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**In the Name of Allah
Most Compassionate, Most Merciful**

Edition Word

O Allah, my Lord

Cast felicity in me , facilitate my cause and unknot my tongue to perceive my speech , thanks be upon Him the Evolver of the universe and peace be upon Mohammad and his immaculate and benevolent progeny .

A fledged edition of Al-Bahr , peer reviewed scientific journal, embraces a constellation of research studies pertinent to engineering and natural sciences we do hope to overlap a scientific gap the specialists observe as an academic phenomenon worth being under the lenses of the researchers, that is why there is diversity in the studies to meet the requirements of the journal readership . For the journal, now, comes to the fore , at the efforts of the editorial and advisory boards and the researchers who strain every sinew to publish in Al-Bahr, to be global as to be published in an international publishing house in line with the global scientific journals.

On such an occasion we do pledge the promise of fealty and loyalty to those who observe our issues with love and heed in the International Al-`Ameed for Research and Studies , Department of Cultural and Intellectual Affairs in the Holy Al-`Abbas Shrine and the strenuous endeavour to cull whatever invigorates the scientific interaction and academic research in Iraq and worldwide to create a new generation keeping pace with the development of the current scientific phase and to lay the hands of the researchers, nationwide and worldwide, upon the desired missions.

Thanks be upon Him ,the Evolver ad infinitum .

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Electrical Properties of $(\text{CdO})_{1-x}(\text{SnO}_2)_x$ Thin Films Prepared by Pulsed Laser Deposition

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الخلاصة

تم ترسيب أغشية اوكسيد الكاديوم بتراكيز مختلفة من اوكسيد القصدير (0، 0.05، 0.1، 0.15، 0.2) على قواعد زجاجية بتقنية الترسيب بالليزر النبضي ليزر النديميوم ياك ذو طول موجي (1064) نانومتر وطاقة قدرها (600) ملي جول وعدد نبضات (500) نبضة. لها تركيب متعدد التبلور، قياسات التوصيلية المستمرة أثبتت ان التوصيلية تتناقص مع زيادة تركيز SnO2 ودرجة الحرارة التلدين، ووجد ان هنالك طاقتي تنشيط تزداد مع زيادة تركيز SnO2 وتقل مع زيادة درجة حرارة التلدين. أوضحت قياسات تأثير هول ان الأغشية انها من نوع n وان تركيز حاملات الشحنة يتناقص مع زيادة تركيز SnO2 ويزداد مع زيادة درجة حرارة التلدين، بينما اظهرت التحركية سلوك معاكساً لذلك.

الكلمات المفتاحية

اوكسيد الكاديوم، اوكسيد القصدير، تقنية الترسيب بالليزر النبضي.



Abstract

CdO thin films have been deposited at different concentration of SnO₂ $x = (0.0, 0.05, 0.1, 0.15)$ and (0.2) Wt. % onto glass substrates by pulsed laser deposition technique (PLD) using Nd-YAG laser with $\lambda = 1064$ nm, energy = 600mJ and number of shots = 500. For it polycrystalline, the D.C. conductivity for the $(\text{CdO})_{1-x}(\text{SnO}_2)_x$ thin films decreases with increasing concentration SnO₂ and decreases with increasing of annealing temperature, found two activation energies increases with increasing concentration SnO₂ and decreases with increasing of annealing temperature. Hall effect measurements show that the $(\text{CdO})_{1-x}(\text{SnO}_2)_x$ thin films were n-type, concentration of charge carriers n_H decreases with increasing of concentration of SnO₂, also charge carriers n_H increases with increasing of annealing temperatures, while the mobility μ_H opposite behavior.

Keywords

CdO, SnO₂, pulsed laser deposition.



1. Introduction

An important branch that has been developed in the last decades is the physics of thin films. Thin solid films were probably first obtained by electrolysis in 1838. Bunsen and Grove obtained metal films in 1852 by means of chemical reaction and glow discharge sputtering respectively. Faraday obtained metal films in 1857 by thermal evaporation on explosion of a current carrying metal wire [1]. Cadmium Oxide CdO the unique combination of thin film properties which were represented by high electrical conductivity, high carrier concentrations and high transparency in the visible range of the electromagnetic spectrum, made it suitable for a wide range of applications in different fields [2]. Stannic Oxide SnO₂ in 1942 Masters succeeded in preparing conductive transparent tin oxide, for the first time. A substance with white color has a molecular weight of (150.69) g/mol. Its density (6.95) g/cm³, its melting point (1630)°C and its boiling point (1900)°C [3]. Stannic oxide is an n-type semiconducting material with a direct band gap of about 4.0 eV and an indirect band gap of about 2.6 eV [4].

