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Effect of SiO_2 ratio on electrical Properties of SiO_2:ZnO Thin Films Prepared by pulsed laser depositions (PLD) technique

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Abstract

In this paper zinc oxide was dopped by various concentrations (5,10,15,20,25) % of silicon dioxide. The mixture was deposited on glass substrate by laser pulse deposition at room temperature to obtain (Zn_2SiO_4) thin films. The D.C conductivity showed a decrease in activation energy by increasing doping from (Ea1=0.096 eV) to (Ea1=0.075 eV) before annealing and after annealing from (Ea1=0.048 eV) to(Ea1=0.027 eV). Hall effect showed that the concentration of carriers increases from ($2.79 \times 10^{18} cm^{-3}$) to ($14.29\times 10^{18} cm^{-3}$) before annealing and from ($0.30\times10^{16} cm^{-3}$) to ($26.25\times10^{16} cm^{-3}$) after annealing. The mobility decreases from($2.3 cm^2$/v. sec) to ($0.99 cm^2$/v. sec) before annealing and from ($7 cm^2$/v. sec) to ($2.5 cm^2$/v . sec).

1-Introduction

The term thin films is used to describe one or several layers of atoms of a substance whose thickness does not exceed one micron. Because the films layer is thin, it is deposited on different materials known as base and depends on the nature of the study, such as glass, silicon and minerals [1,2]. Zn_2SiO_4 (willemite) is a long known material which still retains its place among the best inorganic phosphorus [3]. Having different crystal phases and being sensitive to doping by transition metals and rare earths, it can emit light at different wavelengths in the visible and near IR range. In the past years there were successful attempts to synthesize nano-phase of Zn_2SiO_4 using both solid state techniques [4]. Aimed at the development of novel low voltage phosphorus having high efficiency and chemical stability. One of the advanced methods for solid state synthesis of nanoparticles is ion implantation with subsequent annealing, which allows creation of nanoparticle-host matrix composites with high chemical stability. Many research groups have studied the ZnO nanostructure formation in SiO2 matrices using ion beam synthesis and thermal oxidation [5]. Electrical properties were studied for the purpose of preparation of optical detector.

2- Experiment part

Zinc oxide powder was mixed with silicon dioxide powder according to the value of (X) with a value of (5,10,15,20,25)%wt. respectively. The proportions of the powders were weighed using a sensitive electronic balance. The powders were then mixed into an England mixing machine Type of Spex mixer for (5) minutes and then the powders were compress by hydraulic press of the type (across international). And sintering the tablets in a tube electric furnace at a temperature of (1000℃) for two hours and after the process of sintering left the tablets to cool to obtain the tablets of the compound (Zn_2SiO_4). The process of deposition of membranes according to ratios was accomplished within a vacuum chamber in the laser system under pressure 10^{-3} torr and the laser energy was (1) J, which is the appropriate energy for deposition. After the thin films were prepared, the films were annealing for(1hr) at 400° C in a tube electric furnace To study the electrical properties of Zn_2SiO_4 thin films, the connections were in the form of masks from conductive material and semiconductor films material, which does not add any resistance to the resistance of the semiconductor material where the electrodes were deposited from the aluminum material and placed on the base of the thin films to complete the electrical conduction in the electric circuit. To measure the conductivity, we attach the sample from the thin films deposited on the glass slide with an electric circuit where it is fixed by two wires connected to the two wires. The electrical connection is placed inside the convection oven. The oven contains a digital meter indicating the temperature of the films. With a digital (Ofometer) to Resistance measurement device, which took one reading per 10 degrees of temperature and the range (20^oC-170^oC). The Hall effect measurements is carried out to determine the type, mobility and concentration of the charge carriers, by using Hall effect system (HMS-3000) supplied by the Ecopia company which shown in fig (1).

