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Electrical And Optoelectronic Properties Of p-PbSe/n-Si Heterojunction

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Abstract

Electrical and optoelectronic properties of p-PbSe/n-Si heterojunction detector have been investigated. The electrical properties under dark condition show a rectifying behaviour with low rectification factor, and exhibits soft breakdown reverse current. C-V characteristics suggest that the fabricated diode was abrupt type, built in potential determined by extrapolation from C^{2}-V curve to the point (V=0) and it was equal to (2.25V).

Results of I-V characteristics under illumination conditions with reverse bias voltage exhibit linear behaviour with no saturation limit.

دراسة الخصائص الكهربائية والكهروبصرية للمفرق الهجيني
p-PbSe/n-Si

الخلاصة

في هذا البحث تم دراسة الخصائص الكهربائية والكهروبصرية لكاشف المفرق الهجين p-PbSe/n-Si حيث تم دراسة خصائص تيار- جهد عند الظلام وتبين ان له خصائص تقويمية وذات معامل تقويم منخفض وكذلك أظهرت فولتية انهيار متدرجة في الانحياز العكسي.

ومن قياس سعة – جهد أوضحت ان المفرق من النوع الحاد وتم حساب جهد البناء الداخلي من خلال اخذ امتداد C^{2}-V الى النقطة (V=0) حيث بلغ (2.25V).

تم قياس تيار – جهد في حالة الإضاءة مع الانحياز العكسي، أبدى الكاشف المصنع سلوك خطي مع عدم ملاحظة وجود منطقة تشبع.

1-INTRODUCTION

PbSe is a polar semiconductor, which crystallizes in a face center cubic (f.c.c.) lattice of NaCl type. It is characterized by high dielectric susceptibility, high carrier mobility[1], and narrow band gap (T=293K,PbSe)~ 0.27 eV [2,3] . Optical properties in the visible and infrared regions of spectra are related to the electron transitions. The as-grown films show *p*-type conduction [4,5].

There has been a considerable interest during the past few years in PbSe films, because of their promising applications in IR detector, IR photography and gas detection, Several investigators have attempted, Y. Yoshizumi et al[6] we have shown the effect of oxygen on the properties of evaporated films of of photosensitive PbSe, F. Brionis et al. [7] tested for photoconductivity at room temperature under 700K radiation chopped at 300Hz .The IR radiation was focused to form a light beam 0.8mm wide in order to scan the film looking for homogeneities in response, Y. S. Sarma [8] The electrical characteristics and spectral response of these devices PbS_{1-x}-Si_{x} heterojunctions, S. P. Varfolomeev et al. [9] The influence study of ultraviolet illumination at room temperature on photoelectric properties of activated (by annealing in air)

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polycrystalline PbSe films. Preparation of these devices can be achieved by different methods of depositing the PbSe films onto single crystal Si substrates.

This paper reports on our studies of the electronic properties of heterojunctions of *p*-type PbSe deposited on *n*-Silicon.

2- EXPERMENTAL

Substrates of n-type single-crystal Si wafers with (111) orientation having 3-5 (ohm.cm) resistivity were used in the present study. After scribing these wafers into small pieces (typically 1cm x 0.6cm in size), they were cleaned, and etched with diluted HF solution (1:10) and then washed with running deionized water[10]. The films of PbSe were prepared by thermal evaporation of PbSe powder in a vacuum of the order of 10^{-5} torr, the rate of evaporation was ≈1.6 nm/min , onto clean silicon mirror-like side substrates at room temperature (~300K). The average thickness of the deposits were determined by gravimetric method. The maximum error in the determination of thickness was of the order of 10% estimated for the thinnest films (PbSe films of thickness 250 nm). Ohmic contacts of aluminum [11] were evaporated on the silicon side and PbSe side.

Electrical measurements included current-voltage and capacitance – voltage, Reverse I-V characteristics under different illuminations were characterized.

3-RESULT

3-1 I-V characteristics

A typical current-voltage (I-V) characteristic, in dark, for forward and reverse bias of *p*-PbSe/*n*-Si heterojunction is shown in Fig.(1). In the forward bias the current increases exponentially with voltage as expected. But in reverse bias, the current was found to increase slowly with voltage (soft breakdown) and did not show any trend of saturation or sharp breakdown. This could be due to the domination of edge leakage current which is caused by the sharp edge at the periphery of the contact and also due to the generation of excess carriers in the depletion region at higher fields.

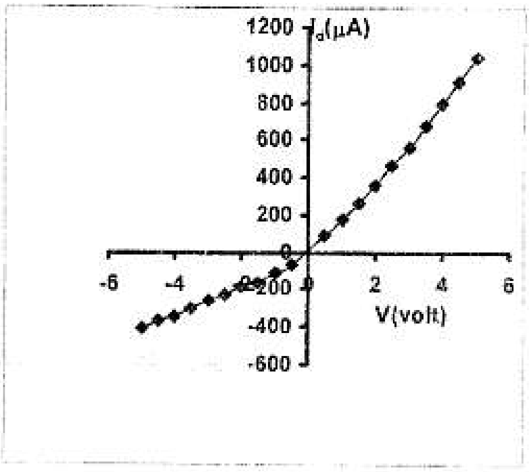

Fig.(1): I-V characteristics of PbSe/Si heterojunction in dark.

In Fig.(2), log I is plotted as a function of voltage.

