Comparison I-V Characteristics of Sb/c-Si and Al/c-Si Junction

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Abstract

Hetero junctions are fabricated by depositing antimony (Sb) and Al films on n-type single crystal(c-Si) wafers by the method of vacuum evaporation with thickness (0.25µm), with rate of deposition equals to 2.77 Å/sec, all samples are annealed in a vacuum for one hour at 473K. The tests have shown that all the films have polycrystalline structure for all Sb films. The barrier heights in (Sb/c-Si) junction was found to be equal 0.825eV, but(Al/c-Si) junction ohmic contact. Current-voltage measurements confirm this behaviour.

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Introduction

Sb/Si junctions have attracted many attentions because their importance properties for this junction . It can be used as rectifying devices in electronic applications [1,2].

This junction is unipolar charge of minority carrier that's dominat on contact operation which has only one kind of charges, by it we could get the rectifier character as a result of potential barrier that creates by finding stable space charges in semiconductor[3].

Antimony can be creates potential barrier with Si because resistivity and work function, but Al metal resistivity is low due to conduction in the metal. The Al metal was chosen as an ohmic contact with the c-Si layer [1].

The aim of this study is prepared Sb/c-Si and Al/c-Si Junction in order to study the Φ_b, I_s and β as a function to annealing and thickness.

Experimental part

Sb and Al films were deposited on the silicon substrates by the method of vacuum evaporation (Type Edward coating system) with pressur 10^{-5} mbar. The thickness of each deposited thin film is (0.25µm), the junctions are annealed in a vacuum at a temperature of 437K for one hour.

Sb structure was studied by X-ray diffraction Fig (1) comparative with standard value in ASTM, used a Philips x-ray diffractometer system which records the intensity as a function of Bragg's angle. The source of radiation was cu(k_α) with wavelength λ=1.5406A°, the current was 30mA and the voltage was 40 kv, The current-voltage measurements in the dark were done for the Sb/Si heterojuntion by using keithley digital electrometer 616 and D.C. power supply. The bias voltage was varied in the range of (0 – 1.4) volt in the case of forward and reverse bias. From plots of the relation between the forward current and bias voltage, potential barrier height

(Φ_b) can be determined from [4]:

$$I_s = A^* T^2 \exp(-q\Phi_b/K_B T) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where A* is the effective Richardson constant modified to take account of both the effective mass of the electrons in the semiconductor, k_B is the Botzman's constant(1.3806×10^{-23} J/k), q is the electronic charge, T is the absolute temperature, the constant I_S is the saturation current.

$$\Phi_b = \frac{K_B T}{q} Ln \frac{A^* T^2}{I_s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

The ideality factor (β) can be determined by the relation :

$$\beta = \frac{q}{K_B T} \cdot \frac{V}{Ln\left(I_F / I_S\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

Where I_f is the forward bias current , the ideality factor (β) is related to the various physical properties of the of heterojunction.

Results and Discussion

For Sb films prepared at R.T and T_a=473K with (0.25µm),from Fig (1) showed Sb films as a polycrystalline structure, but peaks intensity in fig(b1)increase with the increase of annealing a temperature caused by elimination of voids and the reduction of dangling bond concentration (structural defects). These results are in agreement with [5]. These XRD peaks were shown to be the (003), (110) and (006) are listed in Table(1) according to ASTM system.

The current voltage (I-V) characteristics of Al/Si all fabricated junctions of the forward- and reverse biased are shown in figure (2).It can be seen from this curve that the linear

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relation shape behavior between current and voltage for all samples prepared with thickness (0.25µm) and annealed temperature of 473K. This behavior may be interpreted by the work function of Al and c-Si are nearly similar(that's mean the junctions do not creat the depletion layer), (Φ_b) is zero or negative and electron can flow freely in the two directions .In ohmic contact no potential barrier will be formed between Al electrode and c-Si layer. These results are in agreement with [6].

