Design and Fabrication of PbSnSe Photodetector

Abdul-Hussain K. Iltaif[1], Muhammed K. Khalaf[2], Baha'a A. Majeed [3], and Ausama E. Khudhair[4].
[1,2,4]Ministry of Science and Technology,
[3]Al-Mustansiriayh University, College of Education, Physics Dept.,
E-mail: akiltaif@yahoo.com

Received 17/6/2008 – Accepted 3/6/2009

الخلاصة

في هذا البحث تم تصنيع كاشف ضوئي نوع التوصيلية الضوئية للعمل في المدى الطيفي للأشعة تحت الحمراء. تمت دراسة خواصه الكهروبصرية باستخدام مصدر للأشعة ذو طيف انبعاث بالمدى (2-28) مايكرومتر، حيث تم اختبار الكاشف تحت ظروف مختلفة في درجة حرارة الغرفة وبالتبريد بسائل النيتروجين، وكانت أعظم استجابة طيفية لهذا الكاشف تقدر بحوالي (0.4) أمبير/واط، الكشفية كانت بحدود (8×10^8) سم.(هيرتز)$^{2/1}$/واط.

ABSTRACT

In this work, a photoconductive detector of PbSnSe crystal were fabricated and treated for infrared range detection. The optoelectronic properties have been studied using infrared source with emitting spectral range of (1-28) µm, and examined under room temperature and liquid nitrogen (77k).The maximum spectral resonsivity for this detector was 0.4 A/W and the specific detectivity (D*) was 8×10^8 cm.(Hz)$^{1/2}$/W.

INTRODUCTION

Photodetectors are a semiconductor devices that can detect optical signals through electronic processes. The extention of wavelength of coherent and incoherent light sources into the infrared region on one hand and the ultraviolet region on the other has increased the need for high speed sensitive photodetectors. The operation of a general photodetector include basically three processes:

1- Carrier generation by incident light. 2- Carrier transport and/or multiplication by current-gain mechanism if present, and 3- Extraction of carriers as terminal current to provide the output signal[1].

The photodetectors must satisfy stringent requirements such as high sensitivity at operating wavelengths, high response speed, and minimum noise. In addition, the photodetector should be compact in size, use low biasing voltage or current and be reliable under operating conditions.

Anderson and Melchior [2,3] have reviewed high speed photodetectors. A comprehensive review on infrared photodetectors has been given [4] and the photodetectors for optical fiber communications are discussed [5]. Nonlinear saturation behaviors of high speed photodetectors have been studied by [6] and the design considerations for high current photodetectors was established [7]. Yairi et al. [8] studied large signal response of (p-i-n) photodetectors using short pulses with small spot sizes.

In this paper we report the design and fabrication of PbSnSe photodetectors which used in the wavelength range of (8-14) µm.These detectors have many applications such as thermal imaging, guiding as well as in medical and industrial applications.

MATERIALS AND METHODS

PbSnSe crystal has been used to fabricate photoconductive detector from the same type as the following:

The crystal was cut to proper dimensions (6mm length and 3mm width) by using a special cutting machine. The polishing and grinding for these substrates were performed using a polishing machine type TF-250n from (TEANWARTZ Co., Germany) and using diamond pastes with different smooth degree (0.25,1,3,9) Microns. Then, these samples were chemically etched by using a mixture of (CH_3COOH, HF and HNO_3).

The deposition of indium electrodes for these detectors has been done by using coating machine type Balzer under vacuum of 10^{-5} mbar and through a special masking.

The examinations on these detectors were performed by placing them on a cold finger in a cooling system (cryostat) which contain two chambers one under vacuum and have a special window (type ZnSe) to pass the infrared radiation and the other for liquid nitrogen.

RESULTS AND DISCUSSION

The dark current and photo current were measured as a function of operating voltage applied on these detectors under different temperatures as shown in figs. (1 and 2). It is clear from figure (1) the minimum change between the dark and photo currents under room temperature .While , at liquid nitrogen temperature, we can see the clear change and difference between dark and photo current for different radiation intensities and the reason behind that ,the cooling will reduce the thermal excitation and increase the electronic movement (electron mobility) which cause increase in gain factor (G) (the ratio between the photo current and the dark current).The value of this factor was (1.2) under room temperature and about (3) under cooling with liquid nitrogen.

