Some gas sensing properties of PbS thin films

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Abstract

In this research PbS thin film have been prepared by chemical bath deposition technique (CBD).The PbS film with thickness of (1-1.5)µm was thermally treated at temperature of 100°C for 4 hours. Some Structural characteristics was studied by using X-ray diffraction (XRD)and optical microscope photograph some of chemical gas sensing measurements were carried out ,it shown that the sensitivity of (CO_2) gas depend on the grain Size and deposition substrate. The grain size of PbS film deposited on on glass closed to 21.4 nm while 37.97nm for Si substrate. The result of current-voltage characterization shwon the sensitivity of prepared film deposited on Si better than film on glass.

Key words
Gas Sensing,
PbS thin films,

Article info
Received: Sep. 2010
Accepted: Jun. 2011
Published: Oct. 2011

بعض خصائص تحسس الغازات لأغشية PbS الرقيقة

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الخلاصة:

في هذا البحث حضرت أغشية PbS بتقنية الترسيب الكيمياوي عند سمك µm (1-1.5) وعوملت الأغشية حرارياً عند درجة حرارة 100°C لمدة أربعة ساعات. درست بعض الخصائص التركيبية بإستخدام جهاز X-ray والمجهر الضوئي،اما بالنسبة لفحوصات المتحسسات الغازية أثبتت أن التحسسية تعتمد على الحجم الحبيبي ونوع الأرضية المرسبة عليها الأغشية. الحجم الحبيبي للأغشية PbS المرسبة على الزجاج كانت مساوية لـ nm ٢١,٤ بينما الأغشية المرسبة على السليكون تساوي ٣٧,٩٧ ، النتائج أظهرت أن خصائص التيار- فولتية والتحسسية للأغشية المرسبة على الـ Si أفضل مما عليه في الزجاج.

1. Introduction

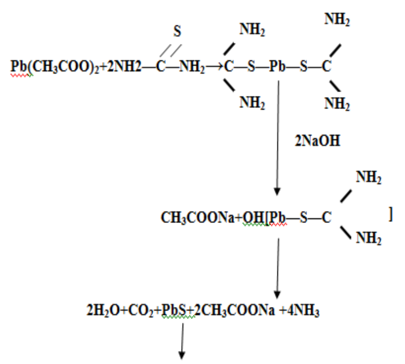
Today there is a great deal of interest in the development of gas sensors for application of air pollution monitoring, detection of harmful gases in mines, grading of agro-products like coffee and spices, home safety, exhaust gas monitoring, hand held breath analyzers etc. Chemical deposition, electrodeposition, and molecular beam epitaxy. Among these methods, chemical bath deposition fromaqueou solutions has some advantages. Indeed, it permits the routine creation of semiconductor nanocrystals. The size of chemically deposited nanocrystals is also much smaller than what can be realized using molecular beam epitaxy and lithographic methods [3]. The development of the methods of colloid chemistry for quantum dots fabrication has led to practical applications of confinement, such as in solution-processed solar cells, lasers and as biological labels [4]. Nucleation and growth in solution leads to nearly spherical crystals. The spherical shape of nanocrystals is very important, for example, for the energy level spectrum of quantum dots [5]. In contrast, deposition by molecular beam epitaxy and electro deposition typically yields nonspherical structures. Nan crystals could also be made by the inverse micelle method [6], but this method is not efficient for creating large crystals or continuous films. In addition, chemical bath deposition involves relatively low costs and is a relatively easy technique. Substrates of various sizes and shapes may be used and no toxic gaseous precursors are needed. Moreover, the chemical bath deposition method allows the production of large volumes of powders and films for industrial applications (gas sensor for example)[7].

2.Experimental procedure

2.1. Synthesis

In this study, we report the growth of PbS films by CBD on silicon (111) and glass substrates. To obtain uniform films glass substrate and silicon was tilted at 60° during deposition. The baths were prepared from aqueous solutions of lead acetate $Pb(CH_3COO)_2$ (0.1 M), alkaline NaOH (2 M) and thiourea $(NH_2)2CS$ (0.1 M), where M is mol/l. Such concentration regions allow depositing not only the residues on the bottom of the reactor but also the film on the substrate [8].

