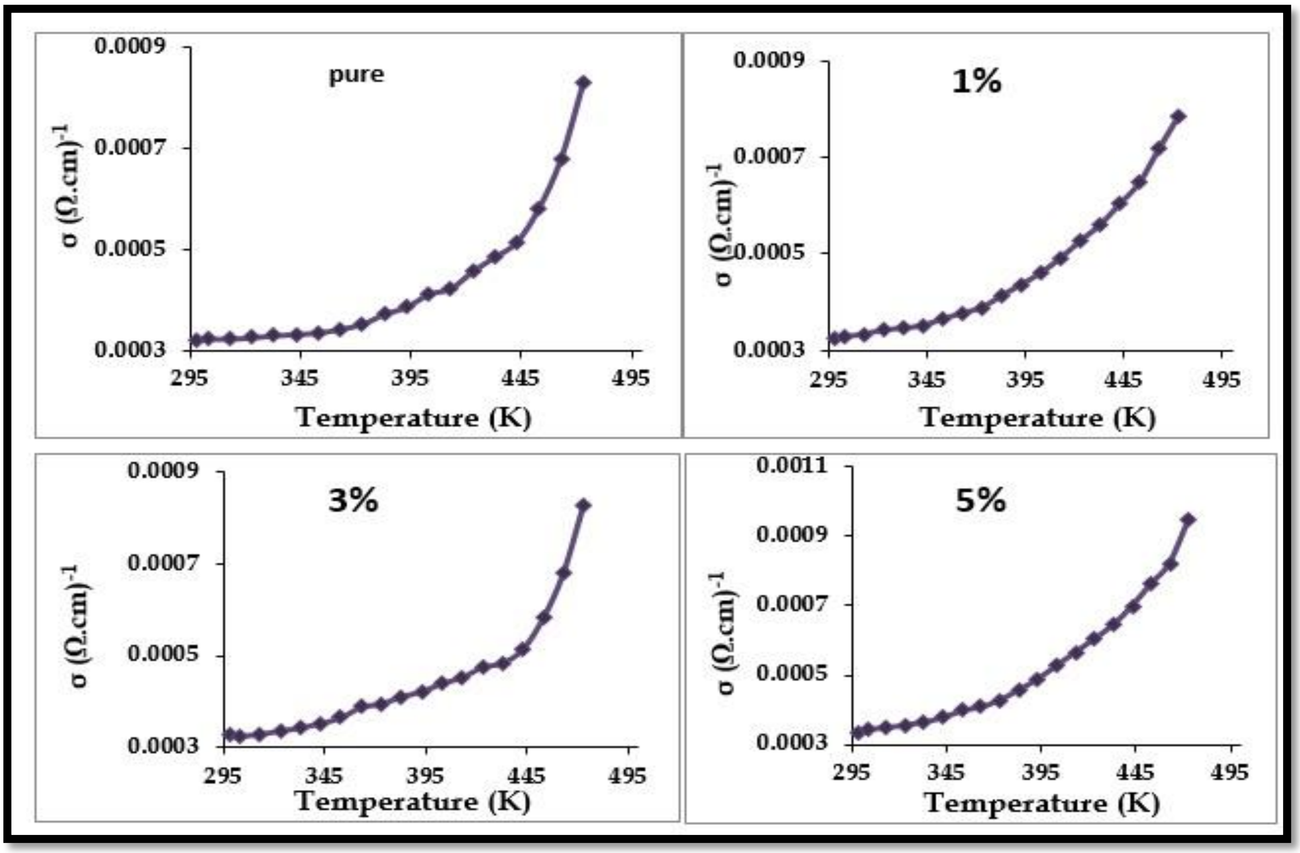

Fig. (3) The variation of conductivity as a function of temperature, for pure and different doping ratio

2. Activation energy result

The electrical activation energy of CdSe and CdSe:Ga thin films were calculated from Ln σ versus (10^3/T) plot as shown in figure (4) .The activation energy depends on the doping and it will be decreasedwith increasing doping ratio .this can be seen in tab.1

$$\sigma = \sigma_o \exp\left(-\frac{E_a}{K_B T}\right) \quad (3)$$

σ_o : is relation constant

(conductivity at (0 °C)).

K_B : Boltzman constant.

E_a : activation energy.

