Construction of Anisotype CdS/Si Heterojunction and Lineup Using I-V and C-V Measurements

Raid A. Ismail*, Abdul-Majeed E. Al-Samarai, Omar A. A. Sultan*****
* Department of Applied Sciences/ University of Technology
** Department of Physics/ College of Education/ Al-Mustansiriyah University
*** NASSR State Company-Ministry of Industry and Minerals

ABSTRACT:

Near-ideal p-CdS/n-Si heterojunction band edge lineup has been investigated for the first time with aid of I-V and C-V measurements. The heterojunction was manufactured by deposition of CdS films prepared by chemical spray pyrolysis technique (CSP) on monocrystalline n-type silicon. The experimental data of the conduction band offset ΔE_c and valence band offset ΔE_c were compared with theoretical values. The band offset ΔE_c=530meV and ΔEv=770meV obtained at 300K. The energy band diagram of p-CdS/n-Si HJ was constructed. C-V measurements depict that the junction was an abrupt type and the built-in voltage was determined from C^{-2}-V plot.

بناء المخطط الطاقي للمفرق الهجين نوع CdS/Si غير المتماثل باستخدام قياسات تيار - جهد و سعة - جهد

رائد علي اسماعيل*، عبد المجيد عيادة السامرائي وعمر سلطان*****
**قسم العلوم التطبيقية – الجامعة التكنولوجية*
***قسم الفيزياء – كلية التربية – الجامعة المستنصرية*
****شركة النصر العامة – وزارة الصناعة والمعادن*

الخلاصة:

في هذا البحث، تم وصف المخطط الطاقي للمفرق الهجين (شبه المثالي) ولأول مره من خلال خصائص تيار– جهد و سعة–جهد. تم تصنيع المفرق الهجين من خلال ترسيب غشاء من مادة CdS بواسطة طريقة الرش الكيماوي الحراري على سليكون أحادي التبلور نوع–n. إن النتائج العملية أوضحت أن مقدار كل من ΔE_c, ΔEv كانت بحدود 530meV و 770meV على التوالي عند درجة حرارة الغرفة، وقد تم مقارنتها مع القيم النظرية. إن قياسات سعة – جهد أوضحت أن المفرق من النوع الحاد وان جهد البناء الداخلي قد تم تحديده من خلال العلاقة البيانية C^{-2}-V.

INTRODUCTION:

Because of their importance in many applications of semiconductor devices, heterojunctions (HJs) have attracted intensive research interest over the past four decades [1-4]. The CdS/Si HJ has been the subject of active research of many devices such as transistor [5], photon detector [6], and solar cell [7]. This junction was made by several methods; the more competitive methods are thermal resistive and sputtering techniques.

However, the authors recently have reported [8-10] the first trial to prepare CdS/Si HJ by means of chemical spray pyrolysis technique.

To understand adequately the current transport mechanism of heterojunction, the band lineup is necessary, so many investigations on the band lineup of many of HJs were reported [4, 11].

In this study we report the construction of p-CdS/n-Si HJ band lineup with aid of I-V and C-V measurements.

EXPERIMENTAL:

1. Heterojunction Diode Fabrication:

The HJ diode analyzed in this paper was fabricated by deposition of CdS prepared by spray pyrolysis of 0.2M aqueous solution of $CdCl_2$ and thiourea onto chemically etched monocrystalline n-type silicon substrate of (111) orientation and 3-5Ω.cm electrical resistivity. Substrate temperature was around 350 ^oC. Ohmic contacts were made on both CdS and Si sides using In and Au-Sb respectively.

2. Electrical Measurements:

I-V measurements were measured with temperature as a parameter in the range (273-318 K). The C-V measurement under reverse bias with frequency of 1MHz was carried out by LCZ meter.

Conductivity type of CdS film was determined using Hall measurement.

