

# Performance of a Nano PbS/Si Hetrojunction Deposited by chemical spray pyrolysis

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**ABSTRACT:** Deposition of polycrystalline Lead sulfide nano thin films onto Si and glass substrates at temperatures (200- 300 °C) was carried out by chemical spraying route using optimized preparative conditions. The XRD pattern confirmed the formation of PbS semiconducting films with orthorhombic structure. The electrical and optical properties of the nano crystalline thin films were studied aiming to better understanding for the electrical and opto-electrical properties of a hetrojunction with p-type Si. It was found that, the average grain size of PbS in the films was between 4 nm and 7 nm. The band gap was also calculated from the absorption co-efficient curves and showed a blue shift due to the grain size of the nano PbS in the films. The current-voltage (I-V) and photoresponse characteristics were obtained with different illumination intensities. The detector exhibits an evident wide-range spectral responsivity.

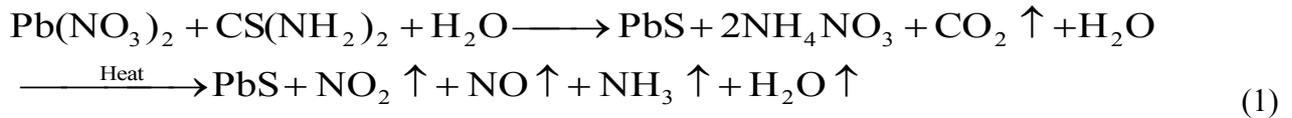
## 1. INTRODUCTION

Quantum confinement in nano semiconductors ( which occurs when electrons are strongly confined in one, two or three dimensions), is the basic behind research and development of low-dimensional semiconductor nanostructures .It had been theoretically and experimentally [1-3], demonstrated that semiconductor quantum wires and dots, where electrons are confined in two and three dimensions respectively, can provide a significant additional enhancement of device performance due to [4] (1) blue shift in photoluminescence, (2) energy levels of core bands and the adsorbater-induced satellite shift simultaneously towards higher binding energy, (3) dielectric constant is suppressed and causes a blue shift in photo absorption. PbS is one of the best known chalcogenides enjoying an increasing interest due to their specific properties, such as band gap enlargement, quantization of the electronic levels, that make them attractive for opto-electronic applications. A variety of techniques have been reported for nanostructures synthesis, among them, chemical spraying pyrolysis method, considered as the most suited for thin film deposition because it allows the size and composition of the nanostructures to be varied, flexibility to use a variety of substrate materials, and does not require sophisticated and costly equipment of deposition [5-7]. Here, we present a heterojunction, based on Si and PbS nanoparticles, fabricated in the Al/PbS/Si/In architecture, where the nanoparticle films are deposited by spray pyrolysis from solutions.

## 2. EXPERIMENT

Silicon and glass are used as a substrate for Nanostructures pbS thin films deposited bychemical spray pyrolysis method. The CSP method has been chosen in this work because the method is economical, requires short processing time, can be performed in atmospheric conditions and can prepare thin films. Silicon wafers used for fabricating PbS/Si heterojunction were p-type (111) orientation with resistivities of (1.5–4 Ω·cm) and (500 μm) thickness. They were rinsed in acetone and ethanol in order to remove dirt and oil, while native oxide layer was removed by etching in dilute (1:10) HF: H<sub>2</sub>O solution. The nano PbS layer was deposited from a solution having optimal deposition parameters including pb(NO<sub>3</sub>)<sub>2</sub> ( 0.01M), CS(NH<sub>2</sub>)<sub>2</sub>( (0.01M). bath temperate

of (300<sup>0</sup>C) and the total deposition time of 90 min .During deposition the following reaction takes place



The film deposition temperature was measured from the glass surface when de ionized water was sprayed. Electrodes were deposited on both sides of the PbS/p-Si. Ohmic contacts from high purity aluminum wire 5N with 200 nm thicknesses onto the back surface of Si, and indium on PbS layer were performed through a metal mask. Dark current–voltage PbS/Si measurements were carried out by applying a voltage to the sample from a stabilized d.c. Fine power supply, type L 30–2 Farnell of range (0.1–5)V. The current passing through the device was measured using a Keithley (602) electrometer.

Capacitance–Voltage characteristics of the heterojunction were measured using a PM 6306 Programmable LRC meter supplied by Fluke. The reverse bias voltage ranged from (0.5–5)V. The junction type (abrupt or graded) and therefore the built – in potential  $V_{bi}$  were determined from intercept at  $1/C^2 = 0$  by extrapolating the curve to the voltage axis.

The spectral responsivity of the PbS/Si heterojunction was measured using a monochromator with spectral range of (360–1000) nm. Power calibration was established using a standard power meter. This measurement was performed with a reverse bias (1V). The Responsivity  $R_\lambda$  and quantum efficiency were calculated from the following equations (11)

$$\eta = \frac{I_{ph} / q}{P_{in} / h\nu}
 \tag{2}$$

Rising and decay time of the photocurrent were measured using a halogen lamp.

