Eng. & Technology, Vol.25, No.1, 2007

Electrical and Photovoltaic Properties of In-pSi Contact

Khalid Z. Yahya*
Received on: 9/2/2005
Accepted on: 20/11/2005

Abstract
In the present work, the electrical and photovoltaic properties of In-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 shows a reasonable agreement with the simple Schottcky-Mott theory. The contact shows good response to white light when it works under bias condition. Peak response of 0.22 A/W at 850 nm wavelength was registered.

Keyword: In/Si contact, photovoltaic, barrier height, responsivity.

الخلاصة
في هذا البحث، جرى دراسة الخصائص الكهربائية والفولطائية الضوئية لاتصال In-pSi ولأول مرة على حد علمنا. استُخدمت طريقتان موثوقتان لإيجاد قيمة حاجز الجهد لهذا الاتصال، إذ أظهرت النتائج اتفاقا مقبولا لقيمة ارتفاع الحاجز مع نظرية شوتكي- موت البسيطة. أظهر الاتصال استجابة جيدة للضوء الأبيض مما يؤهله للعمل كدايود ضوئي في مدى الأشعة المرئية. تم الحصول على استجابية طيفية بمقدار 0.22 A/W عند الطول الموجي 850 nm.

1. Introduction

Metal-semiconductor photodiodes have attracted great attention for opto-electronic devices because of[1-3]: their fast response; a thin entrance window which allows the carriers to be generated in the sensitive region; fabrication of the devices at room temperature so that no degradation in diffusion length and life time occur; and ability to be used on polycrystalline substrates.

In Schottcky photodetectors, 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 photodetectors in the visible range (0.4-0.7 μm), while Ge Schottcky photodiodes have been investigated and found to work in the range (1-2 μm)[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 thermionic emission theory was established by Bethe in 1942. Crowel and Sze later refined this in 1966, the

* School of Applied Sciences, UOT.
Email: khalidzakariya2004@yahoo.com.

https://doi.org/10.30684/etj.25.1.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

epitaxial silicide process developed by Tung in 1984 provides a new insight into intrinsic metal-semiconductor properties. More processing and application of Schottcky barrier structure can be found in references[4-6].

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

2. Experimental Procedure

Silicon wafers used to fabricate In-pSi Schottcky contact were cut from (111) orientation, p-type, single crystal silicon having resistivity of 2.5 Ω.cm with thickness of 550 μm and 0.12 cm^2 area.

A layer (15 nm thick) of a high purity indium (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 thermionic emission current being dominant, the expression of the saturation current density (J_S) is described as[5]:

$$J_S = A^* T^2 \exp\left(\frac{-q\Phi_{Bp}}{k_B T}\right) \quad \ldots\ldots \textbf{(1)}$$

where A* is the modified Richardson constant, T is absolute temperature.

The value of J_S is determined by extrapolating the straight-line region of I-V plot into the point V = 0, and the value of Φ_{Bp} can be extracted from eq. (1). A semi-log I-V plot under forward bias for In-pSi is presented in Fig. (1). The ideality factor ranges about 1.5-2, these values reflect that the carriers transport takes place by tunneling and recombination mechanisms associated with thermionic emission mechanism[7]. Also, it is obvious that the precise extrapolation of the curve to the I-axis is difficult to obtain. Thus, employing Norde method[8] is necessary to determine of the barrier height.

The variation of F(V) against the forward bias voltage is presented in Fig. (2). Φ_{Bp} was extracted from the local minimum point of the curve[8].

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_o and corresponding value of Φ_{Bp}. Also, the ideality factor (n) and saturation current density can be found from the following eq.[9]:

$$V_{OC} = \frac{nk_B T}{q} \ln J_{SC} - \frac{nk_B T}{q} \ln J_o \quad \ldots \textbf{(2)}$$

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

$$\Phi_{Bp} = \chi_S - \Phi_m + E_g \quad \ldots\ldots\ldots\ldots \textbf{(3)}$$

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 In-pSi is 0.30 eV. 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 In-pSi contact[5, 7].

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

Fig. (4) showed the photocurre- nt under different levels of incident light. Also, there is a reasonable photovoltaic performance. A good linearity can be obtained at low levels of illumination intensity as presented in Fig. (5).

Figs. (6 & 7) show spectral responsivity and quantum efficiency of this junction. The figures illustrate peak response at 850 nm which corresponds to the silicon absorption. On the left side of the peak, responsivity shows slow rise-up which is due to the contribution of In layer, while the sharp fall-down at the right side of the peak is a result of deep absorption in the bulk of the silicon.

4. Conclusions

Experimental study for near ideal In-pSi contact shows that barrier height does not obey the 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 In-pSi contact may be used as a detector in the visible region. This kind of detectors can be improved using an antireflection coating[10].