RESULTS AND DISCUSSION:

Result of Hall measurement revealed that the conductivity of sprayed CdS films is a p-type as shown in Fig.(1), this can be attributed to the existence of oxygen which acts as an acceptor in CdS [12].

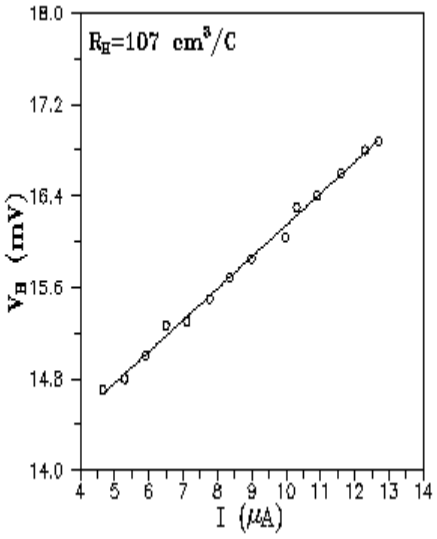


Figure (1): The Relationship between Hall Voltage (V_H) and Passing Current (I) for p-CdS Film.

Fig.(2) shows the reciprocal of square capacitance versus bias voltage, the results of this plot show a linear relationship which gives an indication that the junction is an abrupt type. The built-in voltage V_D can be calculated by extrapolating $1/C^2$–V plot to the point $1/C^2=0$. The intercept voltage V_{int} is related to the V_D by:

$$V_D = V_{int} + (2kT/q) \ldots\ldots\ldots (1)$$

where kT/q is the volt equivalent of temperature. The value of V_D calculated from Eqn.(1) is 1.4 V. Near ideal diode at 300 K is obvious in Fig.(3).

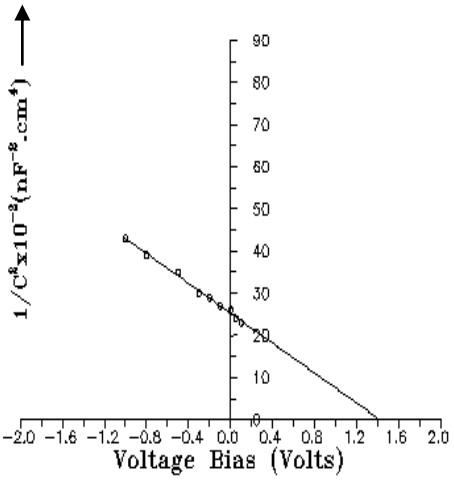


Figure (2): $1/C^2$ vs Reverse Bias Voltage.

I-V measurements under forward bias at temperatures around 300 K in the range (273-318 K) are presented in Fig.(4). The measurements are achieved at low voltage (up to 0.15 V) to cancel the role of the tunneling effect through the junction [13]. Saturation current density J_S can be found by extrapolating the J-V plot to V=0.

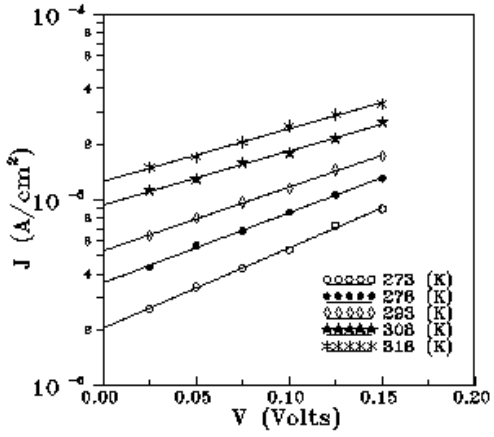


Figure (4): Forward J against V at Temperatures between 270 and 318K.

The variation of J_S with 1/T is plotted in Fig.(5), the value of valence band offset ΔE_v can be deduced from the slope of Fig.(5) using the following equation [14]:

$$Js = A\exp\left[\frac{-q(V_D - \Delta Ev)}{kT}\right] \text{ ------ (2)}$$

where: A is constant.

