



Study of Some Physical Properties of ZnO Thin Film and Its Use as Gas Sensor for H₂S Gas and Photovoltaic Applications.

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Date of Submission: 12-10-2024

Date of Acceptance: 26-10-2024

Abstract

Prepared of zinc oxide thin films by the successive ionic layer adsorption and reaction (SILAR) technique deposited. used zinc sulphate (Zn(SO₄) · 7H₂O), KOH and ammonia (NH₃) on glass and silicon substrates at room temperature. The structure properties were studied by using (XRD) and (AFM), UV-VIS spectrum of the films showed that the optical band gap 3.2eV). Also the sensitivity and photovoltaic were study.

Keywords: Zinc oxide thin film, H₂S gas sensor, SILAR technique, Photovoltaic.

As well as, this study objects to correct the sensitivity of the device gas sensor prepared through chemical technique on silicon and glass substrates. The most important characteristic of the current implementing contains fast response time to H₂S gas. n-type ZnO thin films on silicon and glass substrates using SILAR with the structural, optical, photovoltaic and gas sensing properties straight with micro structural quantities. improvements in fabrication methods have cemented the manufacture of low-cost sensors with perfected sensitivity and precision emulated to those composed using past methods [13].

I. Introduction

ZnO thin film is a wide band gap (3.3 eV)[1], semiconductor and thus, it has been believed as a stress material for diaphanous electrode and electronics[2,3] and closely used in solar cells as window layer and pellucid thin film transistors[4]. ZnO thin films have been calculated as the efficient procedure material in thin film transistors development because of its exhibiting n-type semi conductive characteristic with band gap of 3.3eV and outstanding thermal constancy and can be well oriented crystalline on diverse substrates [5]. non-toxicity, good electrical, optical and piezoelectric manner. ZnO concludes major electromechanical coupling coefficient, and is perhaps the first material of its nature, which was successfully hard-done by to make merchant devices in thin film create [6]. though the main installation of ZnO varistor substantial's is ZnO, ZnO itself does not revelation nonlinear I-V characteristics. The methods to synthesize nano and micro ZnO thin films was advanced [7]. Thin films of ZnO can be deposited by several methods such as magnetron sputtering [8], pulsed laser deposition [9] and spray pyrolysis [16]. Among them sol-gel technique is simple, low cost and large area deposition technique [11].

The goal of this study research to reconnoiter the structure of Nano crystalline thin film ZnO and its employment as an H₂S gas sensor [12].

II. Experimental

Zinc oxide thin films were deposited on p-glass and silicon substrates using aqueous zinc compound solution comprising a mixture of zinc sulfate (Zn(SO₄)•7H₂O) (0.2M), potassium hydroxide (KOH) (1.2M) and ammonia in the first beaker, The second beaker contains distilled water at 70°C to high. The glass and silicone substrates were cleaned with chromic acid and then rinsed with distilled water. The first substrates immersed in a zinc complex solution comprise the mixture for 25 s. The second step substrates rise in distilled water at 70 °C for 15 seconds, then annealing the thin films deposited on glass at 300 °C in air, either films deposited on silicon annealing at 200 °C for 2 hours, as shown in the figure 1. The process of preparing zinc oxide thin films includes three steps:

- i) Adsorption: In first stage of SILAR process, the cations existing in the precursor solution are adsorbed on the surface of the substrate and form the Helmholtz electric paired layer.
- ii) Rinsing: In this stage, overflow adsorbed ions, Zn⁺ and O⁻ are swilled expulsion from the diffusion layer. This results into saturated electrical double layer.
- iii) Reaction: In this reaction stage, the anions from anionic precursor solution are inserted to the system. Due to the low stability of the material, Zn⁺ and O⁻, a solid substance is formed on the interface. The overall reaction can be written as::



a) Solution of zinc-complex

b) solution comprises a mixture.

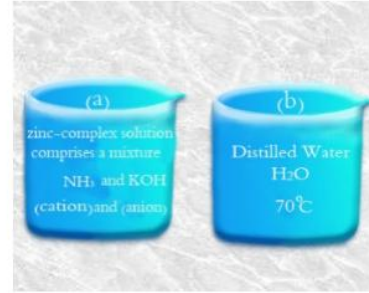


Fig.1. SILAR System

III. Results and Discussion

The figure (2:a and b) the AFM image of Zinc oxide thin film of thickness $3.2\mu\text{m}$ confirms the polycrystalline nature. The surface morphology of the films appear that grain size depends on the

molarity of the precursor solution and annealing temperature. Note the glass and silicon substrates as show in figure (2:a and b), either thin film of deposited on silicon substrate crystallized because silicon is amorphous crystalline surface

