Diyala Journal of Engineering Sciences

ISSN 1999-8716

Vol. 02, No. 02, pp. 77-87, December 2009

Electrical Properties of $Zn_x Se_{1-X}$ Thin Films Prepared by Thermal Evaporation Method

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(Received:17/5/2009; Accepted:29/9/2009)

ABSTRACT - Semi conducting $Zn_x Se_{1-x}$ thin films were prepared at 480nm thickness on glass substrates at room temperature using vacuum evaporation technique. The electrical properties of Znx Se_{1-x} thin films have been investigated, such as dc conductivity and Hall effect. The investigation showed that the composition range $0 \leq x \leq 0.3$ has an influence on the electrical properties of the $Zn_x Se_{1-x}$ thin films. The dc conductivity experiment in the range of temperature 293-423 ^{o}k gave two activation energies E_{a1}& E_{a2} which represented two types of conduction mechanisms. E_{a1} & E_{a2} have values 0.6 & 0.1eV respectively for x=0, while 1.01 &0.107 eV for x=0.3. Also, the study showed that the dc conductivity $\sigma=5.19x10^{-7}$ $(\Omega.\ cm)^{-1}$ for x=0, and decreases with increasing zinc to 3.2x 10^{-7} $(\Omega.\ cm)^{-1}$ at x=0.3. Hall effect study appeared that the type of the carriers is p-type, their concentration is $1.6x10^8 cm^{-3}$ and increases with increasing the fraction of composition x to $2.6x10^{10}$ cm^{-3}. Also, the mobility of the carriers has good relation with zinc content x.

1. INTRODUCTION

In the recent years, there has been growing interest in the synthesis of II-VI semiconductors in non-crystalline thin films form. Among different II-VI binary semi conducting materials, ZnTe, ZnSe, ZnS, CdSe, CdS and CdTe have received much attention due to their device applications.

Zn Se is a wide- Band-gap semiconductor that is used for fabrication of blue and green light emitting devices[1].

For the recent developments on the fabrication of II-VI blue light emitting diodes or blue laser diodes demand high quality ZnSe single crystal as a substrate for homoepitaxial growth. The thermal conductivity of Zn Se by molecular dynamics simulation was studied by (2).

Avdonin et al(3,4) have studied the electrical conductivity and luminescence in Zn Se crystal doped with transition elements and gold. respectively.

Jianyong Duyang and Yongfang Li(5) have been reported the electrical conductivity of thin films of polypyrrole with the variation in voltage at room temperature. Also it was found electrical conductivity of Zn50 Se50 varies with the applied voltage at fixed temperature ranging from room temperature to 180 ˚C (6).

In addition to the determination of the carrier concentration by using Hall effect method, an effort had been done(7) to determine the carrier concentration of doped ZnSe from infrared measurement.

In this work, we have investigated the dc electrical conductivity of ZnxSe1-x polycrystalline thin films. Also, our effort had been done to know the type of carriers, their concentration, and the dependence of these parameters on x-composition.

2- DIRECT CURRENT (DC) ELECTRICAL CONDUCTIVITY (8,9)

The essential features of the Davis-Mott model for the band structure of the amorphous semiconductors, are the existence of the localized states at the extremities of the V.B and C.B near the middle of the gap. This leads to four basically different mechanisms of conduction which are expected to occur in appropriate range of temperature.

Where V.B is the valance band and C.B is the conduction band.

2.1- Extended State Conduction

This conduction mechanism occurs at a high temperature range in which the carriers are excited into extended states above Ec for electrons and below Ev for holes.

The dc conductivity (σ) can be expressed in the form(8).

$$\sigma ext = \sigma_0 \exp\left[-\frac{Ea}{K_B T}\right] ....(1)$$

When σ_o is known as minimum metallic conductivity ,E_C- E_F=E_a is called the activation energy of the semiconductor , K_B Boltzamann constant and T is the temperature measured in Kelvin, E_c it is known as a conduction energy and E_f as Fermi energy.

2.2- Conduction in Band Tails

This type of conduction takes place by thermal hopping through the localized states. The conductivity in this region is given by[8]:

$$\sigma_{IOC} = \sigma_{01} \exp\left[-\frac{E_A - E_F + W_1}{K_B T} \right] \text{..........(2)}$$

E_v ,and E_c correspond to the band edge s of the crystalline material . Those marked E_B ,and E_A correspond to the sharp division between localized and extended states near what would be the top of the valance band and bottom of the conduction band respectively ,while W_1 is the hopping energy.

