High-Speed Response Si PIN Photodetector Fabricated and Studied for Visible and Near Infrared Spectral Detection

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Abstract

In the present work , PIN photodetector has been fabricated by vacuum evaporation technique, Al was evaporated on top side of an intrinsic – type silicon and In was evaporated on down side and doped for each sides of an intrinsic silicon with thermal diffusion technique using a furnace system, in this method PIN photodetector is made.

The optoelectronic and electrical properties of photodetector were studied ,PIN has spectral responsivity in visible and near infrared region and has peak responsivity at wavelength 900nm ,I-V characteristic under dark condition the ideality factor is 3.2 and built-in-potential was determined by extrapolation of the curve ($1/C^3$) to a point $1/C^3=0$ equal 0.8v. a high speed response for the photodetector was determined , it is equal less than 2.35nS.

Keyward: photodetector, vacuum evaporation, thermal diffusion.

تصنيع ودراسة كاشف سليكوني من نوع PIN ذو سرعة استجابية عالية للمنطقة المرئية وتحت الحمراء القريبة من الطيف

الخلاصة

في هذا البحث ، تم تحضير كاشف من نوعPIN بطريقة التبخير تم تبخير معدن الألمنيـوم علـى السطح الأعلى للسليكون النقي وأيضا تم تبخير معدن الانديوم على السطح الأسفل للسليكون ثم جرى أشـابة السليكون بطريقة الانتشار الحراري بالفرن وبهذه الطريقة تم تصنيع كاشف من نوع PIN .

تم دراسة الخواص الكهوبصرية والكهربائية ووجد ان الكاشف له استجابية طيفية للمنطقة المرئيـة وتحت الحمراء القريبة وله قمة استجابية عند الطول الموجي 900nm ومن خصائص تيـار-جهـد وتحـت ظرف الظلام وجد ان للكاشف عامل مثالية يساوي 3.2 ومن خصائص سعة-جهد وجد ان المفرق من النوع المتدرج وتم حساب جهد البناء الداخلي من رسم المنحني $1/C^3$ عند النقطة $1/C^3=0$ وجد ان قيمـة تسـاوي 0.8v ووجد ان للكاشف سرعة استجابية عالية حيث وجد ان قيمتها اقل من 2.35ns .

Introduction

PIN photodetectors are widely used in optoelectronic circuits. In multiple applications such as high speed receivers, optical modulators, and solar energy collectors are used Yet another application of PIN photodetectors is their used in optically controlled optical gates (OCOGs) that can be utilized for ultrafast optoelectronic optical switching, time division demultiplexing, or wavelength conversion in wavelength-division-multiplexed(WDM) transmission systems.[1],[2] Often it is critical to understand the response of PIN detectors to large signal optical inputs. For example, large-optical signal response behavior is important in analog devices such as analog-to-digital converters, Photodetector large-signal response depends on how the voltage change due to photogenerated charge separation rises and relaxes. There are two primary voltage relaxation processes: a global effect, voltage decay through the external circuitry,and a local effect, voltage diffusion—also referred to as diffusive conduction. the voltage change due to the carrier separation in the top diode is represented by an identical opposite voltage change in the reverse-bias bottom diode. Both diodes have their reverse bias voltages reduced locally by equal amounts.[3][4]

The response in this type of photodetector is, by design, strongly dependent on the local voltage decay

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behavior These types of devices have a photo-absorption layer that converts input light into carriers such as electrons and holes. For an ultra wide-band response, the carrier-transit time in the photo-absorption layer should be much shorter than the required system response. The 3-dB-down electrical bandwidth limited by the carrier transit time is related to the carrier-transit distance. This structure permits the bandwidth and efficiency to be specified almost independently because the internal efficiency is determined not by the photo-absorption layer thickness, but by the photoabsorption length. Also it has the advantage to form the array structure because of its vertical arrangement compared with the difficulties rising from the horizontal structures of normal edge-illuminated devices.[4][5] .

The aim of the present work the PIN photodetector is to make evaporation technique and thermal diffusion technique , which is the simplest and low cost technique, the optoelectronic and electrical properties were investigated.

Experimental

Silicon ,cubic shape , intrinsic-type, have thickness 150μm with (111) orientation and high resistivity (1000Ω.cm) are used in this study , two faces top and down sides are polished to the mirror-like surface .

Prior to deposition of two metal Al and In up and down sides respectively , these bulks are chemically etched in dilute hydrofluoric acid to remove a native oxides.