But(I-V) characteristics of Sb/Si in Figure (3) show this curve the forward characteristics shows exponential behaviour, the current increasing rapidly with voltage according to equation (1), for all samples prepared with thickness (0.25µm) and annealed temperature of 473K , that's mean the junctions creat the depletion layer(w) and barrier height(Φ_b). This is in good agreement with [7,8].

From this figure the current increases slightly with the increase of the annealing temperature because increasing temperatures cause a rearrangement of the interface atoms and reduce surface states and dislocalized at interface layer between a-Sb and c-Si which leads to the improvement of the junctions characteristics. This was in agreement with [9,1].

Also we can notice form Table (2) that the value of the ideality factor and saturation current decreases but potential barrier height increases with the increase of annealing temperature. This behavior attributed to reduction of dangling bonds as well as the density of states in Sb.

Conclusions

The structural nature of the Sb is Polycrystalline but after the annealing process crystallization of Sb films increases because of the decrease of the dangling bond. The current-voltage measurements of Sb/c-Si heterojunction case the value of ideality factor decreases with the increase of annealing temperatures but potential barrier height increases with the increase of annealing temperature, this behavior is attributed to reduction of dangling bonds as well as the density of states(defects) in Sb.
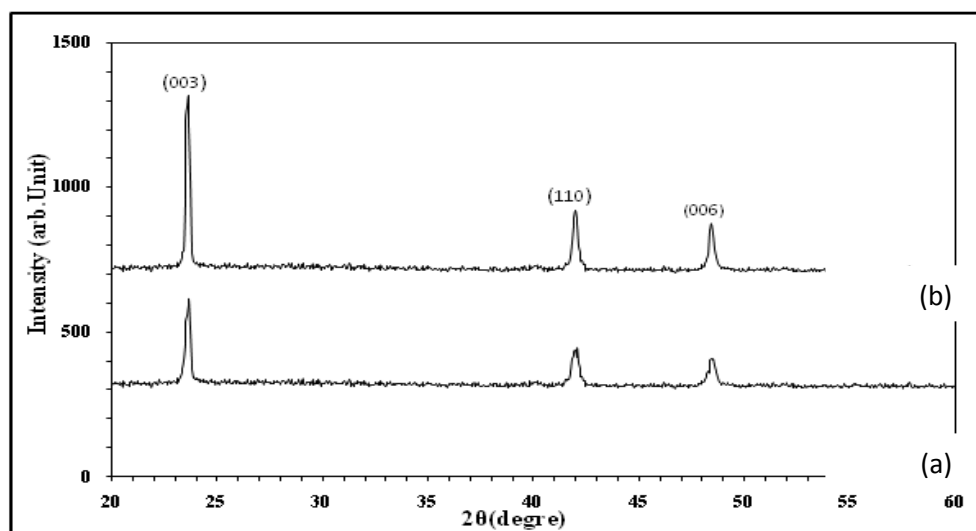
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Table (1): The structural parameters of Sb film

Ta (K)	2θ	d (Å)Exp	d(Å)Std.	hkl
RT	23.709	3.749	3.753	(003)
	42.08	2.145	2.152	(110)
	48.479	1.876	1.87	(006)
473	23.673	3.755	3.753	(003)
	42.003	2.149	2.152	(110)
	48.487	1.876	1.87	(006)

Table (2): Values of ideality factor (β), saturation current (Is) and potential barrier height (Φ_b) for Sb/c-Si hetero junction with thickness 0.25µm and annealing temperatures (RT, 473k).