2.3- Conduction in localized states and Fermi Energy

At low temperature the conduction happens at the localized states and Fermi level by tunneling process with the assistance of photon and the conductivity in this case is given by:

$$\sigma_{IOC} = \sigma_{02} \exp\left[-\frac{W_2}{K_B T} \right] \text{..........(3)}$$

When W_2 has the same physical meaning of W_1 and $\sigma_{o2}<\sigma_{o1}$

2.4- Conduction at very low temperature

The hopping conductivity occurs at very low temperature and obeys the low.

$$\sigma \propto \exp\left[-\frac{B}{T^{1/4}} \right] \text{..........(4)}$$

Where B is constant.

3- THE HALL EFFECT

The Hall effect is one of the most useful tools for studying the transport phenomenon in the crystalline semiconductors. It is a widely used method to distinguish between the types of the carriers, the concentration, and determining the mobility in the semiconductors.

4- EXPERIMENTAL

4.1- Preparation of Zn_xSe_{1-x} , Alloys

The bulk samples of Zn_xSe_{1-x} , where $0 \le X \le 0.3$ have been prepared by direct mixing of highly pure Zn and Se (purity 99.99%) according to the atomic ratio of their constituent elements. The mixture for different values of x kept in evacuated quartz ampoules at 10^{-2} torr. The ampoules were placed in a furnace at a temperature about 800 C° to melt the mixture for twelve hours. Then the ampoules were leaved at the furnace to cool gradually until their temperatures reach the room temperature. Then ampoules were broken and the prepared compound of Zn_xSe_{1-x} have been taken out and powdered to fine size particles. The powder of the compound was used as a source for evaporation to prepare the films.

4.2- Preparation of ZnxSe1-x Thin Films

According to the applications in electronics and microelectronics and for some experimental work, it is necessary to form films in some special shape or form. A spiral form boat is made of tungsten (w) is used for Al deposition and graphite boat is used to deposit Zn_x Se_{1-x} .

Thin films of Zn_x Se_{1-x}, where $0 \le X \le 0.3$ of thickness 4800 A were prepared by using Edwards E(312) unit. The films are deposited on a glass substrate at room temperature while the pressure is kept at 10^{-6} torr during evaporation.

5- RESULTS AND DISCUSSION

5.1- DC Conductivity

The direct current (dc) conductivity (σ) of the compound Zn_x Se_{1-x} for $0 \le X \le 0.3$ thin films have been determined. The activation energy (Ea) of the films was found using equation (1).

The plot of ln σ against $\frac{1000}{T}$ for the as deposited films at R.T was presented in Figures (1). These figures showed in general two mechanisms from which the activation energies Ea_1 and Ea_2 have been calculated, the obtained values of Ea_1, Ea_2 and the dc conductivity (σ) for the as deposited thin films were tabulated in table (1). The data showed that Ea_1 increases as the Zn content increases, these values changed from 0.6 eV for pure Se (x=0) to 1.01 eV for $Zn_{0.3}$ $Se_{0.7}$ as in Fig-2.

Table (1):- Electrical properties of as deposited Zn_xSe_{1-x} thin films

Parameters	Composition			
	0	0.1	0.2	0.3
$\sigma(atRT)(\Omega.cm)^{-1}$	$10^{-7}\times5.19$	$10^{-7}\times.99$٤	$10^{-7}\times4.5$	$10^{-7}\times3.2$
Ea_1(eV)	0.6	0.712	0.917	1.01
Ea_2(eV)	0.1	0.192	0.153	0.107
type	P	P	P	P
$\left(\frac{cm^3}{C}\right)$ RH	$٣,٩\times١٠^{١٠}$	$٧,٩٥\times١٠^{٨}$	$٧,٤٩٦\times١٠^{٨}$	$٢,٤\times١٠^{٨}$
Concentration cm^{-3}	$١,٦\times١٠^{٨}$	$٧,٨٦\times١٠^{٩}$	$٨,٣٤\times١٠^{٩}$	$٢,٦\times١٠^{١٠}$
u (cm^2/v.s)	20280	389	373	96

The reason for increasing Ea_1 with Zn content is belonged to the density of states of Se at the energy gap is greater than that of Zn , so that the conduction of the carriers takes place through the deep level of the energy gap, and this increases the activation energy Ea_1

Also it is found that $Ea_1 > Ea_2$ because Ea_1 represents the energy of holes excited into extended state below E_V from E_F, while Ea_2 is the hopping energy of the carriers through the localized state(10,11).

