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Electrical Properties of n-CdSe/Si-p Junction Prepared by Chemical Bath Deposition Technique, from Different Weights of Sodium Selenosulfate and Constant Molarity

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ABSTRACT

A pn-junction was successfully fabricated by depositing n-type CdSe thin films on p-type Si as a substrate using chemical bath deposition technique (CBD) at 70^{o}C. Time of deposition was 6 hours and the preparing solution was changed every 2 hours during the deposition. Sodium Selenosulfate (with different weights) is the source of Se^{-2} ions, cadmium nitrate is the source of Cd^{+2} ions. The (I-V) characteristics for the n-CdSe/p-Si junction show it behaves as a Zener diode in reverse bias, with Zener resistance (3 and 27×10^{3})Ω. SEM also shows spherical-shape particles with difference grain size (3.8 and 19.8) nm.

Keywords: CdSe/Si junction, Zener diode, CBD, pn junction.

INTRODUCTION

Cadmium selenide (CdSe) is one of the most popular semiconductor compounds that fall into Group II-VI, of the periodic table. CdSe has a direct energy gap (1.7 eV) and a negative type (n-type) semiconductor, meaning that the majority of charge carriers are electrons (Hone *et al.,* 2015). CdSe thin film has been used in various applications such as a solar cell (Bao *et al.,* 2016), photodetector (Shelke *et al.,* 2020), switching memory device (Wu *et al.,* 2017), optic sensor (Ding *et al.,* 2013), Light-Emitting Diode (Rastogi *et al.,* 2018), photoelectrochemical (Gawali *et al.,* 2011), The CdSe films are deposited with different techniques, such as Electrodeposition (Raut *et al.,* 2016), thermal evaporation (Shah *et al.,*2017), successive ionic layer adsorption and reaction (SILMR) (Chaudhari *et al.,* 2016), vacuum evaporation (Khudiar *et al.,* 2012), spray pyrolysis (Beri *et al.,* 2011), electron beam evaporation technique (Mathuri *et al.,* 2017), sol-gel (Hassen *et al.,* 2020), and chemical bath deposition (CBD) (Habte *et al.,* 2019; Rivera-Marquez *et al.,* 2020). (CBD) is the most popular sedimentation method and is characterized by low costs, simple and uncomplicated devices, producing films of large areas, and does not require vacuum. The growth of the thin film and the size of the crystal in the CBD method is affected by several factors, the concentration of the solution, pH, deposition temperature, and deposition time, molarity, and weight of the material.

MATERIALS AND METHODS

Substrate Preparation

One of the important initial steps is cleaning substrate, p-type silicon substrate is used. The Si wafers were manufactured on p-type (boron-doped) silicon, with a 2-inch diameter, one side polished, orientation (100), the thickness of 500 μm, and resistivity of 1 to 10Ωcm. was cleaning: (i) Organic cleaning: removal of insoluble organic material contaminants with a 10-min boiling at (75^{o}C) in NH_4OH+H_2O_{2+}6H_2O [1:1:5] solution. (ii) Ionic cleaning: the procedure was followed by a 10-min boiling at (75^{o}C) in HCl+ H_2O_2+6H_2O [1:1:5] solution. (iii) Oxide stripping: removal silicon dioxide layer using HF:H_2O [1:10] solution diluted for 30s and wished in deionized water (the wafer be hydrophobic), and the wafer ready to use imminently.

Solution of CdSe

A sodium selenosulfate (Na_2SeSO_3) was prepared in two weights, for sample (A): Se=1.3gm, Na_2SO_3= 3.317gm into a conical flask containing 100ml of deionized water for (5-6) h at (70-75) ^{o}C. after that, the solution is filtered and keep in a room temperature. Similarly, the weight for sample (B): Se =1.119gm, Na_2SO_3= 3.498gm. This solution is used as a source of Se^{-2} ions. The formation mechanism of Sodium Selenosulfate (Na_2SeSO_3) in an alkaline solution gives Se^{-2} ions as (Zhao *et al.,* 2013).

$$Na_2SeSO_3 + OH^- \Leftrightarrow Na_2SO_4 + HSe^- \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$
$$HSe^- + OH^- \Leftrightarrow H_2O + Se^{-2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2)$$

For 100ml of the solution contains: 30ml from (Na_2SeSO_3), 1.5gm $Na_2SO_{3,}$ 10ml for 1mol from Cd $(NO_3)_2$ (source of Cd^{+2} ion), 2.5 NH_3,1ml TEA, and deionized water. The cleaned silicon wafer (polished face), and glass slides were placed vertically on the walls of the 100ml beaker solution at 6 hours for 70^{o}C temperature deposition, the solution was refreshed after every two hours for the same substrates.

