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Electrical and Photovoltaic Properties of Sb-pSi Contact

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Abstract

In the present work, the electrical and photovoltaic properties of Sb-pSi contact were investigated for the first time. Two creditable methods were used to determine the value of barrier height for this contact. Experimental results showed a reasonable agreement with the simple Schottcky-Mott theory. The contact showed good response to white light when it works under bias condition.

دراسة الخصـــائص الكهروبصرية للمفرق Sb-pSi

الخلاصة

في هذا البحث جرى دراسة الخصائص الكهربائية والفولتيه الضوئية لاتصال Sb-pSi ولأول مرة على حد علمنا . استخدمت طريقتان موثقتان لإيجاد قيمة حاجز الجهد لهذا الاتصـــال , إذ أظهرت النتائج اتفاقا مقبولا لقيمة ارتفاع الحاجز مع نظرية شوتكي – موت البسيطة . اظهـــر الاتصال استجابة جيدة للضوء الأبيض مما يؤهله للعمل كدايود ضـــوئي فـــي مـــدى الأشـــعة المرئية.

1. Introduction

Metal – semiconductor photodiodes have attracted great attention for opto-electronic devices because of [1-3]:

(a) their fast response;

(b) a thin entrance window which allows the carriers to be generated in the sensitive region;

(c) fabrication of the devices at room temperature so that no degradation in diffusion length and life time occurs; and

(d) ability to be used on polycrystalline substrates.

In Schottcky photo detectors, the junction or barrier consists of a layer of metal, usually transparent and a semiconductor, usually n-type silicon or gallium arsenide. The electron-hole pairs generated by incident radiation are separated by the potential barrier between the metal and the semiconductor [4].

In literature, Cu-CdS, Au-Si, Au-GaAs and so on [4] have been reported as Schottcky photo detectors in the visible range (0.4-0.7m m), while Ge Schottcky photodiodes have been investigated and found to be working in the range(1 -2m m) [3].

The most important factor of metal-semiconductor (MS) contact is the value of the barrier height (Φ_{BP}). Many theories have been presented to explain the mechanism of current transport through such contact. The oldest successful one in the thermoionic emission theory was established by Bethe in 1942 [4]. Crowel and Sze [5] later refined this in 1966; the epitaxial silicide process developed by Tung in 1984 provides a new insight into intrinsic metal-semiconductor properties. A depth treatment and application of Schottcky barrier structure can be found in references [5],[6].

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In this work, we have attempted to evaluate the barrier height of Sb-pSi and compare results with the Schottcky simple theory.

2. Experimental procedure

Substrates of p-type single-crystal Si wafers [7] of resistivity 3-5 ohm-cm with 550mm thick and 0.12cm^2 area and Silicon wafers were used to fabricate Sb-pSi Schottcky contact cut from (111) orientation, and were used in the present study.

A layer (15nm thick) of a high purity Antimone (99.999%) was deposited onto mechanically polished silicon wafers using thermal evaporation technique. Prior to deposition these wafers were chemically etched in dilute hydrofluoric acid to remove native oxides. The vacuum pressure of the system was kept to be 10^{-5} torr during evaporation. Ohmic contact was made on the non-polished surface by depositing 200 nm of aluminum. No antireflection coatings were used in this study.

3. Results and Discussion

When the thermoionic emission current being dominating, the expression of the saturation current density (J_s) will be described as [5]:

$$J_s = A^* T^2 \exp\left(\frac{-q f_{Bp}}{K_B T}\right) \qquad \textbf{(1)}$$

A*:the modified Richardson constant.
T: absolute temperature.

The value of J_S is determined by extrapolating the straight-line region of I-V plot to the point V= 0 and the value of Φ_{Bp} can be extracted form eq.(1). A semi-log I-V plot under forward bias for Sb-pSi is presented in Fig.(1).The ideality factor range between (1.5-2), these values reflect that the carriers transport takes place by tunneling and recombination mechanisms associated with thermoionic emission mechanism [8]. Also, it is difficult to obtain the precise extrapolation of the curve to the Y-axis. Thus, employing Norde [9] method is necessary to determine the barrier height.

The variation in F(V) against the forward bias voltage is presented in Fig (2).Φ_{Bp} was extracted from the local minimum point of the curve [9]. where F(V) given by:

$$F(V) = \frac{v}{2} + \frac{KT}{q} \ln \frac{A^* T^2}{I} \qquad (2)$$

where:
K= boltzman constant,
T= temperature,
q= charge of electron,
A^*= richardson constant
(112 for n-Silicon.)