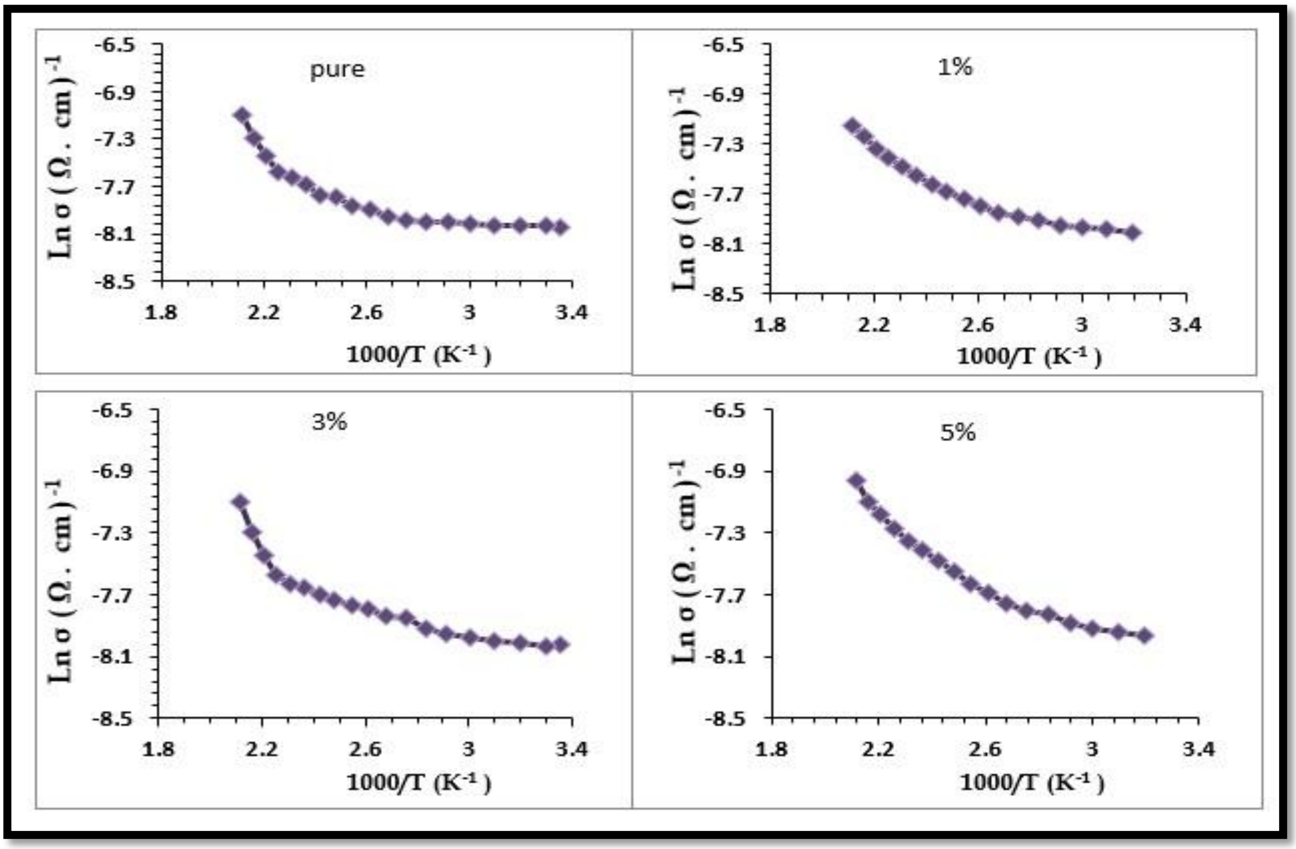

Fig. (4) The variation of ln σ as a function of (10^3/T)

Tab.1 ***The activation energy of CdSe:Ga thin films.***

Thin Film Sample	E_{a1} (eV)	Temperature Range,T (^{o}C)	E_{a2} (eV)	Temperature Range,T (^{o}C)
CdSe (Pure)	0.1404	(25 – 120)	0.2990	(125 – 200)
CdSe:Ga (1%)	0.1051	(25 – 120)	0.2331	(125 – 200)
CdSe:Ga (3%)	0.0911	(25 – 120)	0.2154	(125 – 200)
CdSe:Ga (5%)	0.0413	(25 – 120)	0.1556	(125 – 200)