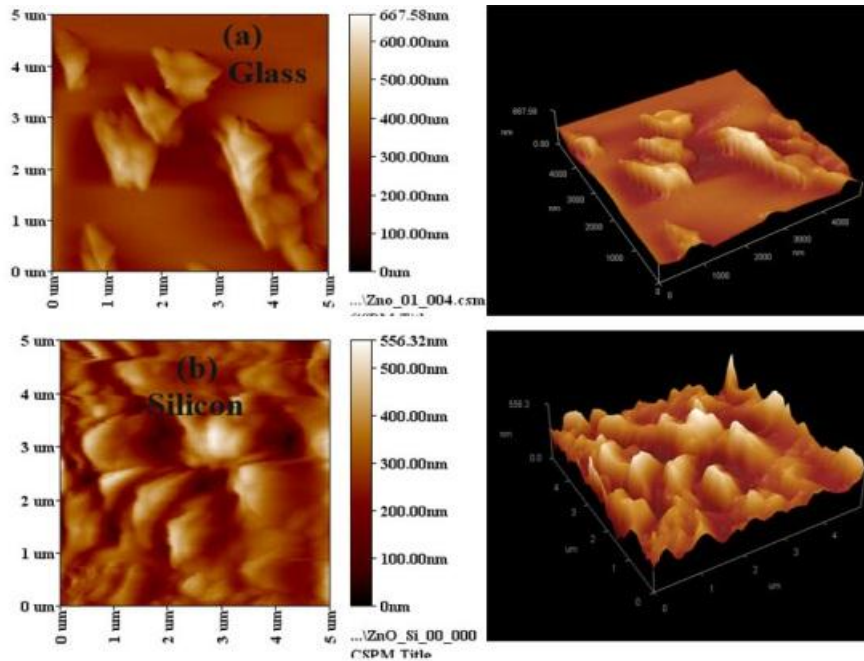


Fig.(2) a. AFM image of ZnO thin film deposited on the glass substrate .and b. AFM image of ZnO thin film deposited on the silicon substrate .

3.1 X-ray diffraction (XRD)

Figure (3: a and b) shows the XRD pattern of ZnO thin film prepared by the successive ionic layer adsorption and reaction (SILAR) on glass and silicon substrates. The film was annealed at 300°C in air for membranes deposited on glass substrate while thin films deposited on silicon substrate at room Temperature with prevalent directional. The microstructure ZnO film on glass substrate is shown in figure (3:a) low polycrystalline appears at 31.81° and 34.48° with direction (100) and (002),

ZnO film polycrystalline increases as shown in figure (3:b) at 31.81° , 34.48° , 36.29° and 56.85° with direction (100), (101), (002) and (110) peaks for silicon. The peaks are appear due to diffraction from (100), (101), (002) (102) and (110) planes hexagonal phase formation as compared with standard [X-ray diffraction data file [N 1997 JCPDS prevalent]. The grain size was calculated by Scherer's formula [14] average grain size (106 nm) to ZnO thin film deposited on glass and (145nm) on silicon. As is expected for hexagonal ZnO structure [15].



$$G.S = \frac{0.94\lambda}{\beta \cos\theta} \dots \dots \dots (1)$$

$G.S$: is the grain, K : is a constant (0.94), λ : is the wavelength of Cu $K\alpha$, θ : is the Bragg's angle
 β : Full Width at Half Maximum (FWHM).

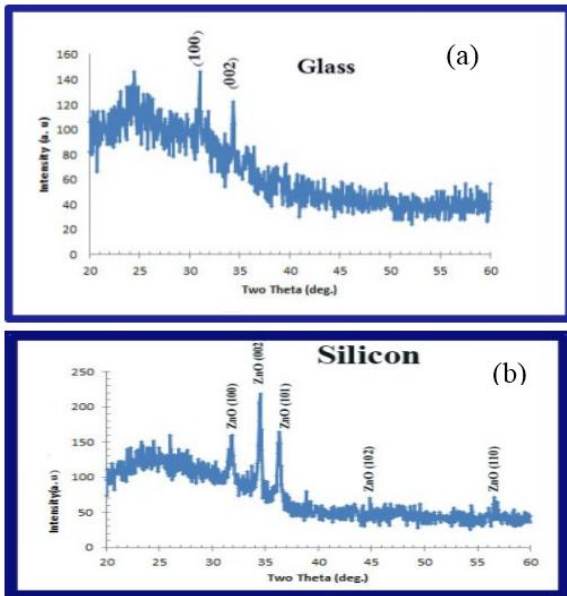


Figure 3. The XRD pattern of the ZnO films: (a) Annealed at 300°C for glass and (b) Silicon at RT.