Fig.(3) exhibits the variation in the open-circuit voltage (V_{OC})against the short-circuit current density (J_{SC}). The linear variation enables one to determine J_0 and saturation current density can be found from the following eq. [10]:

$$V_{oc} = \frac{n K_B T}{q} \ln J_{sc} - \frac{n K_B T}{q} \ln J_o \qquad (3)$$

The result of these two methods is presented in Table (I).
According to Schottcky Model, the barrier height of MS contacts is given by [5] :

$$f_{Bp} = X_s - f_m + E_g \qquad (4)$$

where X_S and E_g are the electron affinity and the energy gap of the semiconductor respectively, and Φ_m is the metal work function. Thus the theoretical barrier height of Sb-pSi is

0.30eV from equation 4. This value is in disagreement with our practical value shown in Table (I). The deviation from Schottcky simple theory can be attributed to the effect of surface states of Sb-pSi contact [5-8]. More than one mechanism in addition to thermoionic emission can contribute to transfer the current through the contact. The effect of recombination and tunneling mechanisms at $V \geq 3KT/q$, can high deviate the values of the n and Φ_{Bp} of the contact [11]

One of the applications of Schottcky barrier is to detect the light .Sb-pSi contact showed a good response to white light under reverse bias mode.

Fig.(4) shows the photocurrent under different levels of inicident light. A good linearity can be obtained at low levels of illumination intensity as presented in Fig. (5).

4. Conclusions

Experimental study for near ideal Sb-pSi contact shows that barrier height does not obey simple theory proposed by Schottcky. Because of the effect of series resistance contact, it is necessary to adopt Norde method to extract the precise barrier height. The calculated Φ_{Bp} from illuminated J_{SC} -V_{OC} plot and dark J-V plot is different. The Sb-pSi contact may be used as a detector in the visible region. This kind of detectors can be improved using an antireflection coating [11].

5. References

1. Kwok K.Ng. "Complete Guide to semiconductor Devices", 1st edn Mc Graw-Hill Inc. **(1995)**.
2. Ponpon J.P. & Siffert P., J. Appl. Phys, Vol. 47 , No.7,p.3248. **(1976)**
3. Budde M., "Detector Measurements and Infrared Radiation", AP Company **(1983)**
4. Rhoderick E. H. & Williams R. H., "Metal-Semiconductor Contacts", (2nd edn.) Calarendon Press, Oxford. **(1988)**
5. Sze S.M., "Semiconductor Devices, Physics and Technology", Mc GrawHill Inc.**(1985)**.
6. Neamon D. A., "Semiconductor Physics and Devices", (1st edn.) IRWIN Inc. **(1992)**
7. Shandalov M. and Golan Y., "Microstructure and morphology evolution in chemical solution deposited semiconductor films: 2.PbSe on As face of GaAs(111)", EPJ Applied Physics proofs, Published online (Inserted Later) - © EDP Sciences. **(2004)**
8. Antruk O. S. & Turan R., Semicond. Sci Technology, Vol.141, p.660. **(1999)**
9. Norde H., J. Appl. Phys., Vol.50No. 7,p. 5052. **(1979)**
10. Panayotatos P. & H.C. Card IEEE Proc. Vol. 127Pt. I No. 6, p.5154. **(1980)**
11. Goetzberger A., Knoblock J., Vob B., "Crystalline Silicon Solar Cells", Translated by Rachel Waddington, John Wiley and Sons Inc. **(1998)**