Subsequently , after oxide removing the bulks washed with running deionized water , a high pure Al are made thin film with thickness 20nm are prepared by thermal evaporation of top side of silicon within a vacuum of the order 10^{-5} torr by balzer coating system after removed from the vacuum chamber , the silicon are doped with accepter impurities to make p-type by thermal diffusion in vacuum tube quartz at temperature 850C°at time 40min by furnace system .In same the method above n-type by In deposition with thickness 20nm in down side of siliconis made, but thermal diffusion at temperature 600ºC. Ohmic contact was made by depositing Al and In film onto p-type and n-type respectively, in same method above. Fig(1)show diagram of PIN photodetector .

The Spectral responsivity measurements of PIN detector are made using monochromatic (MODEL746) in the range 400-1100nm .I-V measurements are done under dark conditions the measurements were carried out at (300k)and Dc power supply was used to bias the detector. The illumination was achieved by He-Ne and diode(550nm) laser fixed at power 1mW.

Results and Discussion

Fig.(2) represents the spectral responivity curve of PIN photodetector biased at 0.5v the spectral response shows the effect between 500 and 1100nm , it means that visible and near infrared region of spectral .The maximum responsivity was around 900nm this result approach silicon intrinsic [11].

Fig.(3) represents the relative quantum efficiency of PIN as function of wavelength, two peak Q.E. was observed at 650 and 900nm Fig. (4)shows I-V characteristics of PIN detector the outline of the reverse bias voltage curve exhibits very small leakage current the rectification factor about 7.2 at 1v and no breakdown found at 2v ,on the other hand the forward current varies approximately exponential with apply voltage it is obey the tunneling-recombination at a high voltage bias, the ideality factor n is 3.2 calculated by the following eq. [6].

$$n = \frac{q}{KT} \cdot \frac{\partial V}{\partial \ln(I_f/I_s)} \quad ....(1)$$

Where q/KT is reciprocal of the volt equivalent of temperature ,I_f is forward current and I_s saturation current density, it is equal 10μA. To shows fig. (5) photo current response of the detector for two laser He-Ne and diode have power 1mW as a function of bias voltage the fig. shows maximum response of the laser at bias between 1 to

1.4v the photocurrent have about 800 to 1000 μA, the laser He-Ne is more responsivity than laser diode.From Fig. (6) shows change of a capacitance as a function of reverse bias . The decreasing of capacitance value with increasing reverse bias voltage was observed due to increasing depletion layer area with increasing reverse bias . [7] The cubic of a capacitance as function of reverse bias, the linearity characteristics of this plot confirms that the junction is graded type as shown in Fig.(7) , the built-in voltage was determined by extrapolation of the curve C^{-3}-V plot where C^{-3}=0 and was found about to be 0.8v.[8], it is agree with Ref.[9].

Fig. (9) shows raise time of PIN detector, the detector increases the speed response with the increase of applied reverse voltage due to the strong electrical field separation charge hole and electron [10]. We calculated the raise time from eq.[11]

$$Tr=2.2RC \quad ......(2)$$

Where R=50Ω , Tr=2.3nS

Conclusion

The obvious result and discussion , conclude that:

1- The PIN photodetector is detected in visible and near infrared region.
2- The Peak spectral responsivity is at wavelength 900nm .
3- The PIN can be used as solar cells.
4- High Q.E. at wavelength 900nm.
5- High speed sensitive to light in period at 2.35ns depends on bias voltage .

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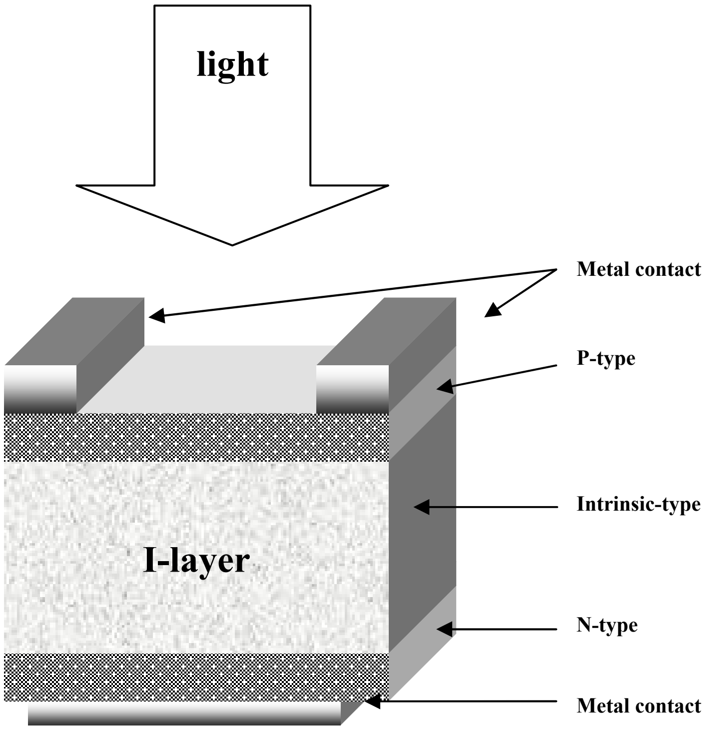