3.2 Optical Properties

Figure (4) shows the absorbance and transmission in UV-visible spectra region for ZnO, measured transmittance in the range 200nm to 900 nm. The higher transmission in for ZnO, therefore ZnO thin film used in solar cells in addition to the large energy gap. While The spectra revealed that the ZnO films have low absorbance in the visible region.

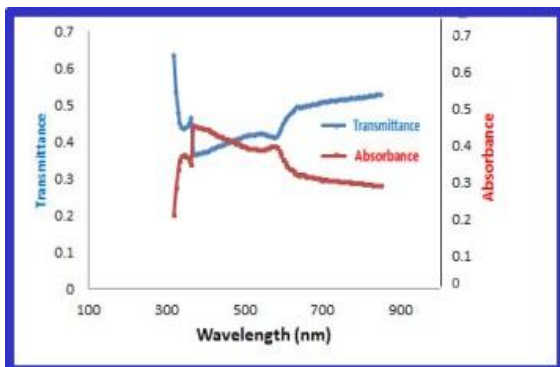


Figure (4) ZnO thin films transmittance and absorbance spectroscopy on glass substrate .

The variation of the absorption coefficient (α) with wavelength for the ZnO films is shown in

Figure(5:a). The absorption coefficient was found to follow the relation [16, 17]. The energy gap E_g was calculated using the relation $(\alpha hv)^2 = A(hv - E_g)^n$, $(\alpha hv)^2$ as a function of hv [18][19], α is the absorbent coefficient of the thin film. Where A is a constant, hv is the photon energy of the incident light, n is an integer which depends on the nature of transition. For direct transitions $n = 1/2$ or $2/3$ while for indirect $n = 2$ or 3 depending on whether they are allowed. The band gap E_g can be obtained by extrapolating the linear portion to the photon shown in Figure (5: b). The value of energy gap (3.2eV).

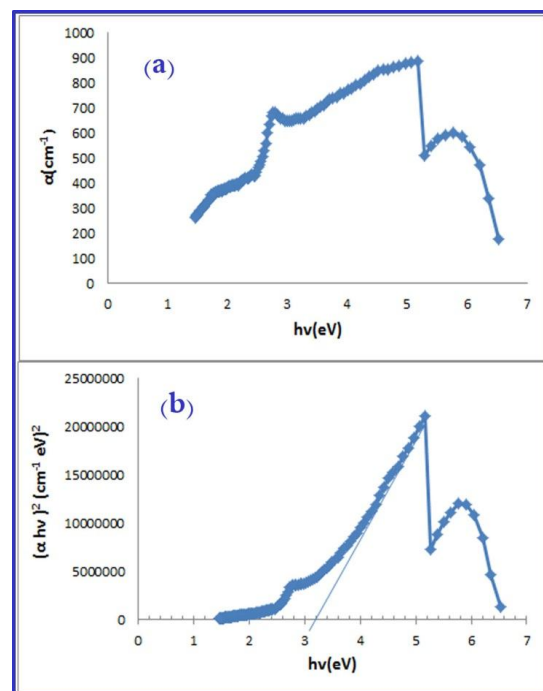


Figure 5:a. Absorption coefficient vs. photon energy deposited on the glass.

b. $(\alpha hv)^2$ vs. hv for ZnO thin film deposited on the glass.

3.4 Gas sensing properties

The figure (6) shown system has been used to measure prepared ZnO thin films on silicon sensitivity for the (H_2S). After connecting the deposited aluminum electrodes on the ZnO thin films with wires and the sample was fixed on a base inside a chamber. The working gases were pumped in to the chamber and recording the change in thin films resistance with time (per 10 seconds), ZnO thin films suffer from the height of potential barrier in the reducer by using H_2S gas closed to 1 ppm. The sensitivity is higher for sensors on the ZnO deposited on silicon ($p-n$ junction) as show in figure 7, because the ZnO sensor resistance become very low and the



response to H₂S was fast. For sensing experiments, the transition ZnO thin films were deposited on the Silicon by the Successive-Ionic-Layer-Adsorption-and-Reaction (SILAR) technique at room temperature [20].