2. Experimental

2.1. Preparation Pellets

High purity powders (99.999%) of CdO and SnO₂ supplied from Fluka were used to form the target as a disk of (2.5) cm diameter and (0.4) cm thickness by pressing it under (4) ton force. The pellets which containing the elements were heated to (873) K for (3) hours

then cooled to room temperature. The temperature of the furnace was raised at a rate of (10) °C/min. The amount of elements content of pellets was evaluated by using the following equation.

$$W_{(CdO)_{1-x}(SnO_2)_x} = W_{CdO} \times (1-x) + W_{SnO_2} \times (x) \dots (1)$$

Where: atomic weight for CdO, =150.69 (atomic weight for SnO₂) and (x=0, 0.05, 0.1, 0.15 and 0.2) (concentration of SnO₂).

2.2. PLD and Thin Film Preparation

The (CdO)_{1-x}(SnO₂)_x films were deposited on glass slides substrates of (2.5×7.5) cm² were cleaned with diluted water using ultrasonic process for (15) minutes to deposit the films at room temperature by PLD technique using Nd:YAG with (λ= 1064) nm SHG Q-switching laser beam at (600) mJ, repetition frequency (6) Hz for (500) laser pulse is incident on the target surface making an angle of (45°). The under vacuum of (10⁻³mbar) at room temperature and annealing temperatures (423 and 523) K were presented.

2.3. D.C. Conductivity Measurements

D.C. electrical conductivity of (CdO)_{1-x}(SnO₂)_x thin films were deposited on the glass substrates, and it was measured using electrical resistance as a function of temperature within the thermal range (303-473) K. This can be done by putting the thin film in an electrical oven of the type (Mettler). Silver paste was used to fix connection wires on the poles, these wires are connected to the circuit. The resistance of thin film has been measured



by connecting the wires to digital electrometer (Keithly 2400). Values of resistance have been measured as a function of temperature.