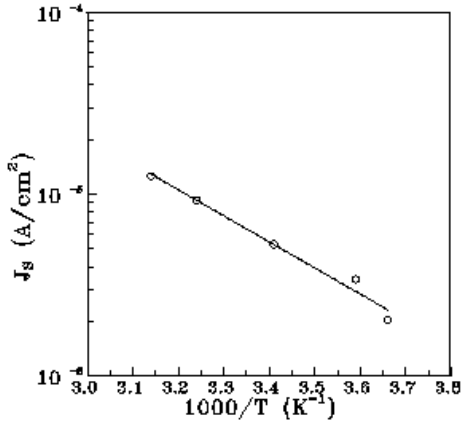


Figure (5): J_S vs 1000/T for Determination of ΔE_v.

The previous equation was selected according to CdS and Si parameters as it is detailed in ref.[14]. Using Eqn.(2) and the slope in Fig.(5), ΔE_v calculated to be 770 meV. The value of ΔE_c was determined with aid of the following equation:

$$\Delta E_c + \Delta E_v = Eg(CdS) - Eg(Si) \quad \text{-------(3)}$$

The value of right side of Eqn.(3) is equal to 1.3eV, hence ΔE_c is equal to 530 meV.From the above result, the band lineup of p-CdS/n-Si HJ was constructed as shown in Fig.(6). The effect of interface parameter is not taken into account because it is difficult to determine [4].

The experimental value of ΔE_c is consistent with the theoretical value (490 meV) [14] with satisfactory accuracy of 0.05 eV. The values of ΔE_c and ΔE_v revealed that the current transport in p-CdS/n-Si HJ is carried out by electrons more than by holes.