Thickness (µm)	Ta (K)	β	Is (µA)	Φb(eV)
0.25	R.T	3.262	0.145	0.825
	473	2.71	0.071	0.844

Fig.(1): XRD of Sb with different annealing temperatures   (a):as deposited(303K) (b):T$_a$=473K

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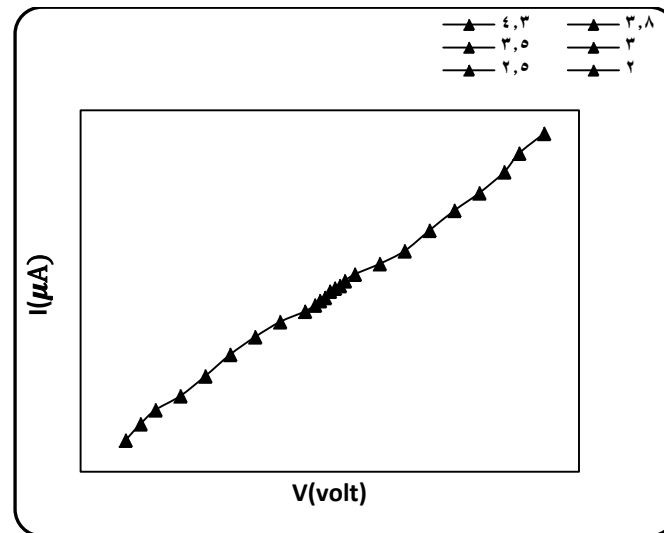
Fig. (2): I-V characteristics in the dark for Al/c-Si at forward and reverse bias voltage with thickness(0.25µm) and annealing temperatures (RT,473K)
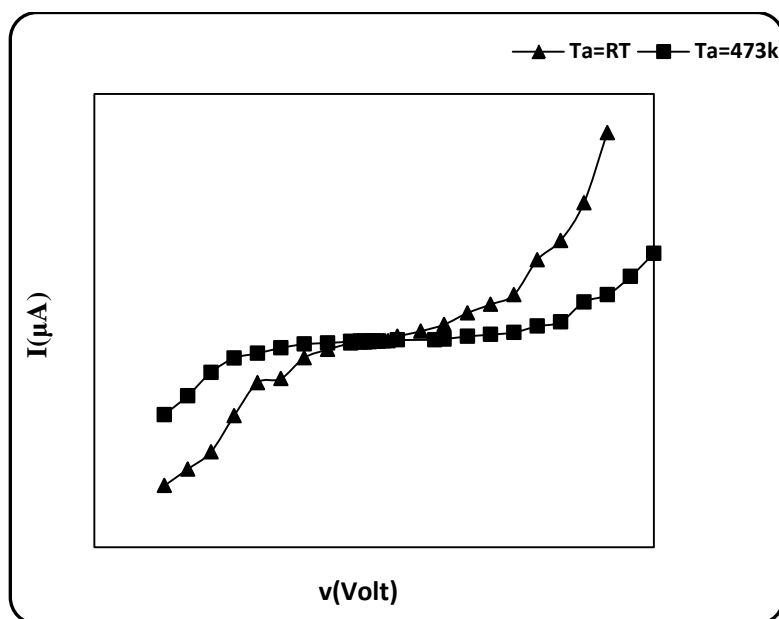
Fig. (3): I-V characteristics in the dark for Sb/c-Si heterojunction at forward and reverse bias voltage with thickness(0.25µm) and annealing temperatures (RT,473K)

مقارنة خصائص تيار- جهد لمفرق Sb/c-Si و Al/c-Si

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الخلاصة

تم تحضيرمفرق هجين من ترسيب أغشية الانتيمون والالمنيوم على رقائق من السليكون احادي البلورة n-type بطريقة الترسيب بالفراغ بسمك(0.25µm) وبمعدل ترسيب 2.77 Å/sec , ثم لدنت العينات بدرجة حراره K 473 مدة ساعة واحدة. أظهرت الفحوصات ان جميع اغشية الانتيمون ذو تركيب متعددة التبلور، ووجد ارتفاع حاجز الجهد في مفرق Sb/c-Si 825eV. لمفرقAl/c-Siولوحظ ان قياس خواص V-Iكانت أوميه وفسر ذلك لعدم وجود حاجز جهد من Si, Al .

الكلمات المفتاحية :المفرق الهجين(Sb/Si)، الخواص التركيبية للانتيمون(Sb)، خصائص فولتية تيار (Sb /Si)