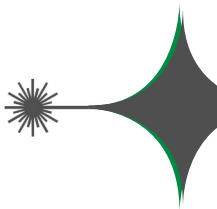
3. Results and Discussion

3.1. The Electrical Properties

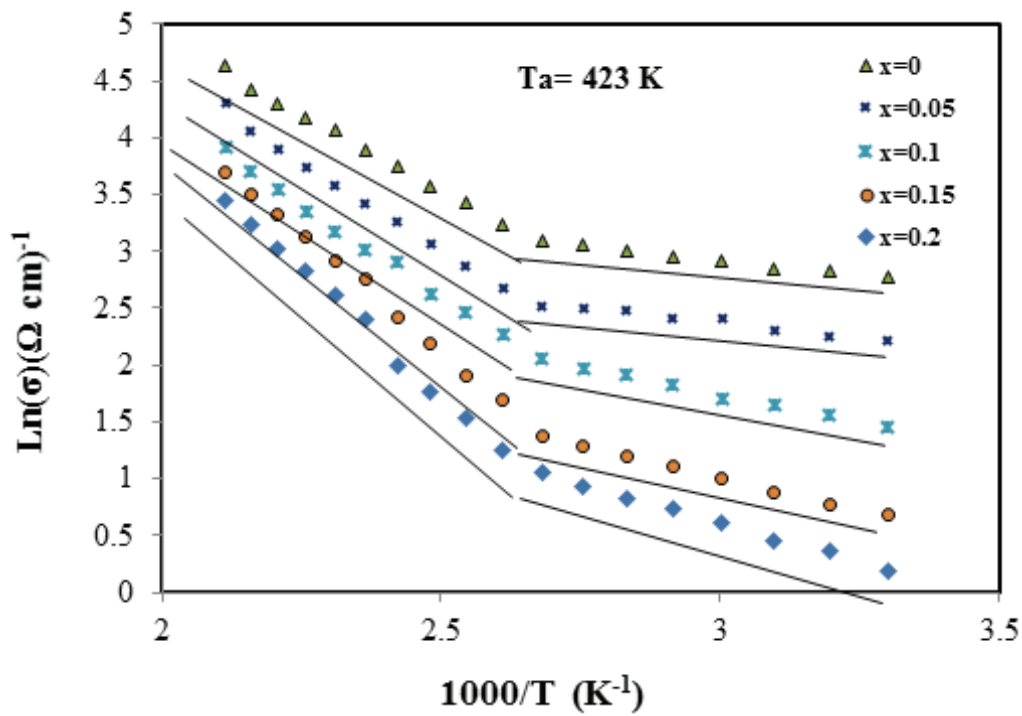
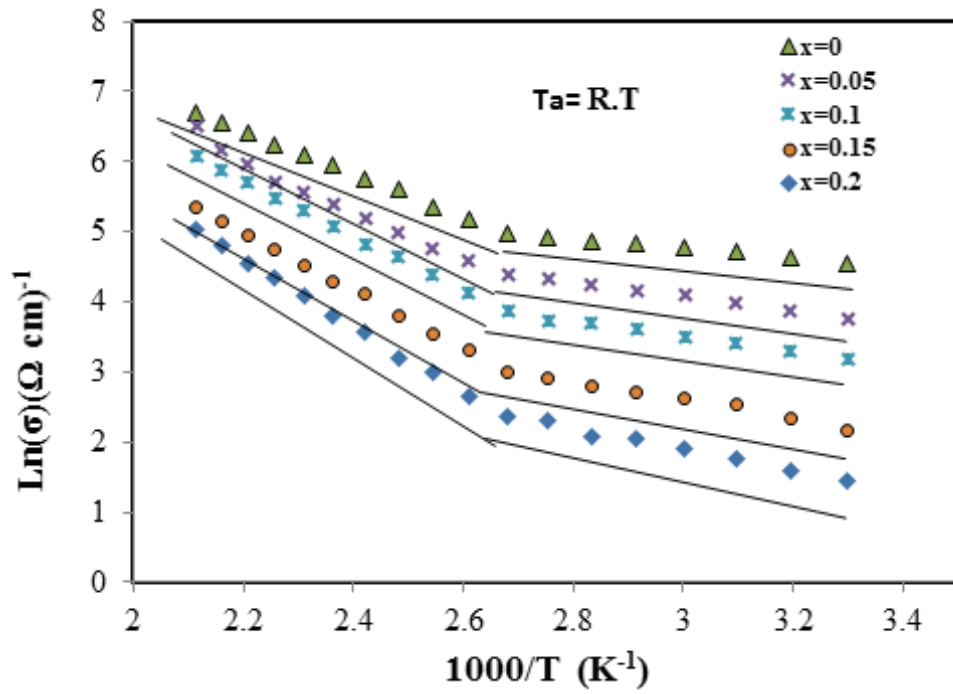
3.1.1. D.C Conductivity

In order to study the mechanisms of conductivity, it is convenient to plot logarithm of the conductivity $\ln(\sigma)$ as a function of $1000/T$ for $(\text{CdO})_{1-x}(\text{SnO}_2)_x$ thin films with different concentration of SnO_2 ($x=0, 0.05, 0.1, 0.15$ and 0.2) at room temperature and different annealing temperatures (423 and 523) K, as shown in Fig. (1). It is clear from these Figures that there are two transport mechanisms, giving rise to two activation energies E_{a1} and E_{a2} . At the higher temperature range (373-473) K, the conduction mechanism is due to carrier excited into the extended states beyond the mobility edge and at a lower temperature range (303-373) K. The conduction mechanism is due to carrier excited into localized states at the edge of the band [5]. It is observed that the activation energies increase while σ_{RT} decreases with the increasing of concentration of SnO_2 and the activation energies decrease while σ_{RT} increase with increasing of annealing temperatures as represents in Table (1). The activation energy E_{a1} for $(\text{CdO})_{1-x}(\text{SnO}_2)_x$ films increases with increasing of concentration of SnO_2 , from (0.057 to 0.132) eV, from (0.041 to 0.118) eV and from (0.038 to 0.101) eV when range temperature changes from (303 to 373) K at ($x=0, 0.05, 0.1, 0.15$ and 0.2) respec-