RESULTS AND DISCUSSION

Morphological characterization of the n-CdSe/p-Si junction

The SEM was shown in Fig. (1), the surface morphology of CdSe thin films. The nanosheet and small grain size of nanoparticals are distributed and interconnected to each other in the sample (A), which led to formation of large surface area which may be the reason for the increase of conductivity. While the large grain size particles in a sample (B) are interconnected with each other with less dislocation density causes more resistance. The dislocation density was calculated using the Williamson and Smallman's relation (Sahu *et al.*, 2017).

$$\delta = 1/D^2 \qquad \text{………………………..(3)}$$

where *D*, is the crystallite size. The dislocation densities for nanocrystalline CdSe for samples A and B have been listed in (Table 1). The value of dislocation density is less than for the (B), which may be due to the growth in crystallite size. So, this cause may be affected on the conductivity and resistance values of the samples.

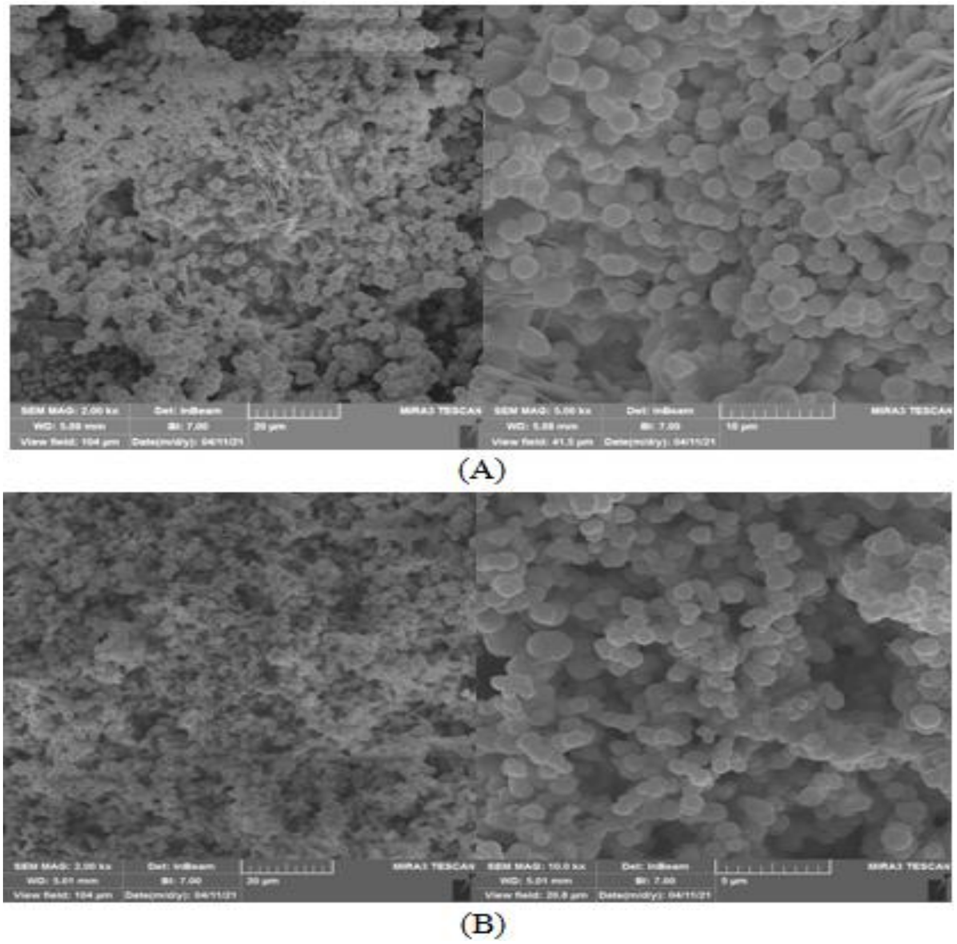

Fig. 1: SEM image of CdSe thin films. Sample A and sample B

Electrical characterization of n-CdSe/p-Si junction

Fig. (2) shows the I-V characteristics for two samples of n-CdSe/p-Si junction, under forward baise, the junction behaves like pn diode, and for reverse baise, the junction behaves like a Zener diode (where the breakdown voltage appears before 5V). The resistivity of n-CdSe/p-Si is an important parameter of diode (R_D) and for zener diode (r_Z) which is calculated by using the equations (4 and 5), (Sabah, 2017), and a set the threshold voltage (V_t), (the beginning of the knee) as shown in Fig. (1):

$$R_D = \frac{\Delta V}{\Delta I} \;, \qquad \text{… ………………… (4)}$$

$$r_{z}= \frac{\Delta V}{\Delta I} \quad , \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