### 3. RESULTS

#### 3.1 Hetrojunction Characteristics

Fig. 1 shows the current-voltage (I-V) characteristics of PbS nano films grown on p-Si (100) substrates at room temperature. This I-V curve indicates that the PbS/Si (100) heterostructures have rectification properties. Table 1 shows the saturation current, ideal factor of the heterojunction. An ideality factor greater than unity is generally attributed to the interfacial oxide layer [12], suggests that current transport is influenced by space charge recombination.

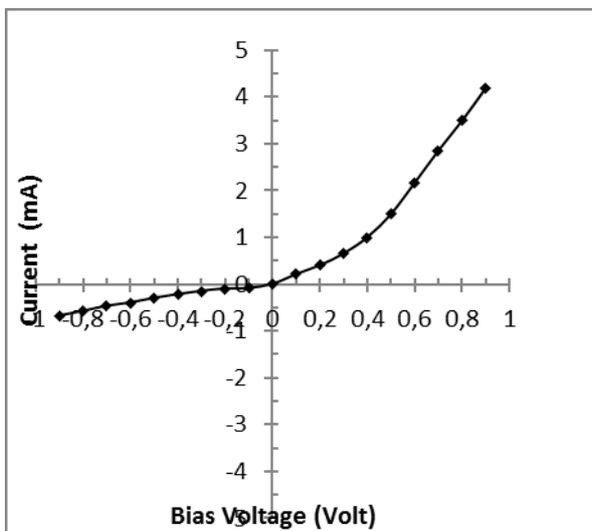


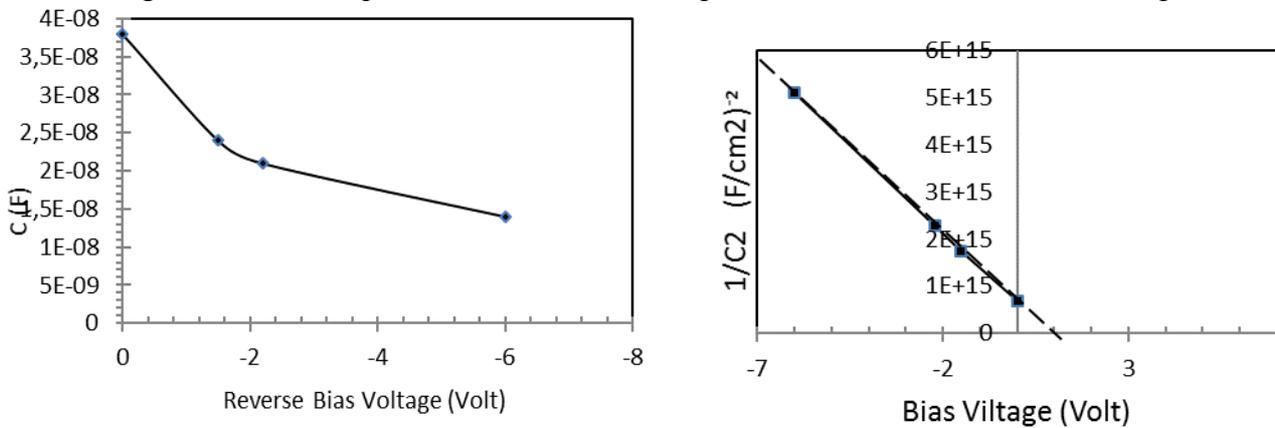
Fig. 1 Shows the current-voltage characteristics

Table 1 Shows the heterojunction parameters.

Factor $\beta$	$I_s(\mu A)$	Ideal deposition parameters		
		solution molarity	Temperature	time
1.38	0.48	0.06 ML	300 C°	90 min

Capacitance and voltage (C-V) characteristics of PbS/Si diode were measured using a PM 6306 Programmable LRC meter. The capacitance is expected to decrease with increasing reverse bias,

due to an increase in the depletion region width. Thus, the voltage dependence shown in Fig. 2 is at least qualitatively consistent with the expected trend. Fig. 3 shows a plot of  $1/C^2$  as a function of bias voltage. The plot of  $1/C^2$  versus reverse bias voltage is linear and the intercept on the x-axis is at the voltage  $V_0 = V_{bi} - kT/q$ , where  $V_{bi}$  is the built-in potential, and  $T$  is the absolute temperature.