The responsivity (R) of these detectors which is the ratio between the Photo current to the input power has been measured for different wavelengths under liquid nitrogen temperature as shown in Fig (3).

We can see from this figure that the maximum responsivity was (0.4) A/W at wavelength 12 µm.Also, the specific detectivity (D*) of this detector has been calculated using the following equation[3]:

$$D^*=R(A_d)^{1/2}/I_n \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where Ad is the detector area
In is the noise current= $(2qId)^{1/2}$
Id is the dark current
q Is the electron charge, therefore,
$D^{*}=8x10^{8}$ cm $(Hz)^{1/2}$/w

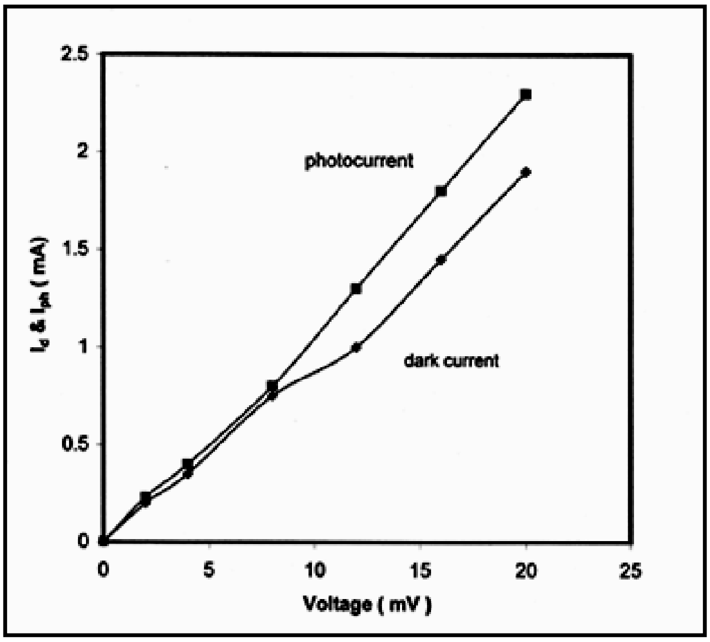

Fig. -1: The relation between dark and photo current versus voltage for PbSnSe detector at room temperature

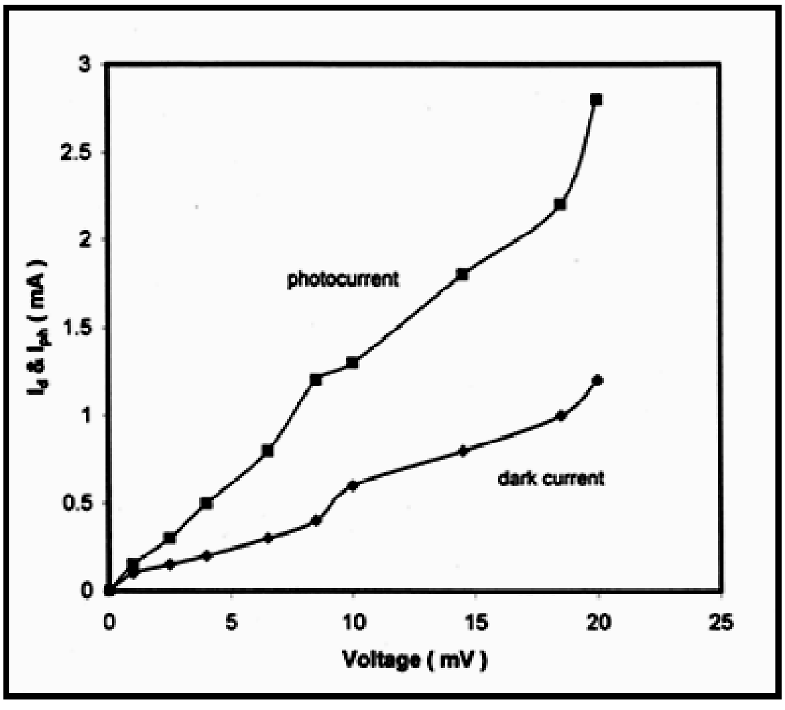

Fig. -2: The relation between dark and photo current versus voltage for PbSnSe detector at liquid nitrogen temperature