The reaction mechanism is of the form:



X- ray shemadzu XRD-diffractrometer (operated at 401CV at accelerating potential and 30 nA with filterd CuClx radiation of 1.5418 Å wavelength) and optical microscope (Nilcon type 120-Japan optical microscope with digital camera DX41200F) at magnification of (300-500x).To study the electrical characterization of the PbS films, the sensor element was connected in series with multimeter as shown in Fig.(1). Electrical resistivity measurements were performed using two multimeter for current and applied voltage measurements and power supply in the range of (0 –20) Volt. Gas sensing measurements have been carried out using home-built gas sensing chamber (gas flow elements) as shown in Fig.(2).

The gas sensitivity of PbS thin film element for CO_2 gas has been evaluated at room temperature. The resistance response of each sensor structure was transformed into a sensitivity value using commonly used formula (1) for the reducing and oxidizing gases [9]:

$$S = \Delta R / R$$

$$S = R_{air} - R_{gas} / R_{air} \quad \ldots\ldots\ldots\ldots(1)$$

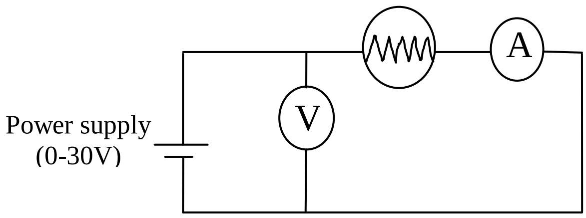


Fig.(1): Sehematic of PbS thin film sensor circuit.

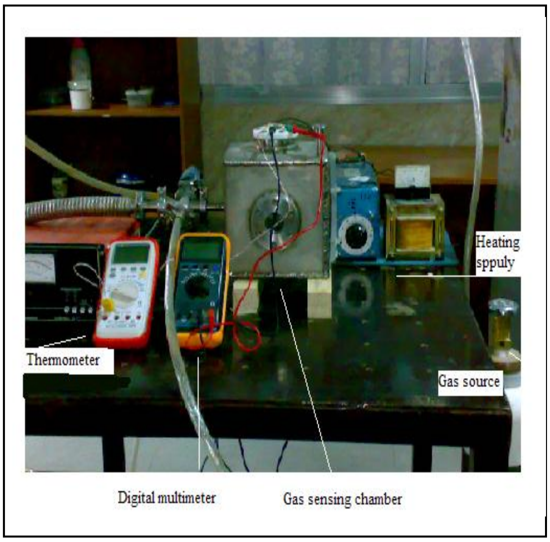


Fig.(2):The gas sensing measurement setup.

3. Results and Discussion

3.1. X-ray diffraction & surface morphology

Figs.(3,4) Shows the X-ray diffraction of (PbS/glass),(PbS/Si) thin film. The peaks of reflections indicate that films are of polycrystalline structure and the intensity of plane (111) reflection is higher than that of other planes, which means that this plan is suitable for crystal growth. We found the peak of reflections indicate that film is crawling within the a mount (2.5°) towards the high (2θ) when we deposited PbS on Si.The peaks of reflections indicate of PbS/Si is suitable for crystal growth than PbS/glass thin film. The PbS grain size broadening measured obeys the Scherrer–Warren equation (2) [10] . We found the grain size of PbS on glass is (21.4) nm and (37.97)nm for Si substrate.

$$G = 0.9 \lambda/\Delta \cos\theta \quad \text{.......... (2)}$$

K_{hkl} =0.9, Δ= full-width at half-maximum (FWHM) of the resolution function(instrumental broadening),

λ=1.6 Å

Surface morphology of the films were carried out using an optical microscope as shown in Fig.(5). The measurement of surface morphology of the films observed Grain size on Si is more apparent than glass.