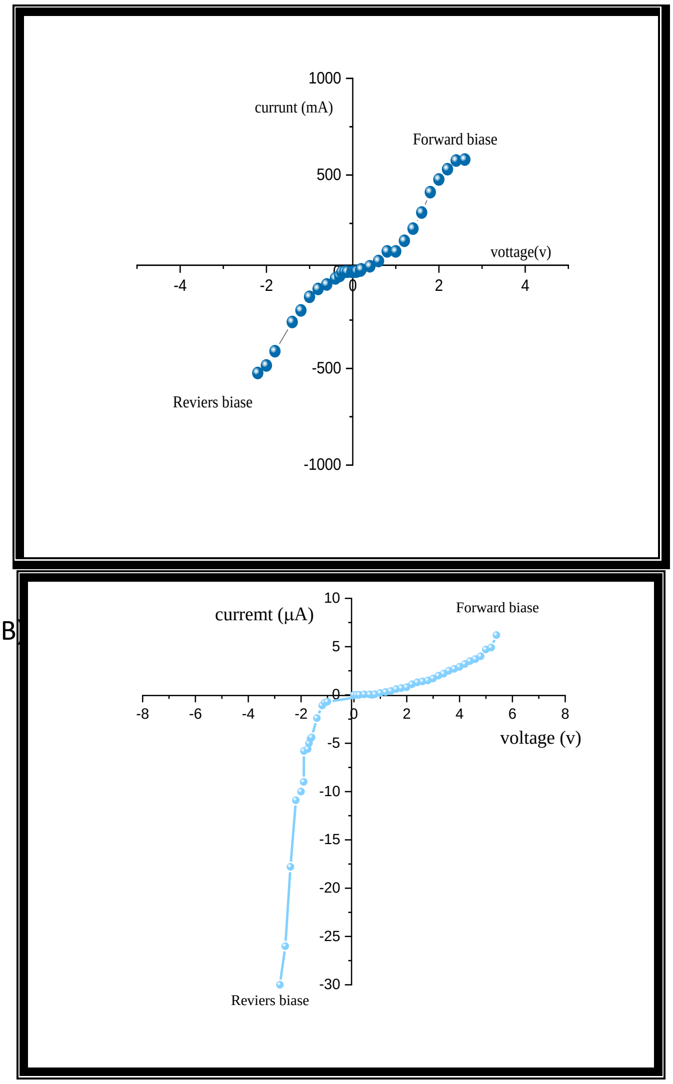

Fig. 2: (I-V) characteristics for n-CdSe/p-Si under forward and revers baise: (a) Sample A and (b) Sample B

The electrical measurement and morphological parameters of SEM of the n-CdSe/p-Si junction have been listed in table 1.

Table 1: Some electrical and morphological parameters of n-CdSe/p-Si junction

Samples	Crystallite Size(nm)	Dislocation density δ (× 10^{17} lin/m^2)	V_t (V)	R_D (Ω)	r_z (Ω)
A	3.8	0.692	0.91	2.35	3
B	19.8	0.255	2.1	85×10^4	27×10^3

As shown in (Table 1), there are a clear difference between the two samples of different weights; the relatively larger grain size of nanoparticles in sample (B) are interconnected with each other with less dislocation density may cause a high resistance as shown in Fig. (2), i.e. sample B, contain a nanospheres with less granular distribution which may decrease the conductivity and increase the resistance, as well as, the difference in the weights of sodium selenosulfites caused a stability of molarity due to solution formation.

CONCLUSIONS

The n-CdSe/p-Si (pn junction) was successfully prepared from different weights and constant molarity. The resistance for each sample is different. This is due to the difference in the weights of Sodium Selenosulfate which effect the morphology of the samples, so the conductivity increases whereas the resistivity decrease. The prepared pn junction behaves as a Zener diode in reverse bias

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الخصائص الكهربائية لوصلة n-CdSe/Si-p محضرة بتقنية الترسيب في الحمام الكيميائي، من أوزان مختلفة لسيلينوسلفات الصوديوم بمولارية ثابتة

الملخص

تم تصنيع وصلة pn بنجاح من ترسيب أغشية رقيقة CdSe من النوع n على ركيزة Si من نوع p. باستخدام تقنية ترسيب بالحمام الكيميائي (CBD) عند 70 درجة مئوية. وكان وقت الترسيب 6 ساعات، حيث يتم تغيير محلول التحضير كل ساعتين أثناء الترسيب. استخدم سيلينوسلفات الصوديوم (بأوزان مختلفة وبمولارية ثابتة) كمصدر لأيونات Se^{-2}، ونترات الكادميوم كمصدر لايونات Cd^{+2}. اظهرت خصائص (التيار–فولتية) للوصلة المحضرة n-CdSe/p-Si أنه يتصرف كثنائي زينر عند الانحياز عكسي للفولتية المسلطة، مع مقاومة زينر بقيمة ohm (3 and 27×10^{3}) لكل حالة. فيما أظهرت نتائج SEM وجود جزيئات كروية الشكل ومنها متجمعة معا ككتل دقيقة ونانوية وذات أحجام حبيبات مختلفة nm (3.8 و 19.8).

الكلمات الدالة: وصلة Si/CdSe، ثنائي زينر، وصلة pn، الحمام الكيميائي.