References

[1] Kwok K. Ng., “Complete Guide to Semiconductor Devices”, (1st edn.) Mc Grow-Hill Inc. (1995).
[2] J. P. Ponpon & P. Siffert, J. Appl. Phys. (1976), Vol. 47, No. 7, p. 3248.
[3] Budde,,,,,,
[4] E. H. Rhoderick & R. H. Williams, “Metal-Semiconductor Contacts”, (1988), (2nd edn.) Clarendon Press, Oxford.
[5] S. M. Sze, “Semiconductor Devices, Physics and Technology”, Mc Grow-Hill Inc. (1985).
[6] D. A. Neamon, “Semiconductor Physics and Devices”, (1992) (1st edn.) IRWIN Inc.
[7] O. S. Anturk & R. Turan, Semicond. Sci. Technology, (1999) Vol. 141, p. 660.
[8] H. Norde, J. Appl. Phys., (1979) Vol. 50, No. 7, p. 5052.
[9] P Panayotatos & H. C. Card, IEEE Proc., (1980) Vol. 127 Pt. I No. 6, p. 5154.
[10] A. Goetzberger, J. Knoblock, B. Vob, “Crystalline Silicon Solar Cells”, (1998), Translated by Rachel Waddington, John Wiley and Sons Inc.

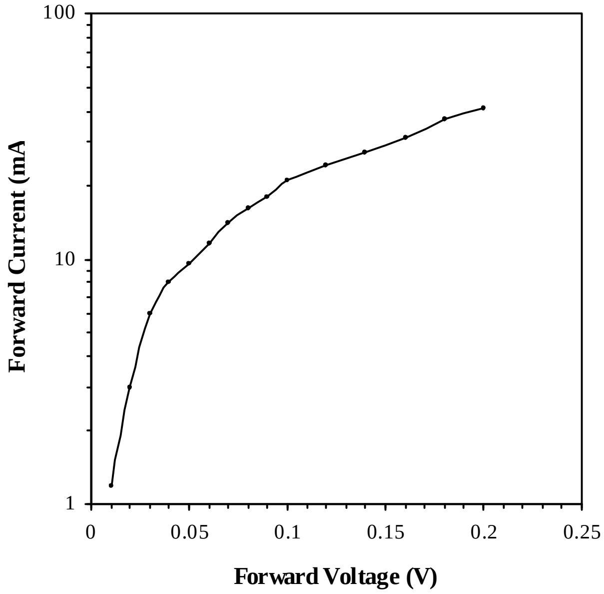

Fig. (1). Forward I-V Characteristics of In-pSi Contact.

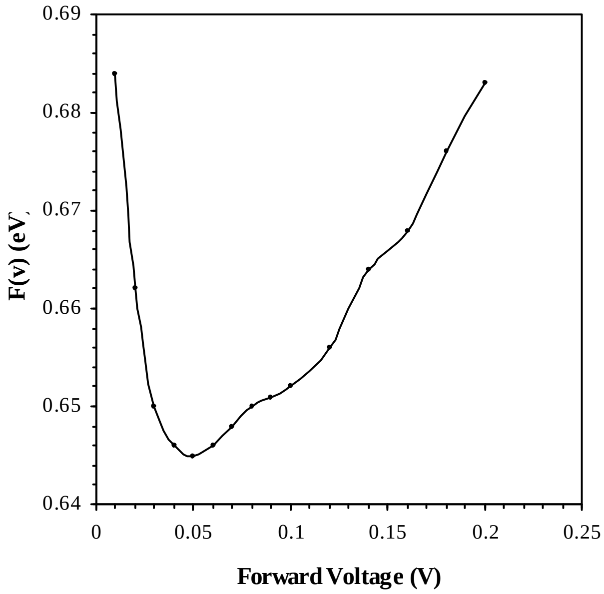

Fig. (2). Calculated F(V) vs the Forward Voltage Through In-pSi Contact.

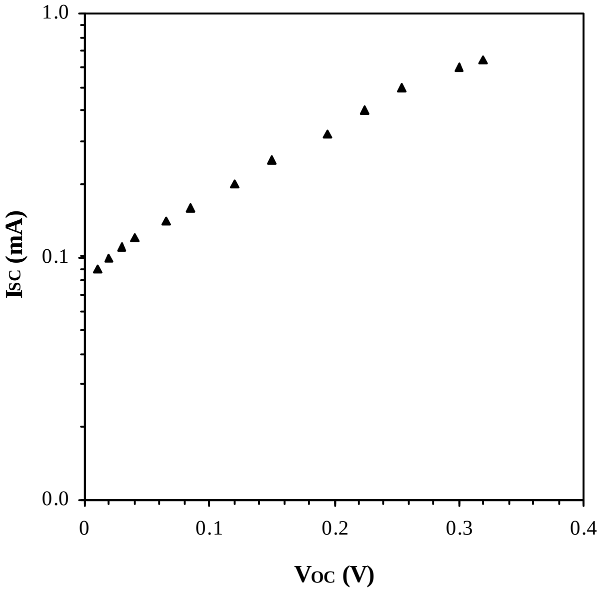

Fig. (3). J_{SC}-V_{OC} Characteristics of In-pSi Contact.