The conductivity (σ) of the $Zn_x\ Se_{1-x}$ thin films decreases with the increasing Zn content as in Fig.3. and this belongs to the variation of the energy gaps of Zinc and selenium.

5.2- Hall Effect Measurements

The Hall measurements of the as deposited $Zn_x\ Se_{1-x}$ thin films at R.T have been taken. Figures (4). represent the variation of Hall voltage (V_H) against the current (I) under variable applied electric field and a constant magnetic field. It appears from the figures, the samples were p-type for the range of composition $0 \le X \le 0.3$.

It can be determine the Hall coefficient (RH), Hall mobility μ_H and the carrier concentration from the following equations(12):-

$$RH = \frac{V_H \times t}{I \times Bz} \text{..........} (5)$$

$$\mu_H = |RH|\sigma \text{..........} (6)$$

It was found from Fig.(5)that the Hall mobility depends on the Zn content (x), it was changed from the value 398 cm^2/v.s for $Zn_{0.1}\ Se_{0.9}$ to 96 cm^2/v.s $Zn_{0.3}\ Se_{0.7}$. The
change in the mobility of the films may be due to the variation the structure of the films with X composition, also it may be due to the difference in the mobility of pure Zinc and pure selenium.

6- CONCLUSION

1. It can be concluded from the investigation of (dc) conductivity (σ) of the Zn_xSe_{1-x} $0 \le X \le 0.3$ thin films, that (σ) increases with increasing temperature, because of the increasing of carriers mobility with temperature.
2. There are two activation energies for the Zn_xSe_{1-x} thin films. Ea_1 represents the conduction due to the extended states in the forbidden energy gap, while Ea_2 is the activation energy of the carriers excited into localized states at the band edge.
3. It could find from this investigation that Ea_1 increases with increasing Zn content (x). The increasing in the Ea_1 causes a decreasing in the conductivity.
4. It obtained from Hall effect experiment; the concentration of the carriers increases with increasing the ratio of Zn (x).
5. The mobility of carriers decreases with increasing Zn content (x).

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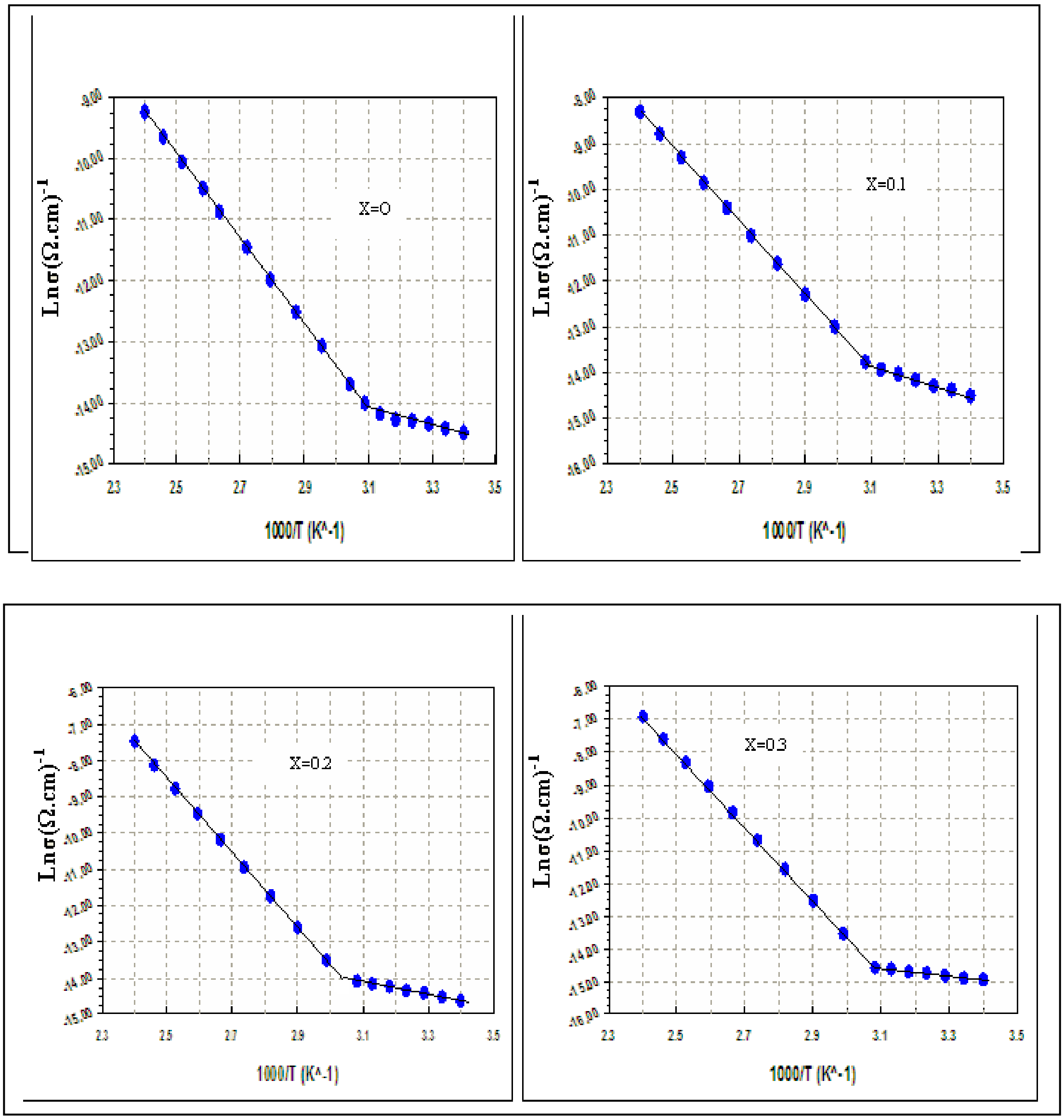