tively, also the activation energy E_{a1} decrease with increasing of annealing temperatures as shown in Figure (2), while E_{a2} increases from (0.262 to 0.408) eV, (0.23 to 0.375) eV and (0.178 to 0.313) eV when range temperature changes from (373 to 473) K at ($x= 0, 0.05, 0.1, 0.15$ and 0.2) respectively, also the activation energy E_{a2} decrease with increasing of annealing temperatures, as shown in Fig. (3). The behavior of E_a with SnO_2 concentration and annealing temperature is the same as that for E_g^{opt} . When E_g^{opt} increases, the carriers need high activation energy E_a to transport them from V.B to C.B and vice versa [6]. From the Table (1), it can also be observed that the activation energy of the first region is less than that of the second region. This can appear in some compounds, where the carrier density could be small enough to give this behavior [7]. From Figure (4) and Table (1), we can observe that σ_{RT} decreases with increasing of annealing temperatures but decreases with increasing of concentration of SnO_2 . The decreases in the conductivity with concentration of SnO_2 is obviously due to the decrease in the carrier concentration as well as in the absorbance i.e.increase in the mobility while the explanation for decreasing in the conductivity with increasing of annealing temperature because of the rearrangement that may occur during annealing [8]. The activation energies could be calculated from the plot of $\ln\sigma$ versus $1000/T$ according to equation [9].



$$\sigma = \sigma_0 \exp(-E_a / k_B T) \dots\dots\dots(2)$$



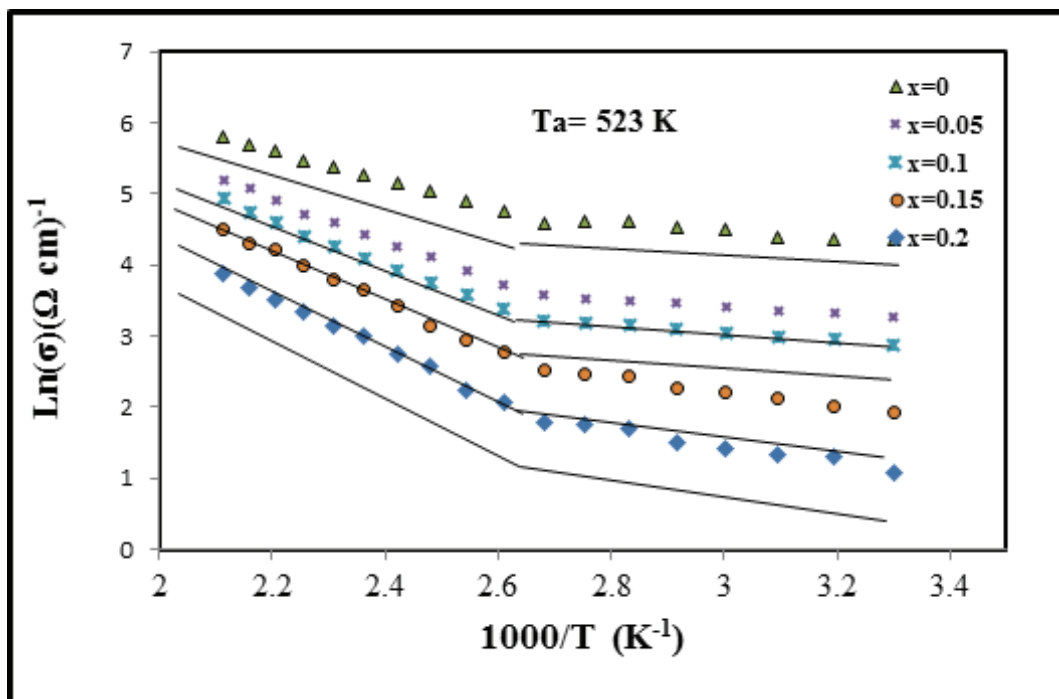


Fig. (1): The relation between $\text{Ln}(\sigma)$ versus reciprocal of temperature for $(\text{CdO})_{1-x}(\text{SnO}_2)_x$ thin films with different concentration of SnO_2 at R.T and different annealing temperatures(432 and 523)K.

