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Fabrication and Characterization of Cu_2S /Si Heterojunction Photodetector Based on Spray Pyrolysis of Cu_2S on Si

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Abstract
In the present work fabrication and characterization of Cu_2S/Si heterojunction photodiodes made by spray pyrolysis method using aqueous solution of $CuCl_2.2H_2O$ onto n-type silicon substrates made. The external quantum efficiency of heterojunction was ٣7% at wavelength of 850nm. The experimental results show peak relative responsivity around 100mA/w , and maximum value of detectivity D^* ($2*10^{11}$cm.$Hz^{1/2}$.w^{-1}).

Keyword: photodetector, fabricated, heterojunction, spray pyrolysis.

تصنيع ودراسة خصائص كاشف المفرق الهجين Cu_2S/Si بطريقة الرش الكيميائي الحراري

الخلاصة
في هذا البحث جرى تصنيع ودراسة خصائص كاشف المفـــرق الهجـــين Cu_2S/Si المصـــنع بطريقة الرش الكيميائي الحراري , وبكفاءة كمية قصوى تصل إلى ٣٧% عند الطول الموجي 850nm . تم دراسة الاستجابة الطيفية كدالة للطول الموجي عند درجة حرارة الغرفــة. لقــد أوضحت النتائج إن قمة الاستجابة الطيفية كانت عند الطول الموجي 850nm والتي تصل إلى 100mA/w وأعلى قيمة للكشفية حوالي (D^*=$2*10^{11}$cm.$Hz^{1/2}$.w^{-1}).

Introduction

The heterojunction has been the subject of active research on many devices such as transistor, thyristors, semiconductor lasers, photodetectors, and solar cells [1-3].
This junction was made by several methods, the more competitive methods are thermal resistive evaporation, sputtering and chemical spray pyrolysis techniques. Such interest is based on the fact that these heterojunction devices have a number of advantages that: i- lower junction formation temperature ii- higher spectral response at short wavelength , and iii-many of the layers have the right indices of refraction that act as antireflection coating[4].

Ternary semiconductors of II-VI have been receiving significaut attention for photovoltaic devices. Among these chalcogyrite-type material, Cu_2S that possesses some exceptional characteristics for heterojunction application with Si[5].
In this paper we report a study of the electrical and photoelectric properties of such p-Cu_2S/n-Si devices by using chemical spray pyrolysis technique, which is an appropriate method because of low cost, easy processibility, possibility of large area fabrication, and ease to affect doping.

Experimental

The film of Cu_2S have been prepared by spray pyrolysis technique from a starting solution of 0.1M aqueous solution $CuCl_2.2H_2O$ and thiourea

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$(NH_2)_2CS$ with an ion solution 1:1. Single – crystal silicon wafers of n-type with (111) orientation are used as substrates. They have a resistivity of the order 2 Ω.cm. Prior to the film deposition, the wafers were degreased with ethanol in ultrasonic bath. Native oxides were removed by dilute hydrofluoric acid. The substrate was maintained at 523K , then these films were allowed to cool down to room temperature. At this stage the carriers in the Cu_2S film were confirmed as p-type by thermoelectric effect. Ohmic contacts were made to the materials forming the heterojuncion by vacuum deposition of 2000Å aluminum film.

The thermoelectronic power (TEP)was evaluated by measuring the Seebeck voltage as a function of temperature. I-V measurement were done under dark condition. The (I-V) measurement were measured with temperature as a parameter in the range (273-323)K. The (C-V) measurement under reverse bias with frequency of 1MHz was carried out using LCR meter.

The spectral measurements of Cu_2S/Si heterojunction detector were made by using a monochromator (optometics U.S.A.Inc.edmund industrial opticals model-04 53954) in the range (400-1100)nm. The results were calibrated by measuring the power of each spectral line using a standerd power meter.

Result

The poly crystalinity of grown film was confirmed by x-ray studies [6], fig.(1).