Fig. (1) show diagram of PIN photodetector

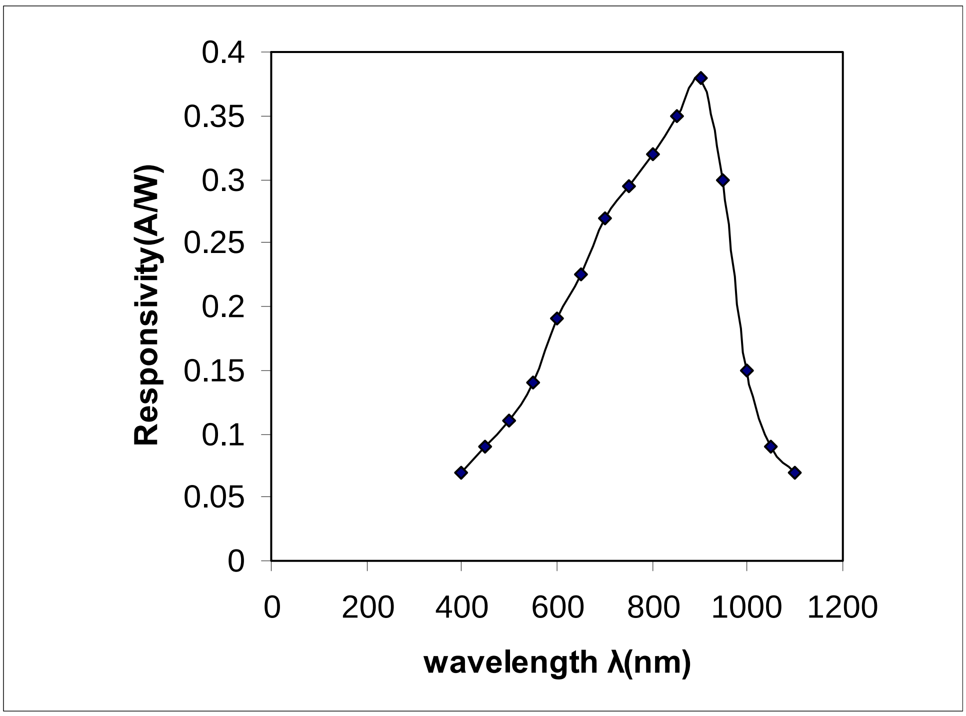

Fig.(2) Spectral Response of PIN Photodetector

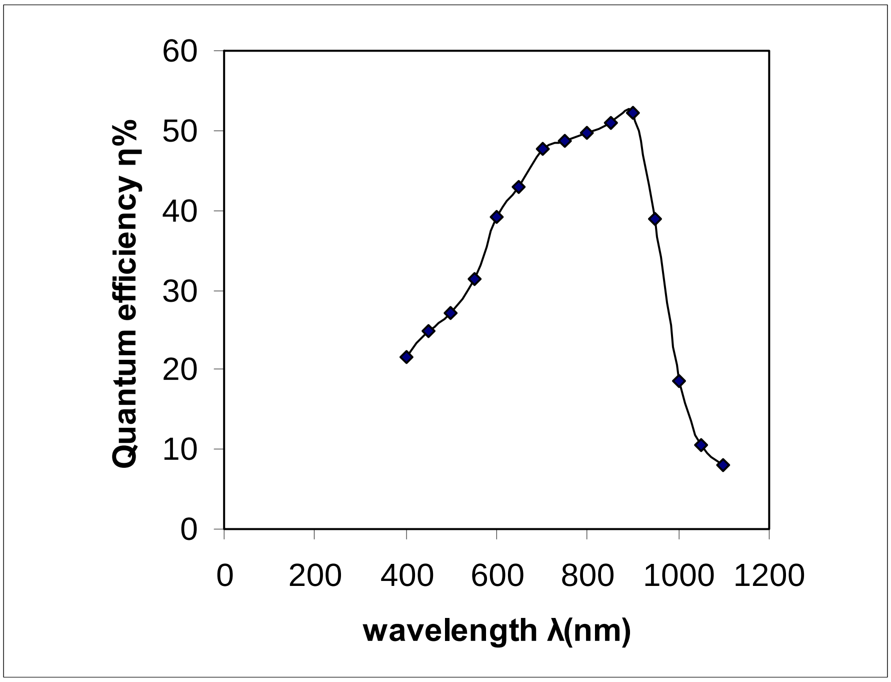

Fig.(3)Relative Quantum Efficiency of PIN as function of Wavelength