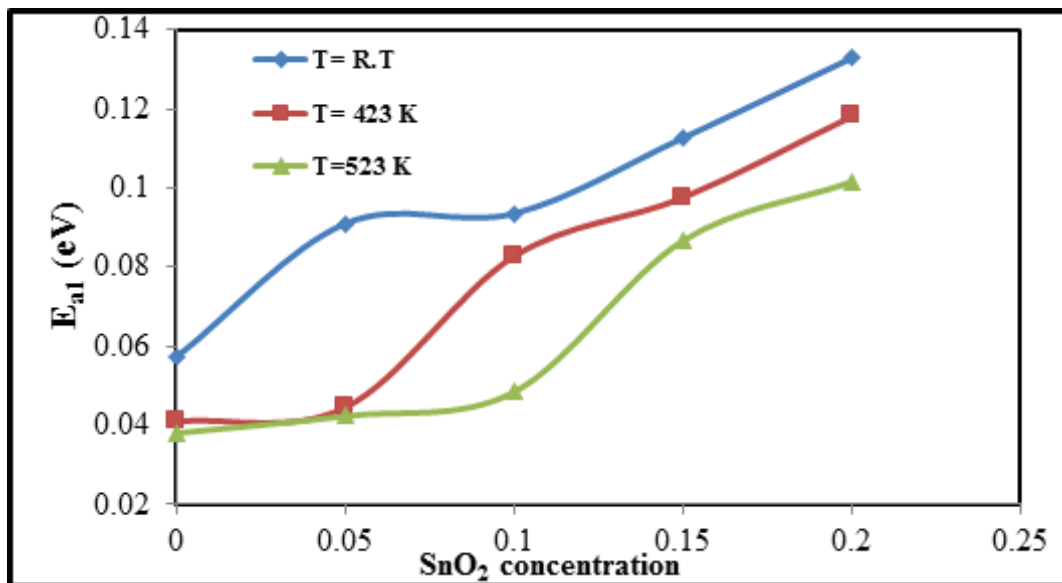


Fig. (2): The variation of the activation energy E_{a1} for $(\text{CdO})_{1-x}(\text{SnO}_2)_x$ thin films with different concentration of SnO_2 at R.T and different annealing temperatures (423 and 523) K.

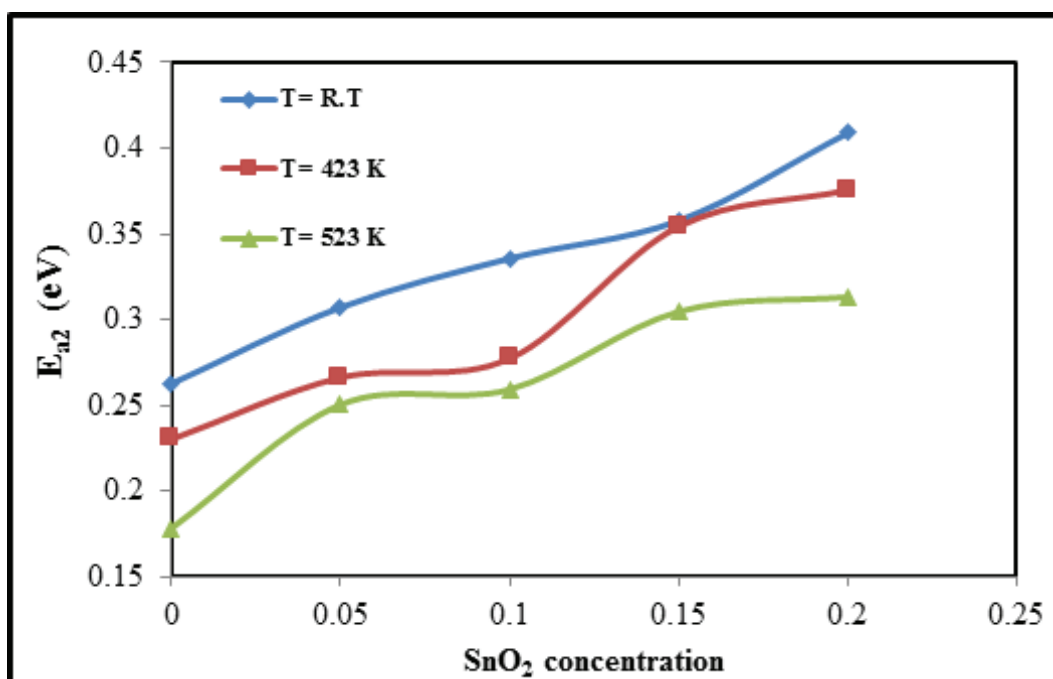
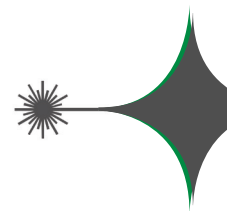