Fig.(1): The variation of In σ vs.1000/T of the as deposited Zn_xSe_{1-x} thin films

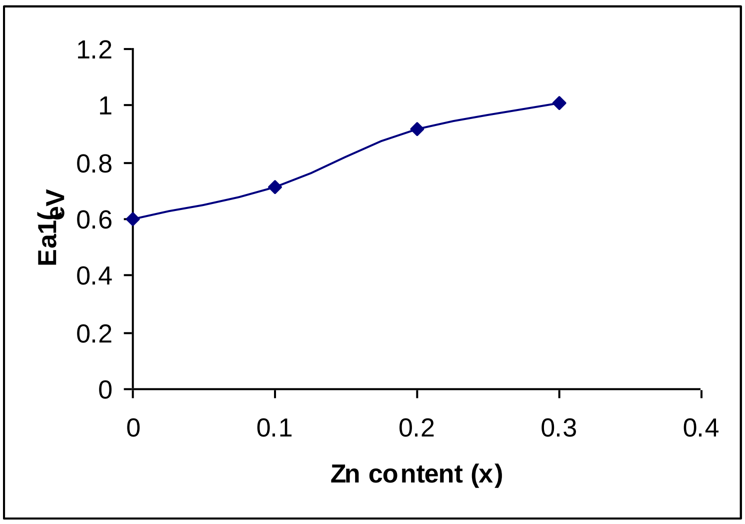

Fig.(2):- The effect of Zn content (x) on the activation energy of the as deposited Zn_xSe_{1-x} thin films