Fig. (1) (HMS-3000) for Hall Measurement

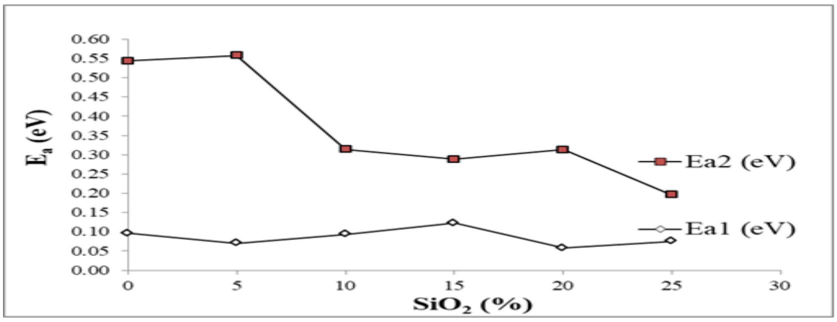
3- Results and discussion

3-1 DC Conductivity

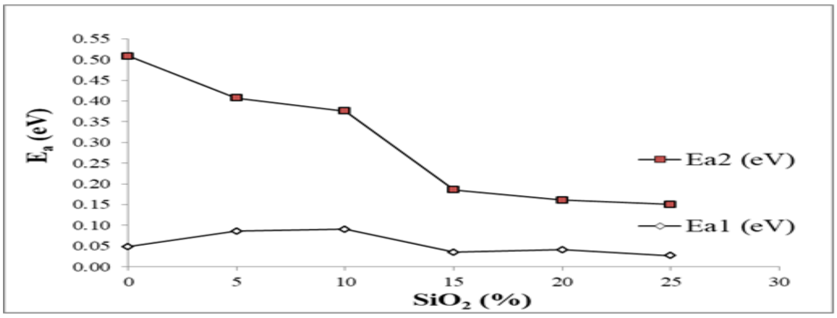
[6].The activation energies could be calculated from the plot of lnσ versus 1000/T according to equation

$\sigma = \sigma_o \exp(-Ea / K_\beta T)$ ----(1)

Where σ electrical conductivity, σ_o is the minimum electrical conductivity at (0K), E_a is the activation energy, K_β Boltzmann constant and T Absolute temperature The figures (2) and (3) showed the activation energy for the Zn2SiO4 before and after annealing. The first region represents the first activation energy the process of jumping between confined levels localized state in energy band gap,then the charge carriers moving from one band to another is not possible at low temperatures. The second region represents the second activation energy at high temperatures where the conductivity is carried out on the basis of the transfer of the charge carriers between the valence and conduction bands in a manner of stimulation or thermal irritation manner of stimulation or thermal excitement . From table (1) we observe the decrease in the values of the activation energies by increasing the rate of doping due to the increase in particle size which leads to a decrease in the density of the granular boundary where there is a tightness in the conduction bands where electrical resistance is lower. anneling led to Improvement the topographical nature of the thin film surfaces and the energy required to transport the charge carriers from the valence band to the conduction band is reduced.This is agree with references [7].



Fig(2) activation energy of Zn_2SiO_4 before annealing



Fig(3) activation energy of Zn_2SiO_4 after annealing

Table (1) activation energy of Zn_2SiO_4

	SiO_2 (%)	E_{a1} (eV)	Range (K)	E_{a2} (eV)	Range (K)
	0	0.096	293-353	0.544	353-463
	5	0.071	293-373	0.558	373-463
Before	10	0.094	293-373	0.314	373-463
Annealing	15	0.122	293-373	0.289	373-463
	20	0.058	293-373	0.313	373-463
	25	0.075	293-373	0.197	373-463
	0	0.048	293-383	0.508	383-463
	5	0.086	293-373	0.407	373-463
After	10	0.090	293-373	0.376	373-463
	15	0.035	293-373	0.185	373-463
Annealing	20	0.041	293-373	0.161	373-463
	25	0.027	293-373	0.150	373-463

3-2 Hall effect

By using the following equations, the concentrations were calculated with the mobility [8].