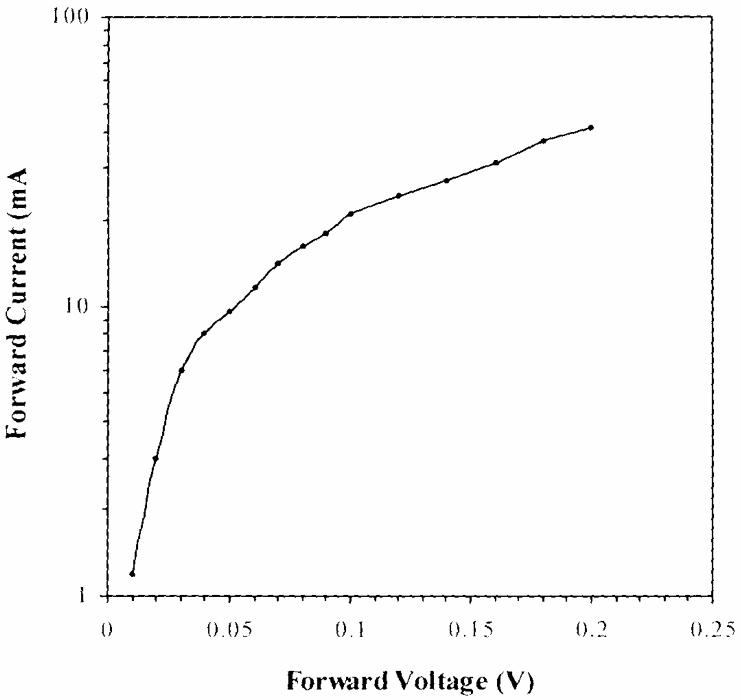

Fig. (1). Forward I-V characteristics of Sb-pSi contact.

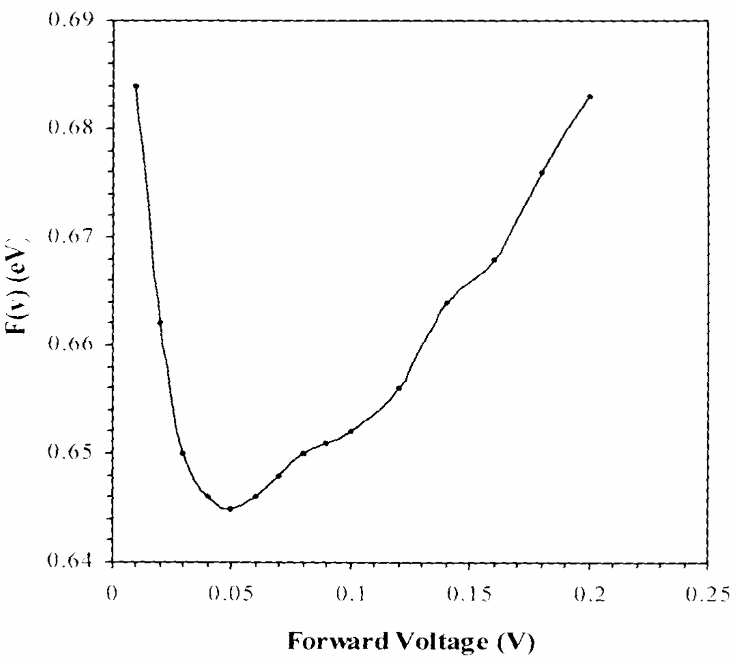

Fig.(2).Calculated F(V) vs. the forward voltage through Sb-pSi contact.

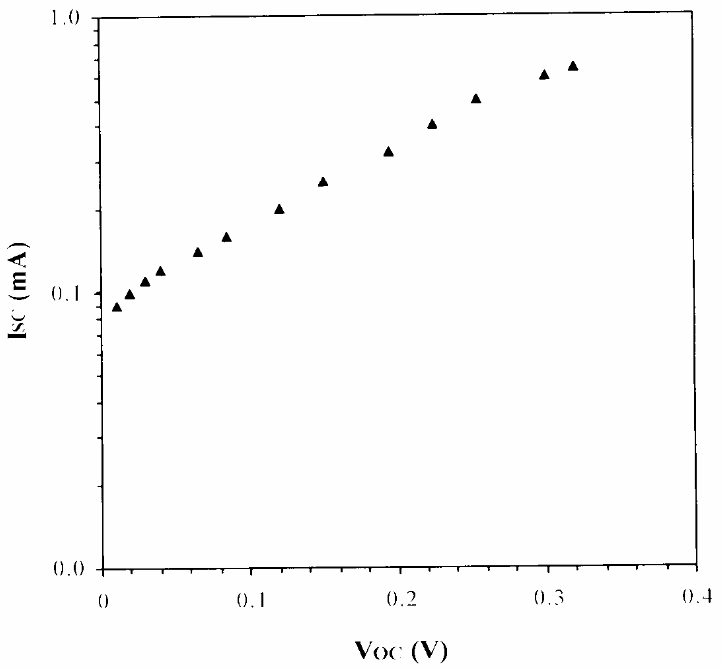

Fig. (3). JSC - VOC characteristics of Sb-pSi contact

Table (I). Results of Φ_{Bp} and n for as -deposited Sb-pSi contact.