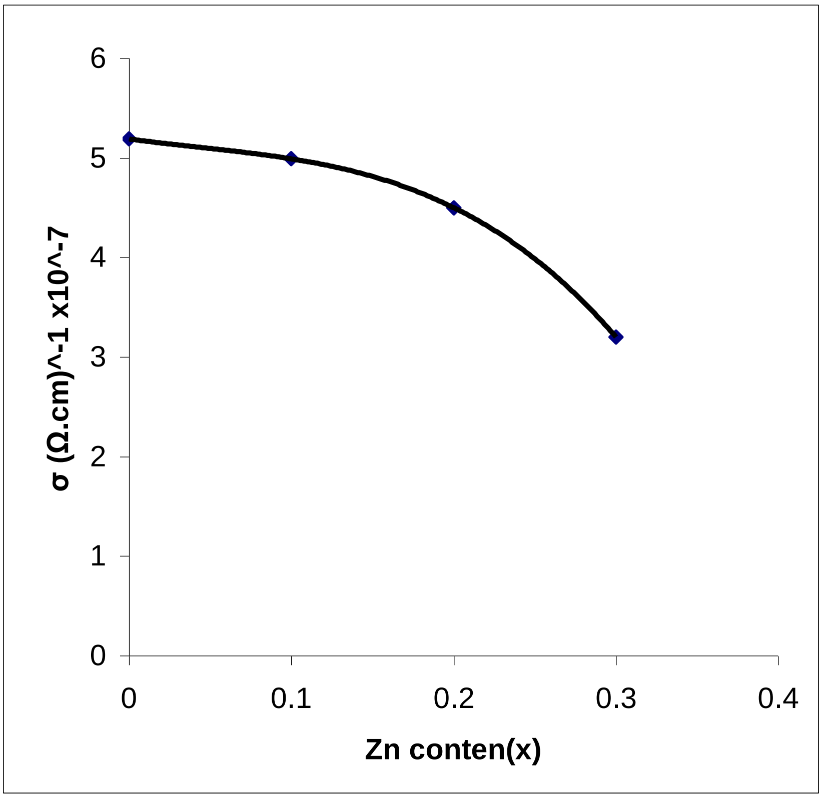

Fig.(3):- The effect of Zn content (x) on the (dc) electrical conductivity of the as deposited Zn_xSe_{1-x} thin films