Fig. (3): The variation of the activation energy E_{a2} for $(\text{CdO})_{1-x}(\text{SnO}_2)_x$ thin films with different concentration of SnO_2 and different annealing temperatures (423 and 523) K.

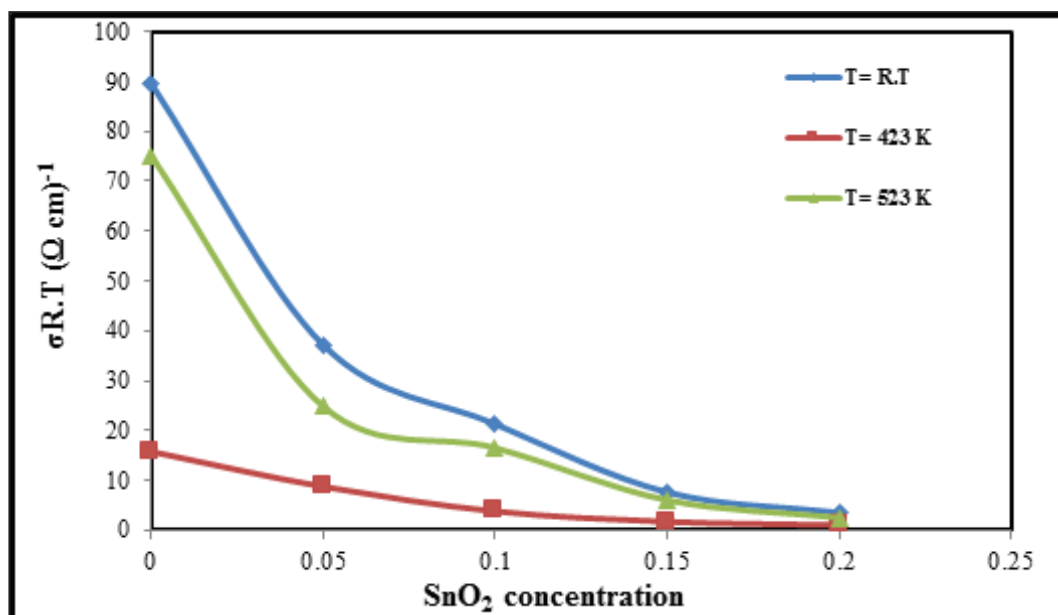


Fig. (4): The variation of conductivity $\sigma_{R.T}$ for $(\text{CdO})_{1-x}(\text{SnO}_2)_x$ thin films with different concentration of SnO_2 at R.T and different annealing temperatures (423 and 523) K.



Table (1):The values of E_{a1} and E_{a2} and these ranges for $(CdO)_{1-x}(SnO_2)_x$ thin films with different concentration of SnO_2 and different annealing temperatures(423 and 523) K.

| T_a (k) | x | $\sigma_{R.T}$ $(\Omega\text{ cm})^{-1}$ | E_{a1} (eV) | Range (Temp.(K | E_{a2} (eV) | Range (Temp.(K |
|--------------|------|---------------------------------------------|------------------|-------------------|------------------|-------------------|
| R.T | 0 | 95.164 | 0.059 | 303-373 | 0.263 | 373-473 |
| | 0.05 | 42.249 | 0.089 | 303-373 | 0.307 | 373-473 |
| | 0.1 | 24.025 | 0.093 | 303-373 | 0.336 | 373-473 |
| | 0.15 | 8.671 | 0.110 | 303-373 | 0.358 | 373-473 |
| | 0.2 | 4.263 | 0.130 | 303-373 | 0.409 | 373-473 |
| 423 | 0 | 15.968 | 0.041 | 303-373 | 0.230 | 373-473 |
| | 0.05 | 9.117 | 0.046 | 303-373 | 0.266 | 373-473 |
| | 0.1 | 4.279 | 0.082 | 303-373 | 0.277 | 373-473 |
| | 0.15 | 1.982 | 0.098 | 393-373 | 0.354 | 373-473 |
| | 0.2 | 1.209 | 0.118 | 303-373 | 0.375 | 373-473 |
| 523 | 0 | 78.241 | 0.040 | 303-373 | 0.178 | 373-473 |
| | 0.05 | 26.558 | 0.042 | 303-373 | 0.250 | 373-473 |
| | 0.1 | 17.895 | 0.047 | 303-373 | 0.259 | 373-473 |
| | 0.15 | 6.817 | 0.087 | 303-373 | 0.305 | 373-473 |
| | 0.2 | 2.945 | 0.098 | 303-373 | 0.313 | 373-473 |