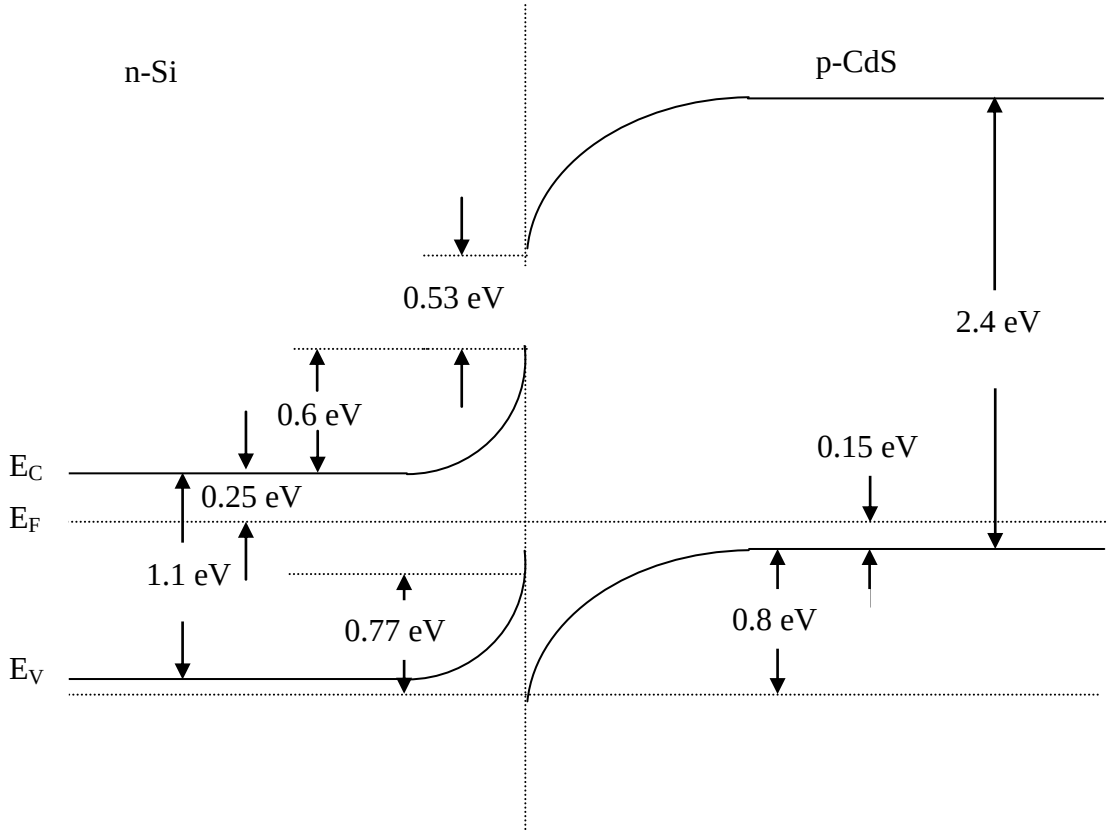


Figure (6): Energy Band Diagram for p-CdS/n-Si Heterojunction.

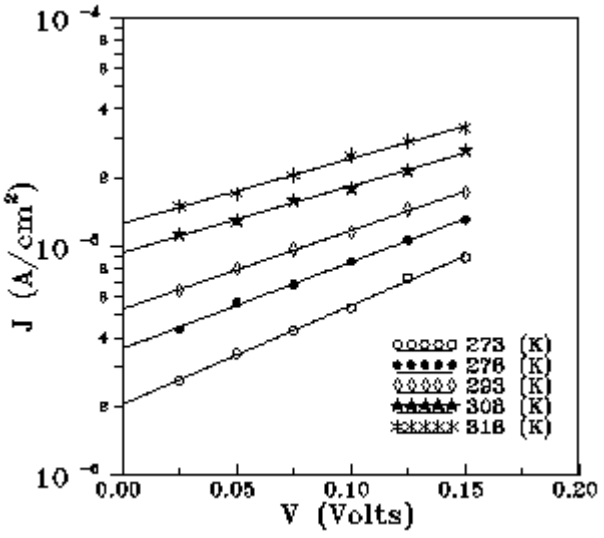
CONCLUSION:

Several conclusions can be drawn on the basis of obtained experimental data as shown below:

1- The junction formed by pyrolysis spraying of CdS thin films on n-type Si is anisotype.
2- C-V results suggest that the junction was abrupt type.
3- Experimental value of ΔE_c seems to be consistent with the theoretically calculated ΔE_c with satisfactory accuracy.

REFERENCES:

[1] D. J. Page, IEEE Trans. Electron Devices, 12 (1965) 509.
[2] Tom Feng, Amal K. Ghosh, and Charles Fishman, Appl. Phys. Lett., 35 (1979) 266.
[3] D. J. Eaglesham, E. P. Kvam, and C. J. Humphreys, Appl. Phys. Lett., 53 (1988) 2083.
[4] A. Georgakilas, E. Aperathitis, V. Fonkaraki, M. Kauyambaki, and P. Panayotatos, Materials Science and Engineering, 44 (1997) 383.
[5] S. Brojdo, T. J. Riley, and G. T. Wright, Brit. J. Appl. Phys., 16 (1965) 133.
[6] D. Nesheva and E Vateva, Proc. 12th Bulgaria Conf. on photo-detector, 21-23 may 1986.



(2000) 77.

[10] Raid A. Ismail, Abdul-Majeed E. Al-Samrai, and Omar A. A. Sultan, Jr. Eng. and Technology, 20 (2001) 486.

[11] A. J. Steckly and S. P. Shen, Solid State Electronics, 23 (1979) 715.

[12] Chailaja Kolhe, S. K. Kulkarni, M. G. Takwale, and V. G. Bhide, Solar Energy Materials, 13 (1986) 203.

[13] A. G. Milnes and D. L. Feucht, "Heterojunction and Metal-Semicoductor Junction", Academic Press, New York, 1972.

[14] B. L. Sharma and R. K. Purohit, " Semiconductor Heterojunctions", Pergamon Press, New York, 1974.