Current–voltage and capacitance-voltage characteristics of Se/Si heterojunction prepared by DC planar magnetron sputtering techniqu

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Abstract

In this work, the effect of annealing temperature on the electrical properties are studied of p-Se/ n-Si solar cell, which p-Se are deposit by DC planar magnetron sputtering technique on crystal silicon. The chamber was pumped down to 2×10^{-5} mbar before admitting the gas in. The gas was Ar. The sputtering pressure varied within the range of $4x10^{-1}$ - $8x10^{-2}$mbar by adjusting the pumping speed through the opening control of throttle valve. The electrical properties are included the C-V and I-V measurements. From C-V measurements, the V_{bi} are calculated while from I-V measurements, the efficiency of solar cell is calculated.

Keywords
Se/Si heterojunction
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خصائص التيار- فولتية والفولتية – السعة للمفرق الهجيني Se/Siالمحضر بتقنية الترذيذ المغناطيسي المستمر

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الخلاصة:

في هذا العمل تم دراسة تاثير درجة حرارة التلدين على الخصائص الكهربائية لخلية الشمسية p-Se/n-Si حيث رسب سيلينيوم بتقنية ترذيذ المغناطيسي المستمر على قواعد من السليكون حيث وصل تفريغ منظومة التفريغ الى ضغط بحدود $2x10^{-5}$mbar قبل ضخ غاز الاركون وبعد وصل الضغط الى mbar ($4x10^{-1} – 8x10^{-2}$) من خلال صمام لتحكم بدخول غاز الاركون وبعد ذلك تتولد لدينا بلازما.الخصائص الكهربائية التي تتضمن C-V و I-V تم قياسها ومن قياسات السعةو الفولتية تم حساب Vbi وكذلك تم حساب كفاءة الخلية الشمسية.

Introduction

The study of chalcogenide glasses has increased in last decades because of their application in the fields of fiber optics, xerography and novel memory devices [1] Metal chalcogenides (sulfides, tellurides and selenides) are of great importance for researchers because they are potential candidates for optoelectronic applications such as photodetectors, solar cells, thin film transistors etc. [2-6].The interest in these materials stems principally from their low phonon energy, extended infrared transparency, high refractive index, high photosensitivity, ease of fabrication and processing, good chemical durability, and special second/third order optical non-linearity [7]. Selenium is one of the most interesting and most studied elements in several different disciplines of the scientific world [8]. Its electrical properties, especially its low dark current, render it suitable for x-ray imaging use. However, until now many of its properties have not been fully explored or understood[9]. Many techniques have been reported for the deposition of Se thin films. These include thermal evaporation technique , chemical bath deposition, spray pyrolysis, metal organic chemical vapour deposition (MOCVD), molecular beam epitaxy (MBE) technique, electrodeposition, photochemical deposition etc, sputtering is an attractive process when scaling up becomes a consideration , the tendency being that the larger area more uniform is the final film. Over the last decade the use of planar magnetron sputtering has opened up new areas for the application of sputtering[10].

. In the present work, sputtering technique has been chosen for the deposition of Se thin films on wafer silicon. Here, we report a detailed study on the electrical properties of such hetrojunction Se thin films as the knowledge of the electrical properties of these films is very important in many scientific, technological and industrial applications in the field of optoelectronic devices, particularly.

Experimental

Thin films of Se were prepared by DC planar magnetron sputtering technique on p-type silicon (111) substrate.The base pressure of the chamber was $2x10^{-5}$ mbar and the growth pressure was maintained at $8x10^{-2}$mbar. The target to the substrate was 6 cm in the on-axis geometry. The deposition time was 10 min, and sputtering power was 16080.9W.where discharge voltage equal to 310 V while discharge current was 5.19 mA and magnetic field was value it 620G.Measurements included C-V characteristics under reverse biasing and I-V characteristics in dark and under illumination by halogen lamp of p-Se/ n-Si heterojunction structure were determined. The effect of annealing temperature (RT, 333 and 353)k on the electrical properties was investigated.

Result and Disscussion

1. Current-Voltage Characteristics Measurements

Fig.(1) shows the variation of current density (J) and bias voltage (V) of Se/Si heterojunction Prepared by DC planer magnetron sputtering at different annealing temperatures (RT, 333, 353) K .