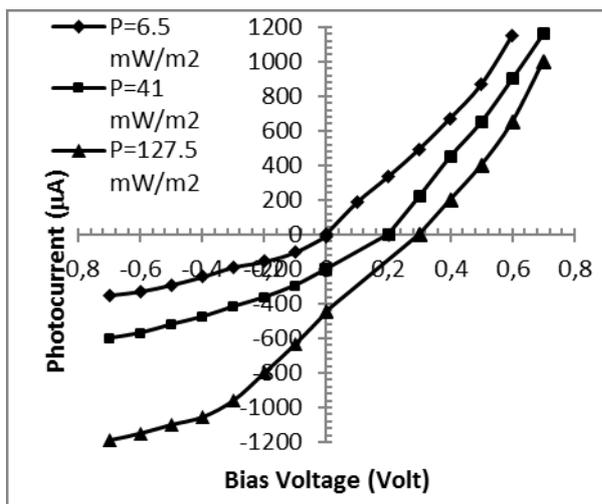


**Fig.2 The voltage dependence of junction capacitance Fig. 3 A plot of  $1/C^2$  as a function of bias voltage**

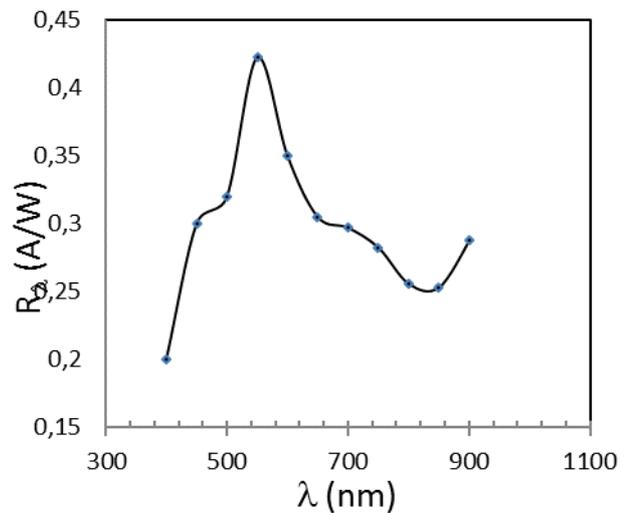
The linearity in the plot of  $C^{-2}$  as a function of  $V$  indicates the uniform doping of depleted region and abrupt junction.

Fig. 4 shows the heterojunction photocurrents as a function of voltage under steady state illumination at different light intensity. The photocurrent monotonically increasing with incident light intensity, also the photocurrent shows no saturation at the voltage range.

Fig. 5 shows the heterojunction spectral responsivity. It clearly proved that this material had very good photo response, where the maximum response exists at  $\lambda = 0.5 - 0.52\mu\text{m}$ . For all wavelengths less than  $0.5 \mu\text{m}$ , the responsivity increases with increasing wavelength, while for longer wavelengths, responsivity decreases with increasing wavelength. Fig.6 shows the heterojunction quantum efficiency, where a quantum peak at  $\lambda = 520\text{nm}$ . The quantum efficiency value is not constant across the entire spectrum of wavelengths measured, and shows a reduction in the value for all wavelength shorter and greater than  $520 \text{ nm}$  and this more probably due to recombination at the surface and in the bulk.



**Fig. 4 Hetrojunction photocurrents**



**Fig.5 Hetrojunction spectral quantum efficiency**

#### 4. CONCLUSIONS

Nano crystalline heterojunction formed by deposited PbS on p-type Si by chemical spray pyrolysis. The best performance was obtained with 90 min. deposition. Photo-electrical measurements show a decreasing response at wave range  $0.4 \mu\text{m} \leq \lambda \leq 0.9 \mu\text{m}$ . monotonically increasing with incident light intensity, a quantum peak at  $\lambda = 520\text{nm}$ .

#### References

- [1] K. Yu, J. Chen, Enhancing solar cell efficiencies through 1-D nanostructures, *Nanoscale Res. Lett.* 4 (2009) 1-10.
- [2] V. Svrcek, A. Slaoui, J.C. Muller, Silicon nanocrystals as light converter for solar cells, *Thin Solid Films* 451-452 (2004) 384-388.
- [3] Ali M. Mousa and Adawiya J. Haider, Performance of a Nano CdS/Si Heterojunction Deposited by CBD; *International Journal of Semiconductor Science & Technology (IJSST)* Vol. 3, Issue 4, Oct 2013, 11-18.
- [4] C.Q. Sun, B.K. Tay, S. Li, X.W. Sun, S.P. Lau, T.P. Chen, Bandgap expansion of a nanometric semiconductor, *Mater. Phys. Mech.* 4 (2001) 129-133.
- [5] A. M. Mousa, M. A. Mohammed, and R. Kadhim, Structural and optical characterization of InAs nanocrystals deposited by spray pyrolysis; *AIP Conference Proceedings* 1653, 020073 (2015).
- [6] Ali M. Mousa, Selm M. H. AL-jawadi & Suad M. Kadhim AL-SHAMMARI, Performance of a nanostructured PbS/Si Heterojunction Deposited by CBD; *International Journal of Semiconductor Science & Technology (IJSST)* Vol. 3, Issue 4, Oct 2013, 11-18.
- [7] Lung-Chien Chen, Cheng-An Hsieh and Xiuyu Zhang, Electrical Properties of CZO Films Prepared by Ultrasonic Spray Pyrolysis; *Materials* 2014, 7, 7304-7313