	J-V	J_{SC}-V_{OC}	**Norde Method**
Φ_{Bp} (eV)	0.64	0.62	0.645
n	1.5	2	-

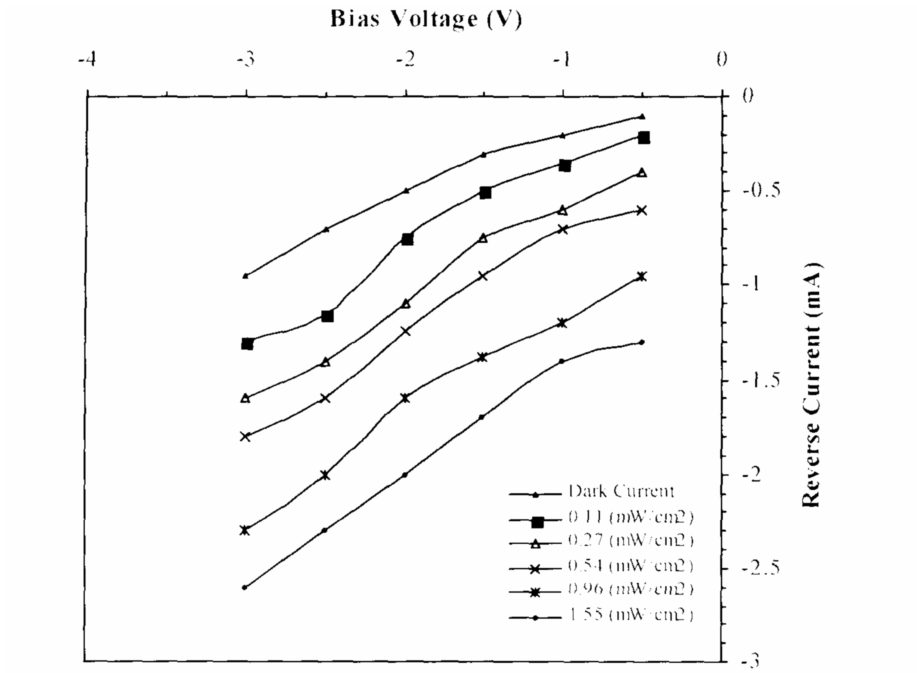

Fig. (4). Reverse photocurrent as a function of bias voltage.

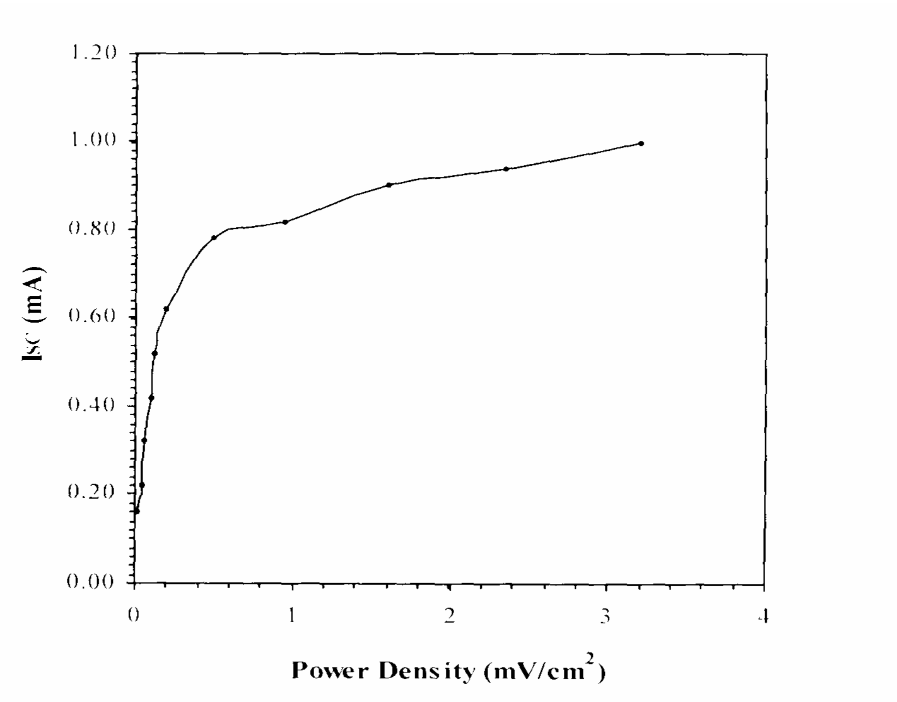

Fig.(5). Short – circuit current versus illumination power density