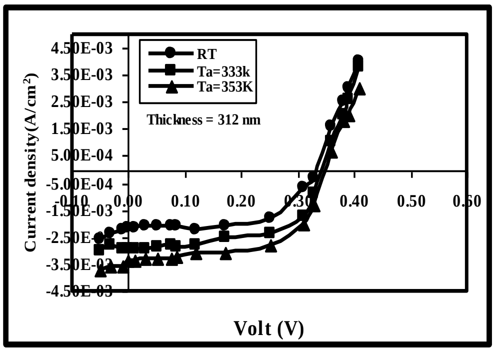

Fig.(1) shows I-V characteristics Se/Si heterojunction Solar Cell at forward and reverse bias voltage at different annealing temperatures

It see from this figure that the current density increases with increasing of the bias voltage, i.e. J_{ph} increases with increasing of the depletion region width (W) according to the relation below [11];

$I_{ph} = qa\, G_{ph} (L_p + L_n + W)$……….. 1.

where G_{ph} is generation rate of photo carriers, L_p and L_n are the diffusion length of holes and electrons, respectively.The current density increases with increasing of annealing temperature and this is attributed to the increasing in the grain size, reducing the grain boundaries,and improvement of structure which leads to the increase of the mobility and increase the photocurrent density as well as the increase of the depletion width which leads to an increase of the creation of electron-hole pairs**.** The open circuit voltage(V_{oc})increases with increasing of annealing temperature due to the reduction of the defects and localized states and increasing of the mobility and all these parameters are tabulated in the Table (1)

Table (1): shows the values of Voc ,Isc , Imax, Vmax and the efficiency (η), for a-Se/ Si heterojunction with different annealing temperatures

Ta K	V_{oc} (Volt)	J_{sc} (mA/cm	J_{max} (mA/cm^2)	V_{max} (Volt)	η
R.T	0.336	4.43	4.1	0.283	2.10
333	0.343	6.20	5.05	0.300	2.75
353	0.352	7.12	6.0	0.330	3.60

2. Capacitance-Voltage easurement

Fig.(2,) shows the variation of capacitance as a function of reverse bias voltage in the range of (0-1) Volt at frequency equal to 1 kHz for Se/Si heterojunction at different annealing temperatures. It is clear that the capacitance decreases with increasing of the reverse bias voltage and annealing temperatures these decreasing was non-linear as shown in Fig.(2). This result is confirmed by a given equation[12]

$$\frac{C}{A}=\left[\frac{q\varepsilon_n\varepsilon_p N_n N_p}{2(\varepsilon_n N_n+\varepsilon_p N_p)}\right]^{1/2}(V_D-V)^{-1/2}$$

Where q is the electronic charge, C is the capacitance, N_n and N_p are the donor and acceptor concentrations, ε_n and ε_p are the dielectric constants of n and p – type semiconductor, respectively, V_D is the built – in junction potential, V is the applied voltage, and A is the area of the junction.

It is clear from this figure that the decreasing in capacitance was non-linear . Such behavior is attributed to the increasing in the depletion region width, which leads to increase of the value of built– in voltage.

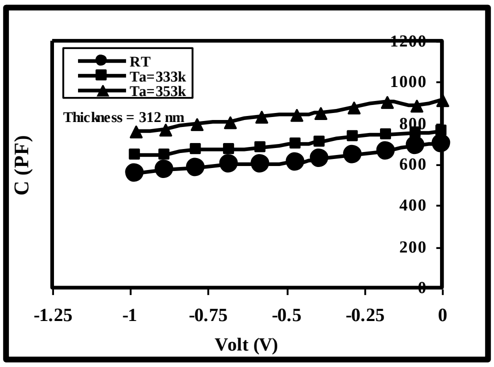

Fig.(2) The variation of capacitance as a function of reverse bias voltage for Se/Si heterojunction at different annealing temperatures.

Fig.(3) shows the inverse squared capacitance squared against applied reverse bias voltage for Se/Si heterojunction at different annealing temperatures. The plots revealed straight line relationship which means that the junction was of an abrupt type .The intersection of the straight line with the voltage axis at $1/C^2=0$, represent (V_{bi}) [13,14].It observed from this figure that the built–in voltage increases with increasing of T_a (as a result of the decrease in the capacitance value) and the increase of the depletion width. This variation may be due to the improvement in the structure of the prepared film.

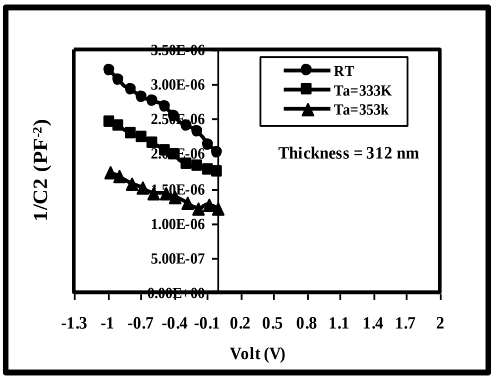

Fig. (3): The variation of $1/C^2$ versus reverse bias voltage for Se/ Si heterojunction at different annealing temperatures

Conclusion

Se thin films were deposited on wafer silicon substrate at room temperature by DC planar magnetron sputtering technique under vacuum $2*10^{-5}$ mbar before admitting the argon gas in it. The thickness of the films was found to be 400nm measured by weighted method technique .The effect of annealing temperature on the electrical properties of the films which is included C-V characterization and I-V characterization under dark and illumination light were measured. We can calculate the V_{bi} from C-V measurements while from I-V measurements, the efficiency of solar cell is calculated.

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