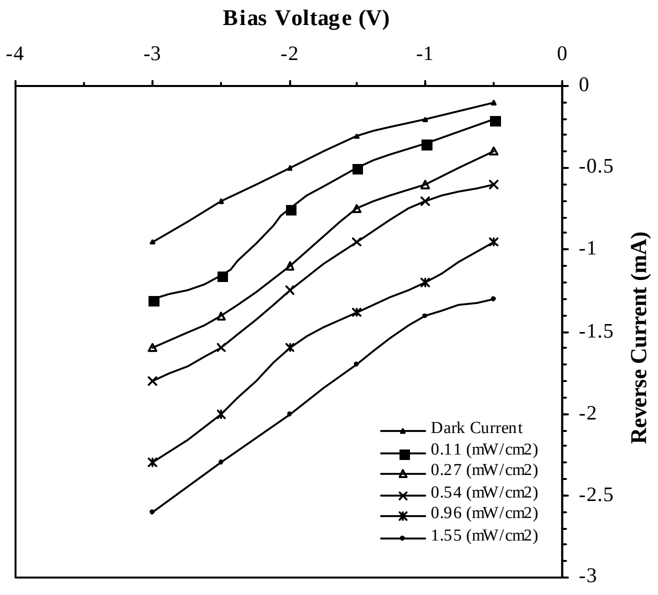

Fig. (4). Reverse Photocurrent as a Function of Bias Voltage.

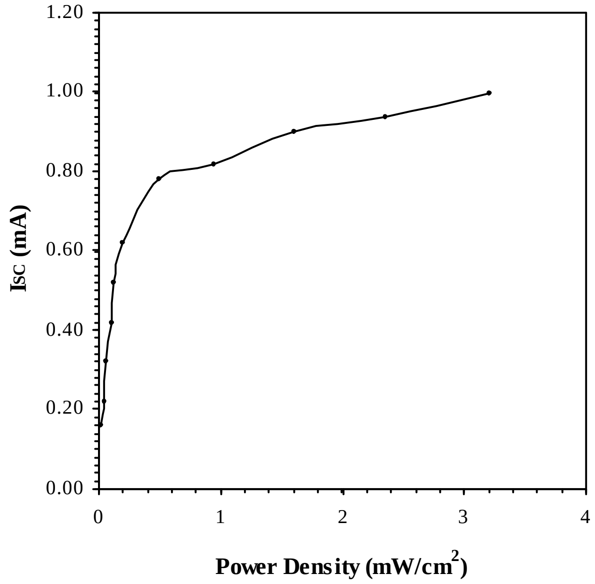

Fig. (5). Short-Circuit Current versus Illumination Power Density.

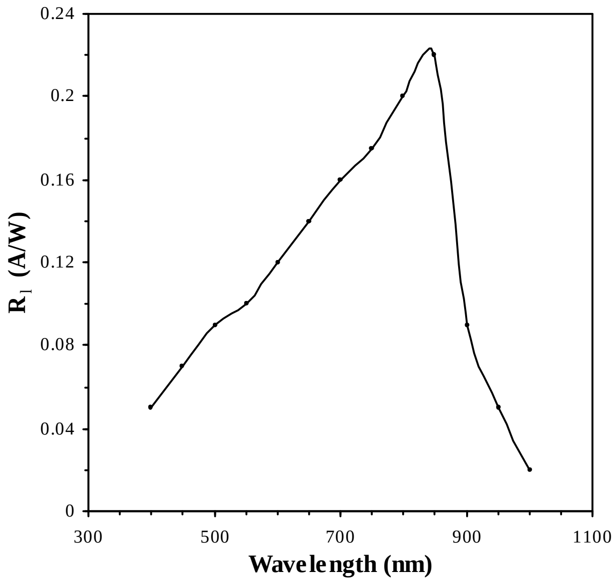

Fig. (6). Spectral Responsivity of the In-pSi Contact.

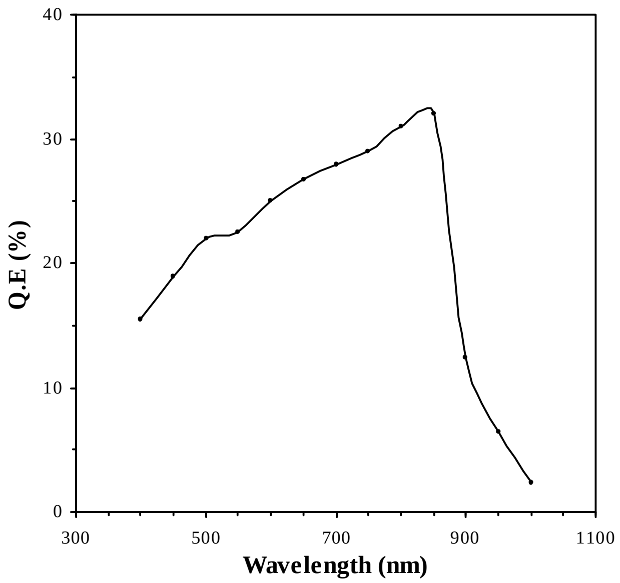

Fig. (7). Quantum Efficiency of the In-pSi Contact.

Table (I). Results of F_{Bp} and n for As-Deposited In-pSi Contact.

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