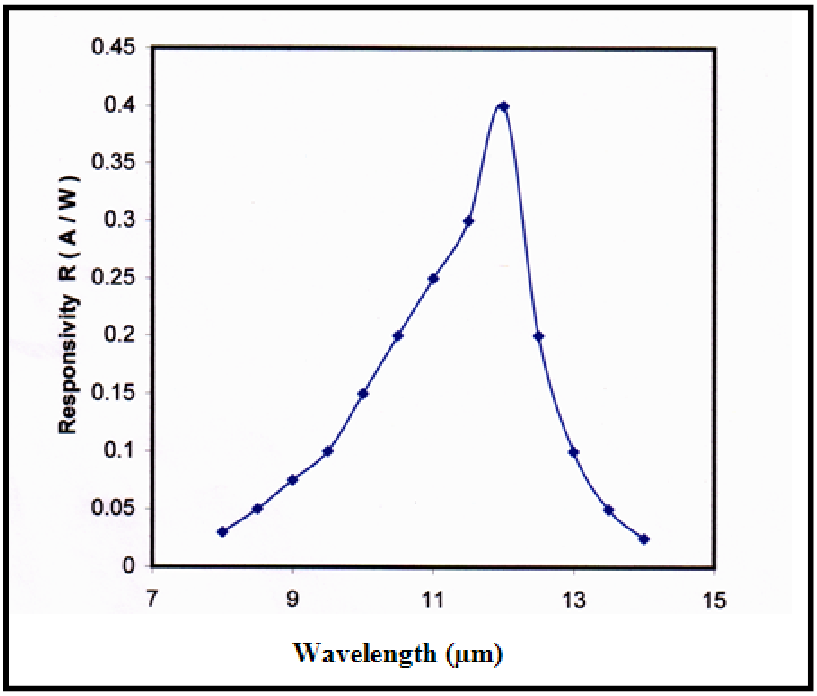

Fig. -3: The relation between Responsivity and Wavelength for PbSnSe detector

We can conclude from our measurements, it is possible to fabricate the PbSnSe detector with a high responisivity and detectivity which can be considered as a good replacement to mercury cadmium telluride (HgCdTe) detector in spectral range (10-13) µm and working at liquid nitrogen temperature.

REFERENCES

1. Sze S.M. and Kwok K. Ng., "Physics of Semiconductor Devices", CH.13 photodetectors and Solar Cells, P.663, John Wiley&Sons Inc.3rd Edition, (2006).
2. Anderson L.K. and Fisher M.B.," High speed photo detector for microwave demodulation of light "In L.Young, Ed., Advance in microwave, Vol. 5, Academic, New York, (1970).
3. Melchior H.," Demodulation and photo detection techniques," in F.T, Arecchi, Ed., Laser hand book, Vol.1, North Holland, Amsterdam, (1972).
4. Willardson R.K. and Bear A.C.,"detector for light wave communication"Appl. Phys. Lett., Vol.37, P.P.322 (1980).
5. Lee T.P. and Li T.Y.," Photo detectors with high output voltage "Appl. Phys.Lett., Vol.33,P.P.629, (1978).

6. Huang Y. L. Y. L. and Sun C.K.," Nonlinear saturation of p-i-n photo detectors" J.Lightwave Techno., Vol. 18, P.P.203, (2000).
7. William K.J. and Esman R.D.,"High current photodetectors,"J.Lightwave Techno."Vol.7, P.P.1443,(2001).
8. Yairi M.B., Demir H.V. and Miller D.A.B.,"Large- signal response of p-i-n photodetectors using short pulses with small spot sizes" IEEE.J.Quantum Electron., Vol. 40, No.2, P.P.143-151, (2004).