This sensor behavior that is related to the adsorption and desorption of oxygen. The Oxygen (O₂) molecules are adsorbed on the surface of ZnO thin film, they would extract electrons from the conduction band and trap the electrons at the surface in the form of ions. This will lead a band bending and an electron depleted region. The electron-depleted region is so called space-charge layer, of which

thickness is the length of band bending region reaction of these oxygen species with reducing gases or a competitive [20]. Adsorption and alternative of the adsorbed oxygen by other molecules decreases and can reverse the band bending, resulting in an increased conductivity, in other words, when the gas molecules come into contact with this surface, they may interact with this oxygen leading to increase in conductivity. As the sensing mechanism involves the surface reactions between free carriers and the surrounding environment. It was found that resistance change.

$$\Delta R = |R_{\text{air}} - R_{\text{gas}}|$$

The sensitivity of the sensor element to gases was calculated according to the formula [21] as in equation (1).

$$S (\%) = \frac{|R_a - R_g|}{R_a} \times 100 \quad \dots\dots(1)$$

The electrical resistance of ZnO film in air (R_a) and in the presence of (R_g) was measured to evaluate the gas responses, defined as equation (1).

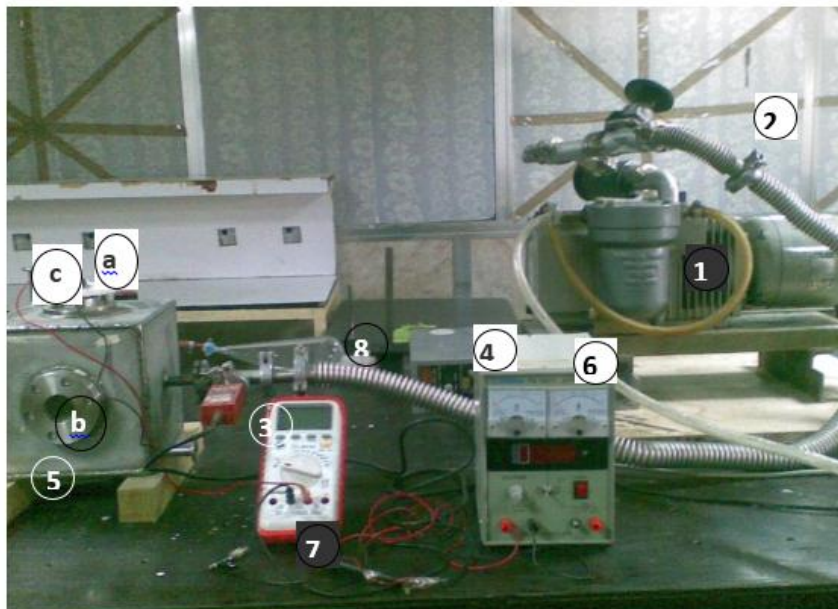


Figure (6) Gas Sensing measurement setup (1- Rotary pump vacuum bellows 2- conductivity tubes 3- vacuum head 4- reader of pressure 5- system Chamber a- electrical feed through and pump gas b- Glass window c- Lead through 6- DC Power supply 7- multi meter 8- metal base)

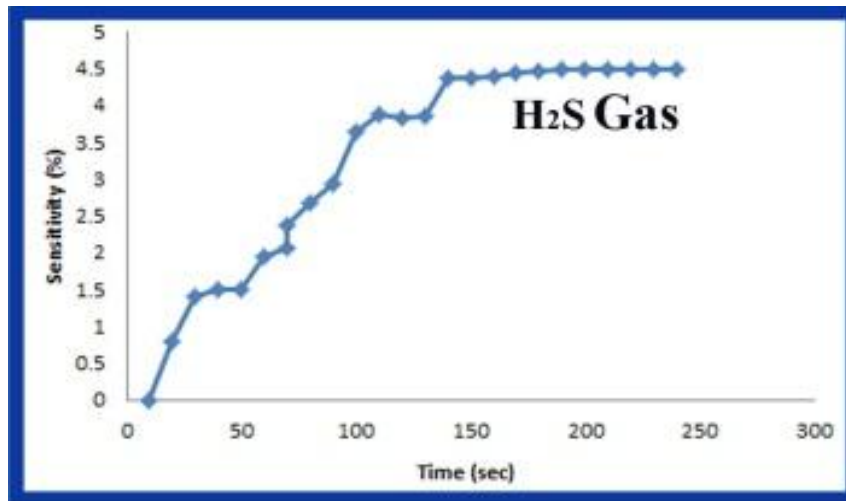


Figure 7. Sensitivity variation as a function of Time (sec) for ZnO thin film deposition on silicon to H₂S gas.

Figure 8 represents the response time and is defined as the conduction time for the gas sensor. The current was monitored for 60 s and no change in current was observed. result measurements that agree to a 60 sec relay of H₂S gas.