Result of seeback effect reveal that the conductivity of sprayed Cu2S films is a p-type as shown in Fig.(2), this result in full agreement with result obtained by other workers [7].

The (I-V) characteristics under dark condition of Cu_2S/Si heterojunction were investigated. The behavior of the bias gave anisotype heterojunction, i.e. Cu_2S behaves as p-type. Fig.(3) shows the rectification property of a typical HJ chip at room temperature observed on a curve tracer. The current for this heterojunction can be desecribed by relation[8]:

$$I \propto \exp(AV) \quad \ldots\ldots(1)$$

A semi-log (I-V)plot under forward bias is presented in fig.(4). This figure shows that forward current consist of two regions. The first one represents the recombination current, while the second region represents the tunneling current, i.e. Cu_2S/Si heterojunction obeys the tunneling-recombination model. The ideality factor n is calculated by the following equation[9]:

$$n = \frac{q}{KT} \frac{\partial V}{\partial \ln\left(\frac{I_F}{I_S}\right)} \quad \ldots\ldots(2)$$

where q/KT : reciprocal of the volt equivalent of temperature.

The value of n was determined to be 1.6 in region I (up to0.08v) and 5 in region II at 300K. This large value of n could also be due to the recombination of carriers at interface due to the defects produced by the different properties for the two materials of heterojunction[10].

From the same figure we observe the current –voltage (I-V)characteristics depends on the temperature. The saturation current density of first region I is determined by extrapolating (I-V) curve of this region to find its intercept with V=0.

C-V characteristics of Cu_2S/Si heterojunction chips were studied on a bridge arrangement. The C-V plot of one of the chips is shown in Fig.(5) which gives the straight line plot of C^{-2} versus V is as expected from the theory[11]. From the intercept of this curve, the value V_{bi} was found to be 0.6 volt.

The photoresponse measurement of Cu_2S/Si heterojunction photodetector was carried out by determining the short-circuit photocurrent I_{SC} as a function of wavelength in the range (400-900 nm). The maximum value of responsivity was (0.28A/w) at λ=850nm

Fig. (6) presents a relative spectral responsivity of Cu_2S/Si photodiode. It is clear from the figure, there are three distinct regions. The first region we observe low value of responsivity at shorter wavelength region may be due to the absorption of light near the surface which has large amount of surface recombination of the photogenerated carriers. The second region shows an increase in R_λ passing through the maximum value at λ= 800 nm . the third region shows that the responsivity decrease reaching the cutoff wavelength of the silicon.

Fig. (7) shows the experimental results of Cu_2S/Si quantum efficiency which gives maximum about 37% at the wavelength 850nm.

Fig. (8) shows the dependence of D* on wavelength at 300K. we can calculate from equation[1,3]:

$$D^* = \frac{R}{I_n}\sqrt{A\Delta f} \qquad \ldots\ldots(3)$$

where I_n is noise current given by $I_n = \sqrt{2qI_d\Delta f}$, the I_d is a dark current (50nA) , A is sensitive area of photodiode, q is electron charge and Δf band width.

Conclusions

The Cu_2S film is p-type deposited on to n-Si by chemical spray pyrolysis technique to introduce anisotype heterojunction photodetector.The C-V result suggests that the is abrupt type. Results show that this technique is an appropriate to fabricate detector with a quantum efficiency of(37%) and responsivity (0.28A/w). The forward current of this junction obeys the tunneling-recombination model.