3.1.2. Hall Effect

The type of charge carriers, concentration (n_H) and Hall mobility (μ_H), has been estimated by using (Ecopia HMS-3000) for Hall Measurement Systems. Table (2) shows the main parameters estimated from Hall effect measurements for $(CdO)_{1-x}(SnO_2)_x$ thin films deposited with different concentration of SnO_2 ($x=0, 0.05, 0.1, 0.15$ and 0.2) at room temperature and different annealing tempera-

tures (423 and 523) K. We can notice from this Table that the films have a negative Hall coefficient. This mean that the type of conducting (n-type charge carriers).Also we can notice from Table (2), that the carrier's concentration (n_H) decreases with the increasing of concentration of SnO_2 , while Hall mobility (μ_H) increases with the increasing of concentration of SnO_2 , while Hall coefficient increases with increasing, also the carrier's concentration



(n_H) increases with the increasing of annealing temperatures, while the Hall mobility (μ_H) decreases with the increasing of annealing temperatures, also Hall coefficient decreases with increasing temperature. This may be due to the decrease in defects inside the energy gap and to the transformation to crystalline structure. It can be seen that the carrier mobility increases

with decreasing the carrier concentration which is due to the increase in concentration of SnO_2 and vice versa. The decrease of mobility in higher temperature is caused by lattice scattering of charge carriers, also the large value of carrier concentration determines a decrease of the mobility [10]. We can measure the Hall mobility as [11].

$$\mu = \frac{\sigma}{n.e} \dots\dots\dots (3)$$

$$\mu = \sigma |R_H| \dots\dots\dots (4)$$

Table (2): Hall effect measurements for $(CdO)_{1-x}(SnO_2)_x$ thin films with different concentration of SnO_2 at R.T and different annealing temperatures (423 ad 523) K.

| Ta (K) | x | $n_H \times 10^{18} (cm^{-3})$ | $R_H \times 10^{-2} (cm^3/C)$ | $\mu_H \times 10^1 (cm^2/V.s)$ | Type |
|------------|------|--------------------------------|-------------------------------|--------------------------------|------|
| R.T | 0 | 0.308 | 0.060 | 0.007 | n |
| | 0.05 | 0.218 | 0.085 | 0.015 | n |
| | 0.1 | 0.163 | 0.114 | 0.030 | n |
| | 0.15 | 0.028 | 0.668 | 0.031 | n |
| | 0.2 | 0.001 | 12.2 | 0.300 | n |
| 423 | 0 | 0.641 | 0.029 | 0.038 | n |
| | 0.05 | 0.492 | 0.038 | 0.022 | n |
| | 0.1 | 0.272 | 0.068 | 0.029 | n |
| | 0.15 | 0.196 | 0.095 | 0.113 | n |
| | 0.2 | 0.002 | 6.25 | 1.33 | n |
| 523 | 0 | 4.373 | 0.004 | 0.004 | n |
| | 0.05 | 2.547 | 0.007 | 0.005 | n |
| | 0.1 | 1.438 | 0.013 | 0.008 | n |
| | 0.15 | 0.701 | 0.026 | 0.037 | n |
| | 0.2 | 0.122 | 0.153 | 0.070 | n |



4. Conclusions

The activation energies increases with increasing concentration of SnO_2 and decreases with increasing of annealing temperatures. Hall measurements showed that all the thin films are n-type.

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