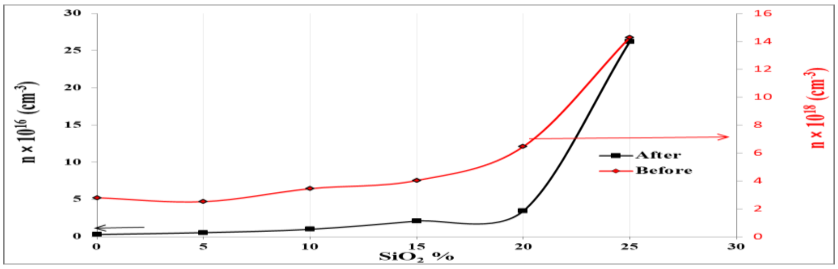
$$R_H = -1/ne.......(2)$$

Where R_H is Hall coefficient, n is carrier concentration and e=1.602x10^{-19}C

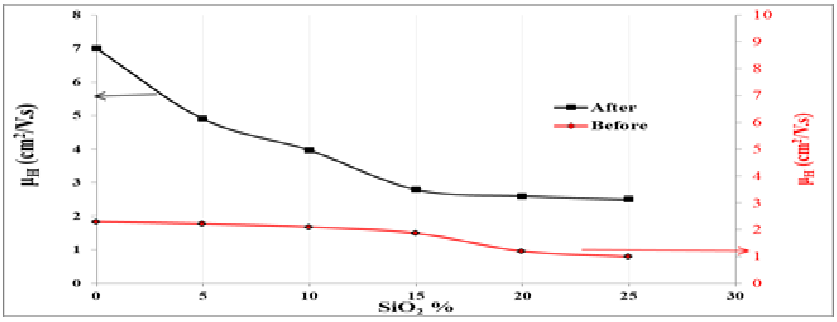
$$\sigma = n\ e\ \mu_H\ ....(3)$$

Where μ_H is mobility

The effect of Hall of the prepared films was measured and the results showed an increased concentration of carriers by increasing the rate of doping and annealing . The mobility is reduced by increasing the rate of doping and annealing .The reason is due to increased homogeneity of the surfaces of the thin films and regularity and order of nanoparticles that result in reducing crystalline defects and this seems clear in Fig (4) which shows the concentration of carriers before and after annealing and fig (5) which shows the mobility before and after annealing This agrees with the references [9,10,11].



Fig(4) carrier concentration of Zn_2SiO_4 before and after annealing



Fig(5) mobility of Zn_2SiO_4 before and after annealing

Table (2) Hall effect of Zn_2SiO_4

	SiO_2 %	n×10^{18} (cm^{-3})	μ_H (cm^2/v.sec)
	0	2.79	230
	5	2.51	222
Before	10	3.44	210
	15	4.03	187
	20	6.46	120
	25	14.29	99
	SiO_2 %	n×10^{16} (cm^{-3})	μ_H (cm^2/v.sec)
	0	0.30	7.00
After	5	0.54	4.90
	10	0.99	3.97
	15	2.10	2.79
	20	3.46	2.60
	25	26.25	2.50

4- Conclusion

1-The Hall test showed that samples prepared were (n-type).

2- The doping increased the concentration of charge carriers.

3- Doping led to a decrease in mobility.

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تأثير نسبة اوكسيد السليكون على الخواص الكهربائية لأغشية اوكسيد الخارصين المشوبة باوكسيد السليكون والمحضرة بطريقة الترسيب بالليزر النبضي

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الملخص

في هذا البحث تم تشويب اوكسيد الخارصين بتراكيز (5،10،15،20،25)٪ من ثاني أكسيد السيليكون وتم ترسيب الخليط على ارضيات زجاجية بواسطة الترسيب بالليزر النبضي عند درجة حرارة الغرفة للحصول على اغشية سليكات الخارصين. وأظهرت نتائج التوصيلية الكهربائية ان طاقة التنشيط قد قلت من (Ea1=0.096 eV) الى (Ea1=0.075 eV) قبل التلدين اما بعد التلدين فقد قلت من (Ea1=0.048 eV) الى (Ea1=0.027 eV). أظهرت نتائج تأثير هول ان تراكيز الحاملات زادت من ($2.79 \times 10^{18} cm^{-3}$) الى ($14.29 \times 10^{18} cm^{-3}$) قبل التلدين أما بعد التلدين فتزداد من ($0.30 \times 10^{16} cm^{-3}$) الى ($26.25 \times 10^{16} cm^{-3}$). أظهرت نتائج الاحتمالية انها تقل من ($2.3 cm^2/v.sec$) الى ($0.99 cm^2/v.sec$) قبل التلدين أما بعد التلدين فتقل من ($7 cm^2/v.sec$) الى ($2.5 cm^2/v.sec$) .