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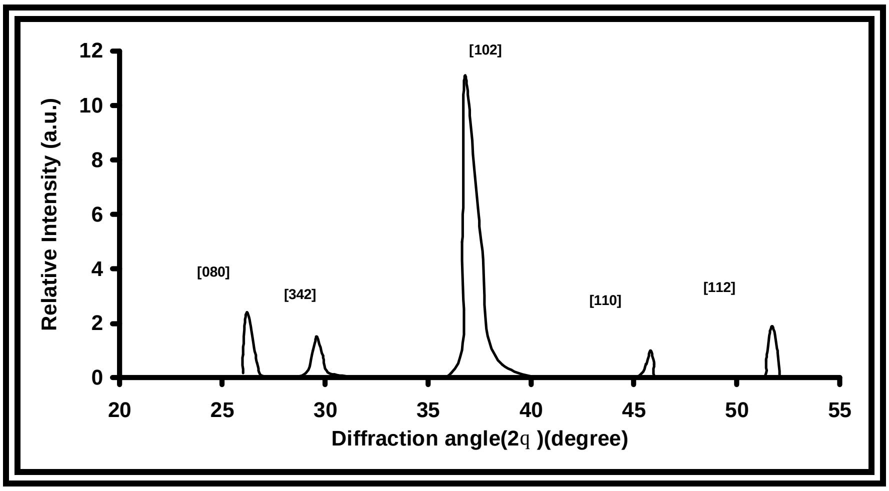

Fig.(1) X-ray diffraction of Cu_2S film grown on Si substrate.

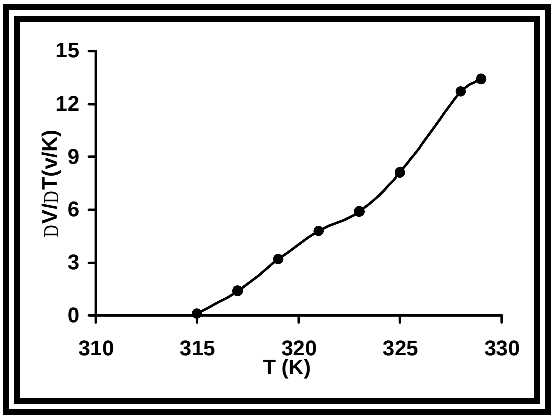

Fig.(2) Seeback effect versus temperatures.

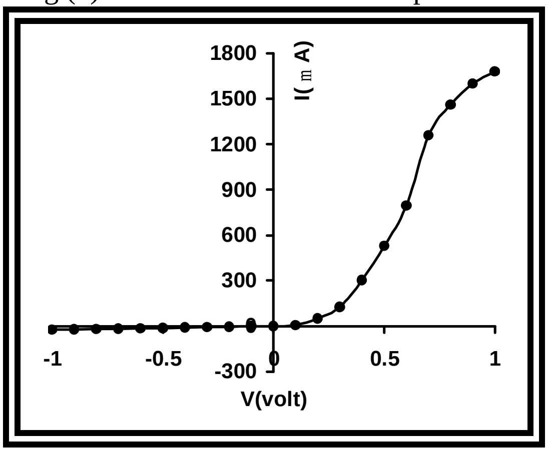

Fig.(3) Current-voltage characteristics for p-Cu_2S/n-Sianisotype heterojunction.

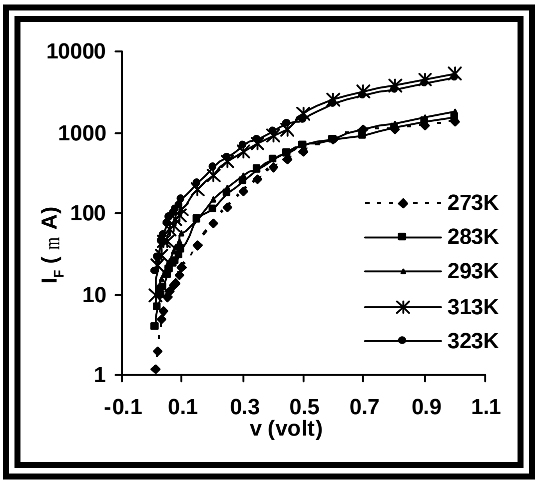

Fig.(4) Dark forward I-V characteristics for the p-Cu_2S/n-Si structure measurement at different temperatures.