From the Tab.1 it can be seen that two separated regions throughout the heating temperature range, the first region is at low temperatureand the secondregion is at higher temperature , indicating different conduction mechanisms dominating at specific temperature intervals[61]. These two conduction mechanismsmean that the conductivity is non-linear with temperature, as shown in figure (4). These two types of low and high temperatureregions have been already reported by other researchers [15, 17].The first activation energy (E_{a1}) occurs at low temperatures, in which the conduction mechanism is due to charge carriers' transport (hopping) to localized states near the conduction band [21]. In this temperatureregion, the temperature dependence of conductivity for allConcentration of (Ga) increases slightly with small activation energies and also the second activation energy (E_{a2}) occurs at high temperatures (decrees with increase Concentration of Gallium)but the variable values as shown in the table 1.

The activation energy of CdSe:Gathin films in the low temperatureregion is found to be smaller than that in thehigh temperature region , confirming that the conduction mechanism in the high and low temperature regions is a thermally activated process known as ‘ thermionic emission’ and ‘ variable range hopping mechanism’ , respectively [21] .

It is obvious that the activation energyin the high and low temperature regions decreases with the increase in the Gallium concentration. This decrease is expected to be due to the energy gap of CdSe:Gathin films decreases with theincrease in the Gallium concentration , which requires lower energies . Doping causes the Fermi level shift towards the conduction band (CB) led to the formation of donor levels within the energy gap near the conduction band [22,23]. Thus, it will absorb photons of low energy, the activation energies are greater than **K_BT(0.0258 eV)**at room temperature,this shows that there is no fully activated for electrons at room temperature.

3. Hall Effect result

Hall measurement to determine whether a material is (n-type) or (p-type). Measurement of the conductivity of a specimen will not give this information, since it cannot distinguish between positive hole and electron conduction, but Hall Effect can be utilized to distinguish between the two types of carriers [20].is widely used in the initial characterization of semiconductors. It allows the density of the charge carriers to be determined, as well as carrier mobility , simple techniques such as four-point resistively measurements are usually sub-stituted [20].

When the magnetic field is applied perpendicular to the electric field, it yields a current (I_H) then the transverse (*e.m.f*), which is called Hall voltage (V_H), is set up across the sample. So that Hall coefficient (R_H) is given by [20].

$$R_H = \frac{V_H}{I} \times \frac{t}{B} \quad ....(4)$$

Where:

t: is the thickness of the film.

The carrier density (n_H) is related to the Hall coefficient by the following equation [20]:

$$n_H = \pm \frac{1}{q \ R_H} \quad .... (5)$$

Where:

q: is the charge of electron, and it equals ($1.6*10^{-19}$ coulomb).

The type of the charge carrier of the CdSe:Gathin films their concentrations and Hallmobility have been calculated from Hall measurements , can be shown in Tabel.2

Tab.2 shows the Hall coefficient *(R_H)*, concentration *(N_D)* and mobility *(μ_H)* of carriers charge of CdSe:Ga thin films.

Thin films ample	σ ($\Omega^{-1}.cm^{-1}$)	R_H ($cm^3.C^{-1}$)	μ ($cm^2.Volt^{-1}.sec^{-1}$)	n x 10^{+18} (cm^{-3})
CdSe (pure)	137.7	-0.6636	91.34	94.07
CdSe:Ga(1%)	181.1	-0.2773	50.23	225.1
CdSe:Ga (3%)	182.7	-0.2698	49.29	231.4
CdSe:Ga (5%)	187.1	-0.2544	47.59	245.4

The carrier mobilities of charge carriers is found to decrees with increasing doped parentage because Hall mobility (μ_H) depends on doped ratio (decrease of mobility in doped gallium is caused by ionized impurities scattering of charge carriers).

Also the values of carrier concentration increase with the increasing of Ga-content in the films as shown in table (2).Hall measurements indicate that CdSe and CdSe:Ga thin films have the same conduction n- type, The above results of the Hall

Effect are in a good agreement with the reports [15,16].

Conclusions

The conductivity at room temperatures increases with increasing Ga concentration. All films have been shown two activation energies, and these values decrease with increasing Ga, Hall effect results have shown that the sample of the pure CdSe film wase n-type and the same of doping CdSe:Ga films, the charge carrier concentration and Hall mobility increase with increasing Ga concentration.

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