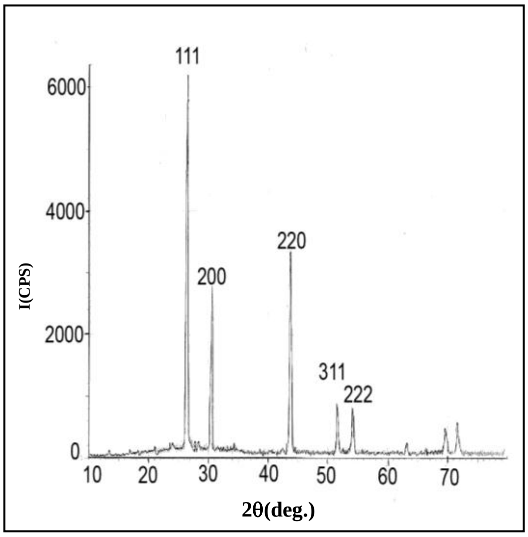


Fig. 3 : Xay Diffraction Spectra for PbS/glass thin film.

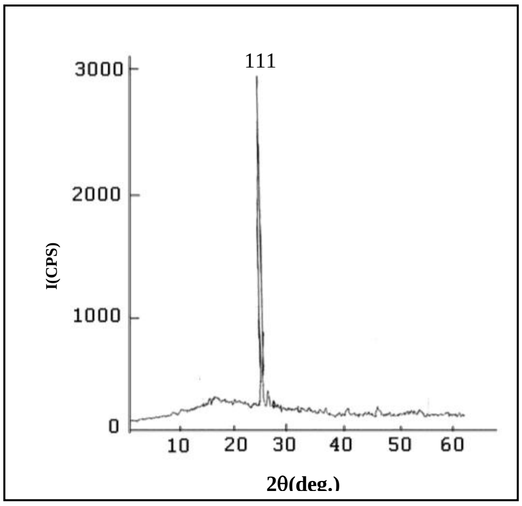
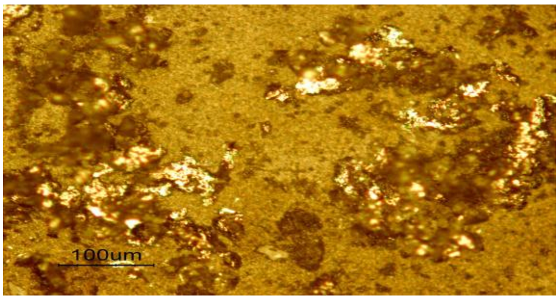
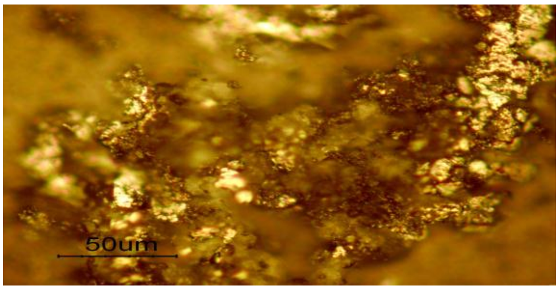


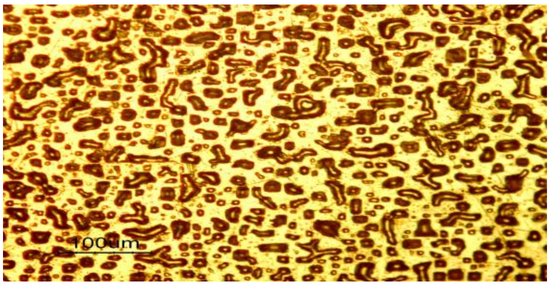
Fig. 4: X-ray Diffraction Spectra for PbS/Si thin film.