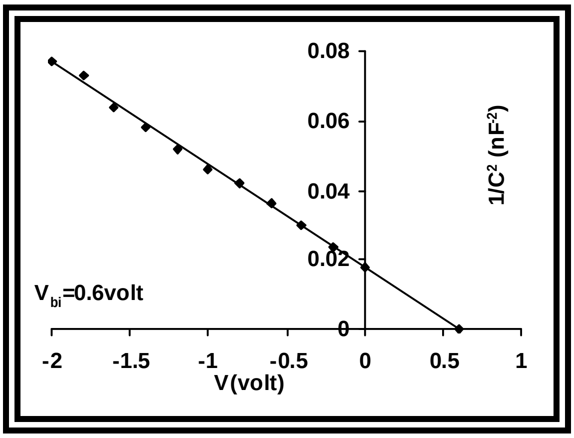

Fig.(5) Capacitance -voltage characteristics for p-Cu_2S/n-Sianisotype heterojunction.

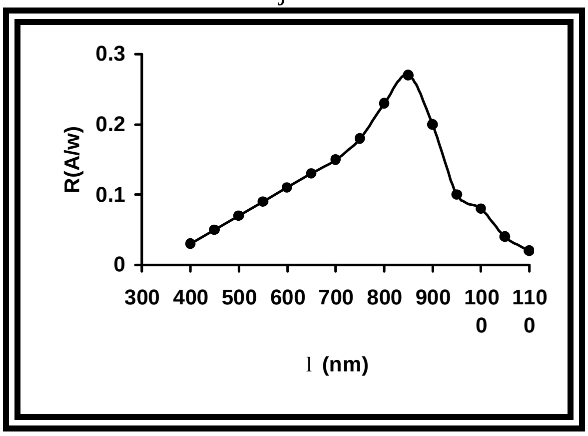

Fig.(6) Relative spectral response of Cu_2S/Si heterojunction photodetector.

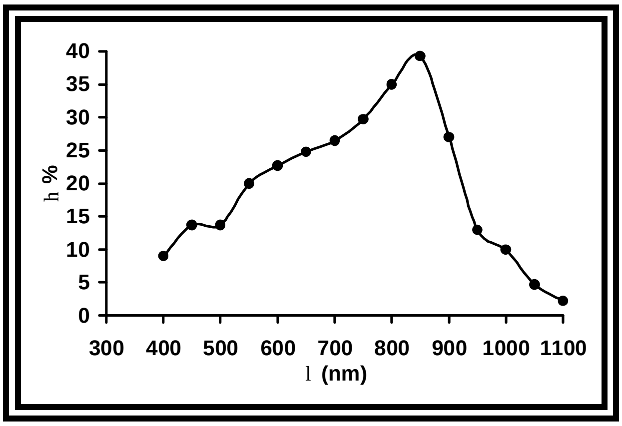

Fig.(7) Quantum efficiency of Cu_2S/ Si photodetector as a function of wavelength.

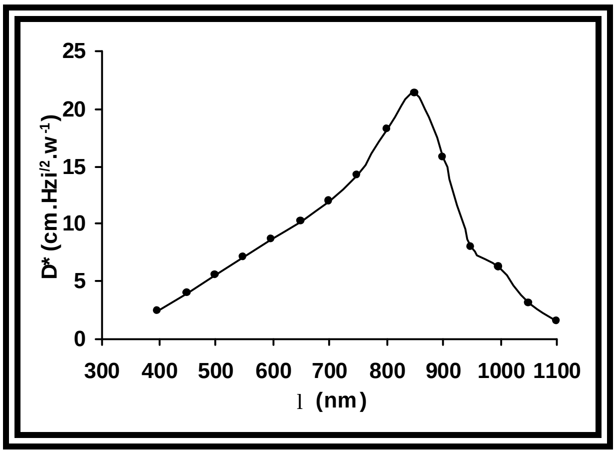

Fig.(8) Detectivity versus wavelength for Cu_2S/Si photodetector.