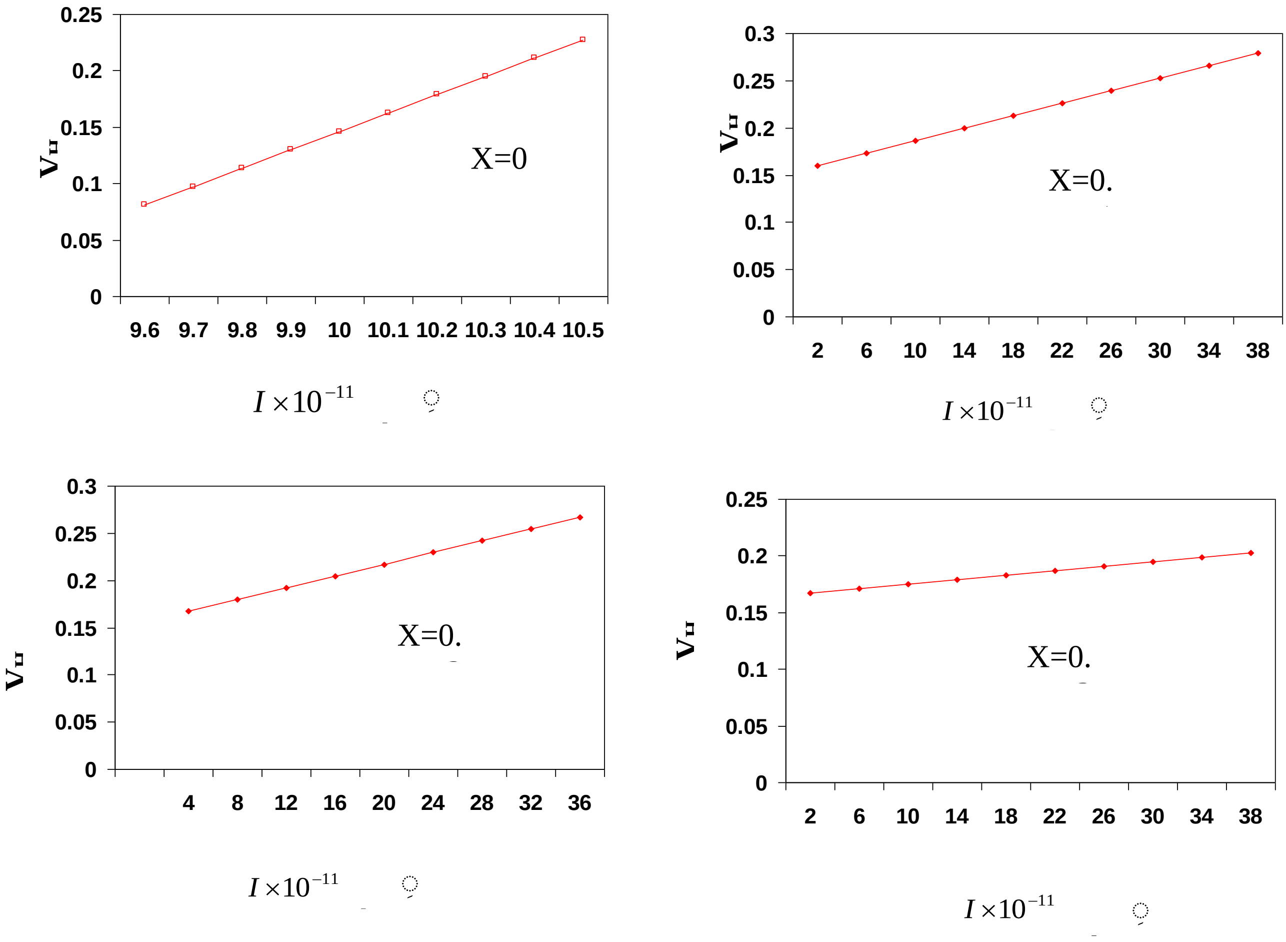

Fig.(4):- The variation of Hall voltage vs .current for Zn_xSe_{1-x} thin films

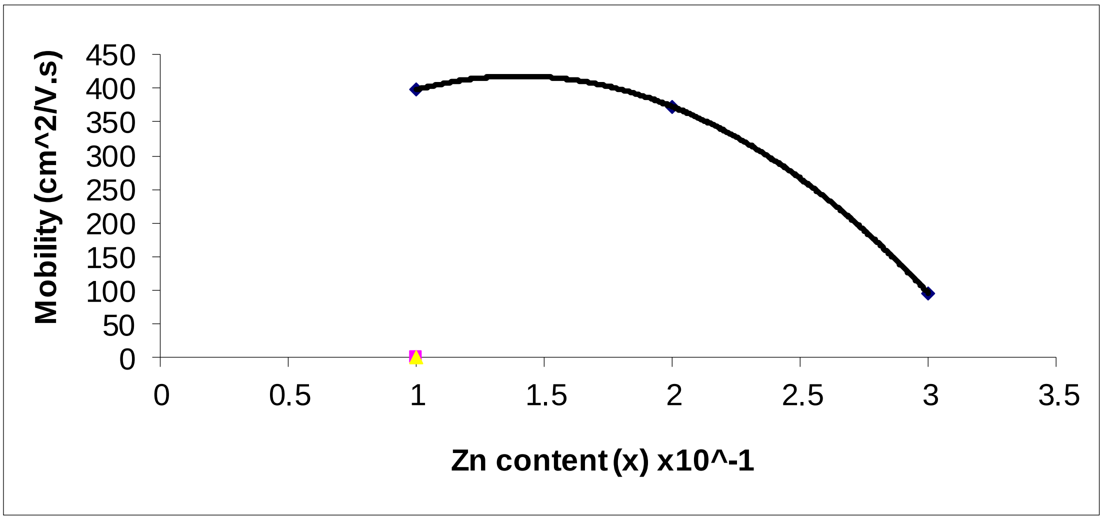

Fig.(5):- The dependence of carriers mobility on Zn content (x) of the as deposited Zn_xSe_{1-x} thin films

الخواص الكهربائية للأغشية الرقيقة للمركب $Zn_x\ Se_{1-x}$ المحضر بطريقة التبخير الحراري

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الخلاصة

حضرت الأغشية الرقيقة لمادة شبه الموصل Zn_xSe_{1-x} على شريحة زجاجية وبسمك nm (٤٨٠) وبدرجة حرارة الغرفة بطريقة التبخير الحراري . درست الخواص الكهربائية لهذه الأغشية كالتوصيلية المستمرة وظاهرة هول , أظهرت هذه الدراسة بان النسبة التركيبية اللاغشية الرقيقة ٠,٣ >x>٠ لها تأثير واسع على هذه الخواص . التوصيلية المستمرة ضمن المدى الحراري (٤٢٣-٢٩٣ ºk), أظهرت طاقتي تنشيط E_{a1},E_{a2} والتي تمثل نوعين من ميكانيكية التوصل الكهربائي وكانت القيم 0.6eV,0.1eV تمثل E_{a1},E_{a2} على التوالي عندما تكون x مساوية إلى الصفر وتتاثر هذه القيم بقيمة x بحث تصبح E_{a1},E_{a2} مساوية إلى 1.01eV,0.1eV عندما ٣ .x=0 , وأظهرت الدراسة بان التوصيلية المستمرة تكون $5.19x10^{-7}(\Omega.cm)^{-1}$ عندما ٠ =x وتنخفض بازدياد x حتى تصل إلى $٣.2x10^{-7}(\Omega.cm)^{-1}$ عندما x=0.3. دراسة ظاهرة هول اثبت بان الحاملات من النوع الموجب (p) وتركيزها هو $1.6x10^{8}cm^{-3}$ ويزداد بازدياد تركيز الزنك (x) حتى يصل الى $2.6x10^{10}\ cm^{-3}$. وكذلك فان التحركية لها علاقة بتركيز الزنك x أيضا.