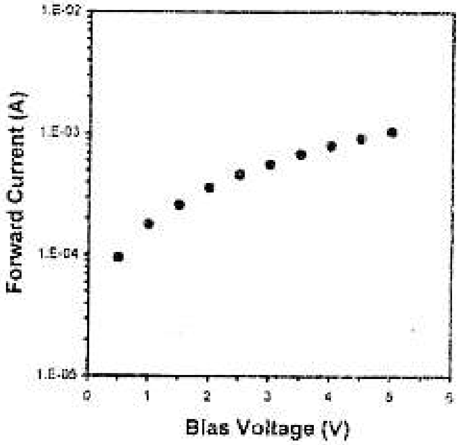

Fig.(2): I-V characteristics of PbSe/Si heterojunction in log scale.

3-2 C-V characteristics

Junction capacitance measured as a function of bias voltage for the PbSe/Si diodes shows $C \propto V^{-1/2}$ dependence (Fig.3) which indicate an abrupt junction in that case. Under these conditions, The C-V characteristics of the heterojunction can be explained on the basis of Anderson's model [12], according to which

$$\frac{C}{a}=\left[\frac{qN_{A1}N_{D2}\varepsilon_1\varepsilon_2}{2(\varepsilon_1N_{A1}+\varepsilon_2N_{D2})}\cdot\frac{1}{V_D-V}\right]^{\frac{1}{2}}\text{.........(1)}$$

Where q: is the electronic charge, ε_1 and N_{A1} are dielectric constant and concentration of acceptors in p-type semiconductor, ε_2 and N_{D2} are dielectric constant and concentration of donors in n-type semiconductor and V and V_D are the applied bias and built-in Voltage, respectively. Value of V_D estimated from $1/C^2$ vs V plot obtained for heterojunction, the built- in potential (V_D) for the PbSe/Si System was found to be (2.25 V).

The concentration of acceptors (N_{A1}) in PbSe film was calculated from the known values of C, V_D and N_{D2} by using eqn. (1) under zero bias condition .The value of the dielectric constant (ε_1) for the PbSe film were taken from our optical data [1].

From the slope of these graph (Fig.3), the carrier concentration of acceptors in PbSe is found to be ($N_{A1}=1.62\times10^{13}$)cm^3.

To calculate concentration of donors in n-type semiconductor (i.e. Si) according to relation (2) is found to be ($N_{D2}=1.04\times10^{15}$) cm^{-3}.

$$N_{A1}=(\rho\, q\, \mu_n)^{-1}\text{........(2)}$$

Where μ_n : is mobility carriers (1500 cm^2/V.s) and ρ: is resistivity.

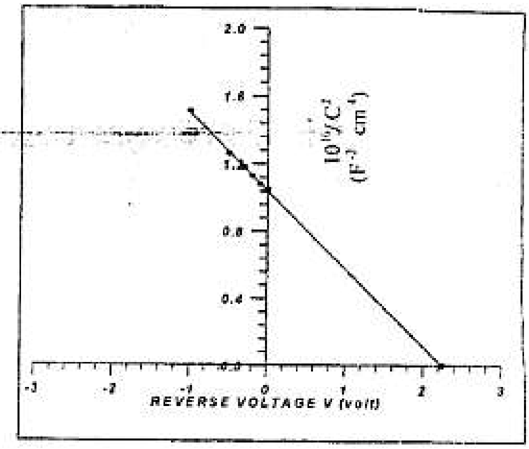

Fig.(3): C^{-2} (C = capacitance per unit area) as a function reverse bias voltage

Fig.(4) gives the I-V characteristics for the PbSe/Si heterojunction at different illuminations. It is shown that photocurrent increases with reverse bias voltage and no saturation region was observed. This can be attributed as follows; since photocurrent (I_{ph}) is a function of diffusion length and junction width[12]:

$$[I_{ph}=qAG(W+L)]\text{......} \qquad (3)$$

where A: is area, G: is generation rate ,W: is the depletion width and L: is the diffusion length, therefore when L becomes so short (<<w) due to the effect of mismatch defects , I_{ph} will depend essentially on W which in turn depends on bias voltage. Thus, I_{ph} will increase with increasing bias voltage.

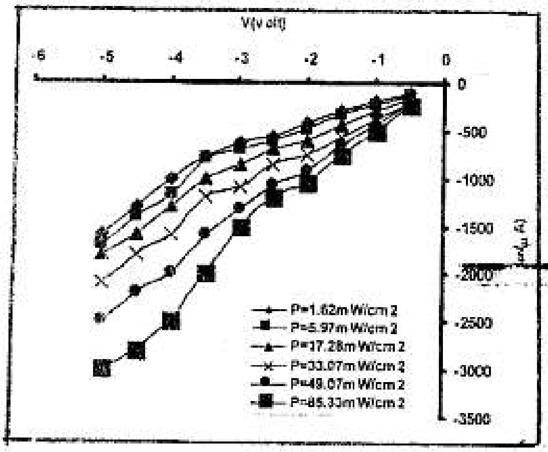

Fig.(4): Reverse photocurrent as a function of bias voltage

4-CONCULISION

From what has been mentioned above, we can conclude that anis type *p*-PbSe/*n*-Si heterojunction behaves as a poor rectifier due to the noise that comes from the narrow gap PbSe film. The junction is abrupt type.

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