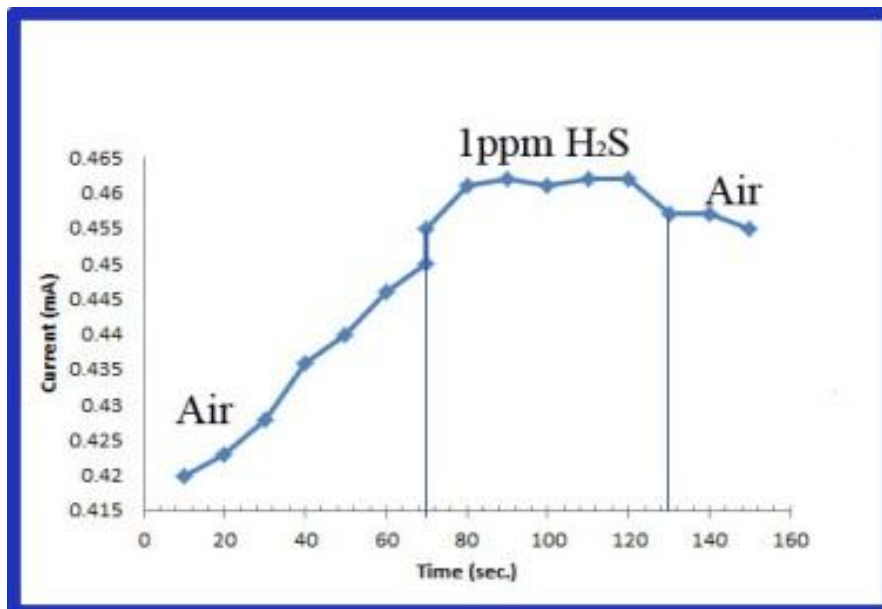


Fig.8 The response of ZnO thin film to 1ppm H₂S gas

Photovoltaic Properties:

The I-V curves for 3.5 μm thick ZnO in the dark and under illumination are shown in Figure 6. The lighting intensity of (470LUX) was used to incident light in examined, the photo-generated carriers alter the electric field distribution and change carrier conduction during illumination [22]. It seems that illumination increases the conductivity of ZnO and reduces the series resistance of the solar cells.

The dependence of solar cell efficiency on incident light wavelength, measured in the wavelength range between 400 nm to 750 nm (470LUX) visible light. The photovoltaic is based on using semiconductor materials in solar energy conversion, electrons will move downhill to *n*-type through the solid junction and holes move upward towards *p*-type side by electron-hole ($e^- h^+$) pairs.

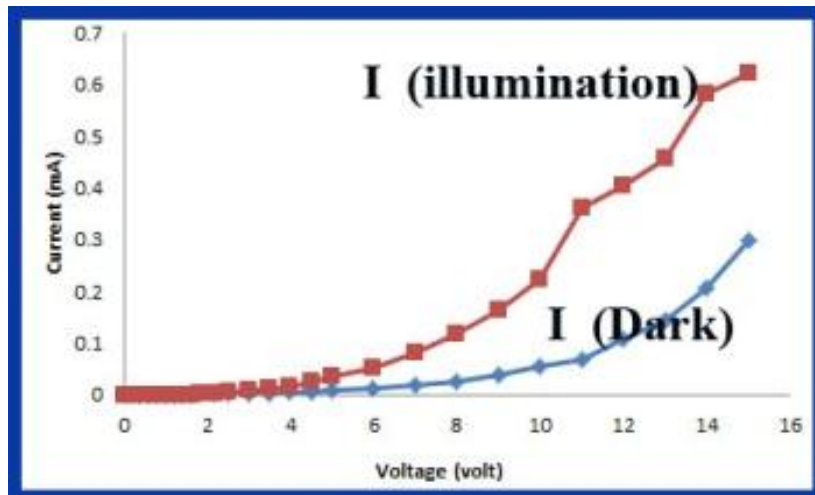


Fig (9) I-V characterizes

IV. Conclusion

The ZnO thin film deposited by the successive ionic layer adsorption and reaction (SILAR) on glass and silicon substrates. Polycrystalline thin films from result XRD, the average grain size (106 nm) for deposited ZnO on glass and (145 nm) on silicon. Optical transmittance is above 60% in the visible region with band gap (3.2eV). Good sensitivity of ZnO thin film to H₂S. The response time (65- 125) sec., the thin film showed response H₂S gas. The semiconductor contains a *p-n* junction use in photovoltaic cell and solar cell applications.

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