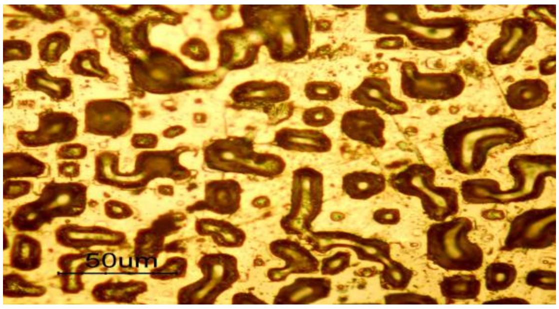
PbS/glass at magnification of 200x



PbS/glass at magnification of 500x



PbS/Si at magnification of 200x



PbS/Si at magnification of 500x

Fig. 5: Optical Micrographs of PbS thin film

3.2. Gas Sensing Measurements

Fig. (6) shows the variation of the current of the layers according to the applied voltage in presence of CO_2 gas and air. It is observed that resistivity of Pb/glass is less than Pb/Si. The variation of the current according to the applied voltage in presence of CO_2. It is observed that resistivity decrease with CO_2.

The normalized sensor response magnitude to CO_2 gas with exposed time variation are shown in Fig (7 and8) It was found that, the PbS/Si sensor responded more than PbS/glass and rise time is shorter. However, the sensor response for reducing gas, defined as the ratio of the baseline resistance to the sensor resistance after exposure to gas (ΔR/ Rair), is 0.01- 0.02 , of PbS/Si and 0.123-29.6 of PbS/glass at 300K.

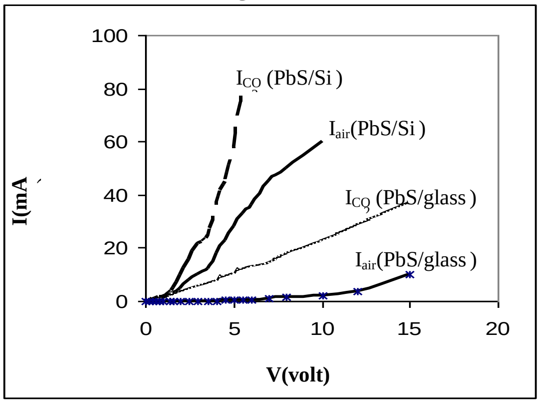


Fig. 6: Current- Voltage characteristics of PbS sensors in CO_2 gas and air –gas references.

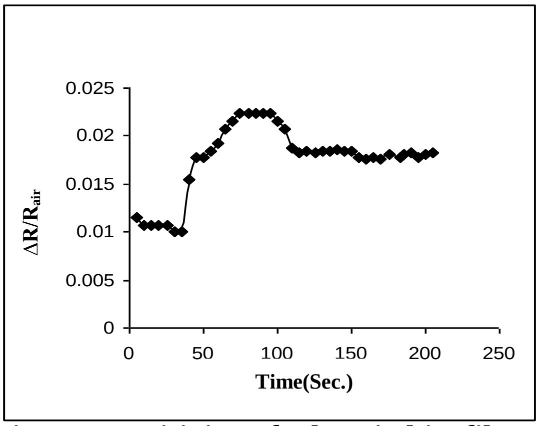


Fig .7: Sensitivity of PbS/Si thin films to CO_2 gas

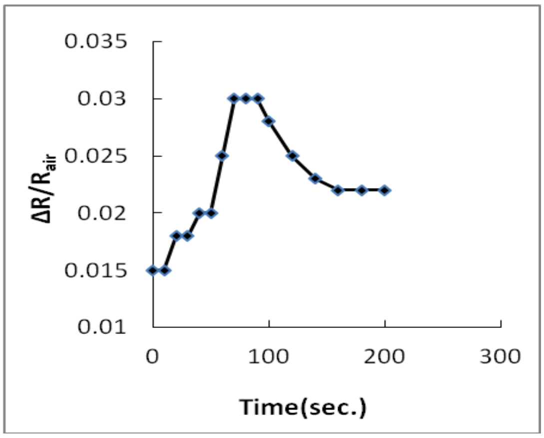


Fig. 8: Sensitivity of PbS/glass thin films to CO_2 gas

4. Conclusions

PbS/Si film exhibited good sensitivity to the CO_2 gas with more response-recovery characteristics than PbS/glass because crystal growth of PbS thin film on Si appear more crystalline than PbS thin film on glass.

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