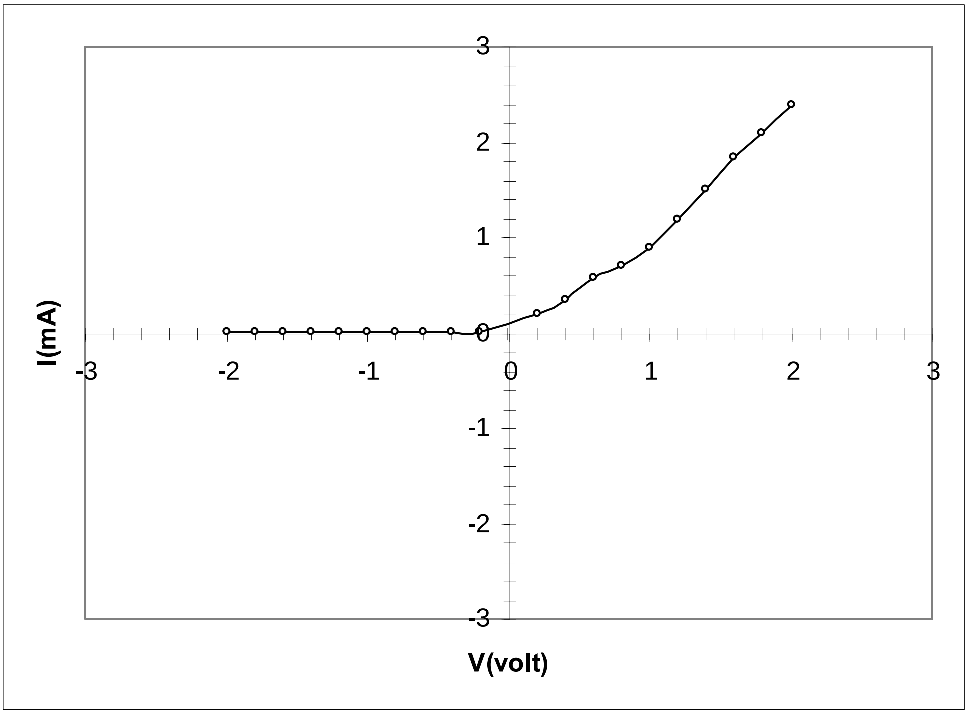

Fig.(4) I-V Characteristics of PIN Photodetecter

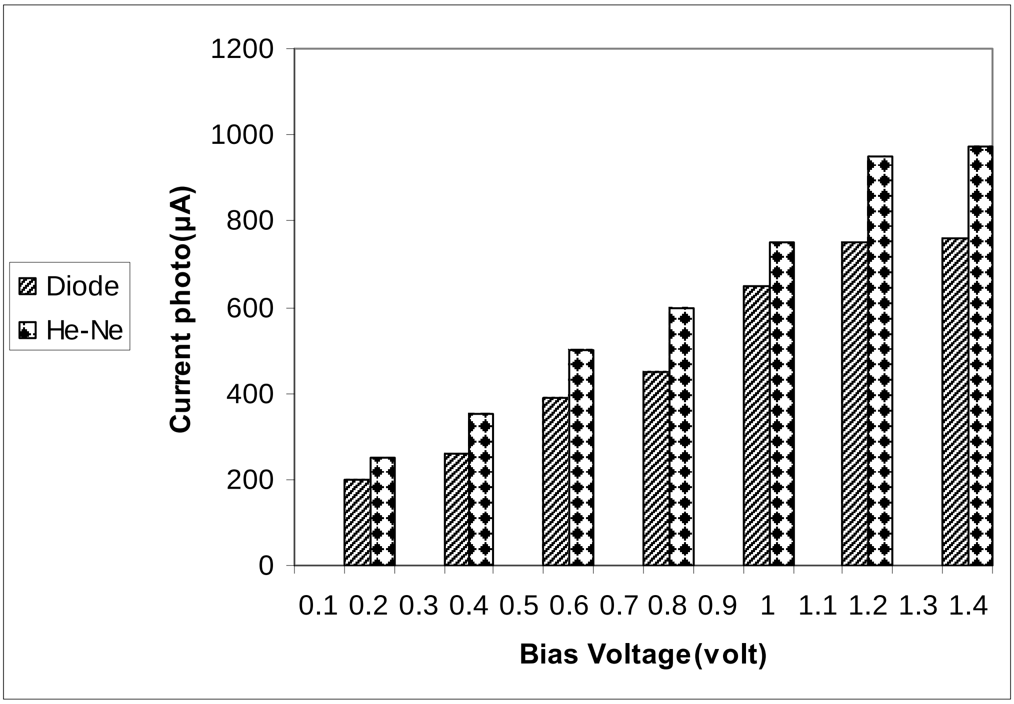

Fig. (5)Spectral Response of detector for two laser He-Ne and diode have power 1mW as function of bias voltage

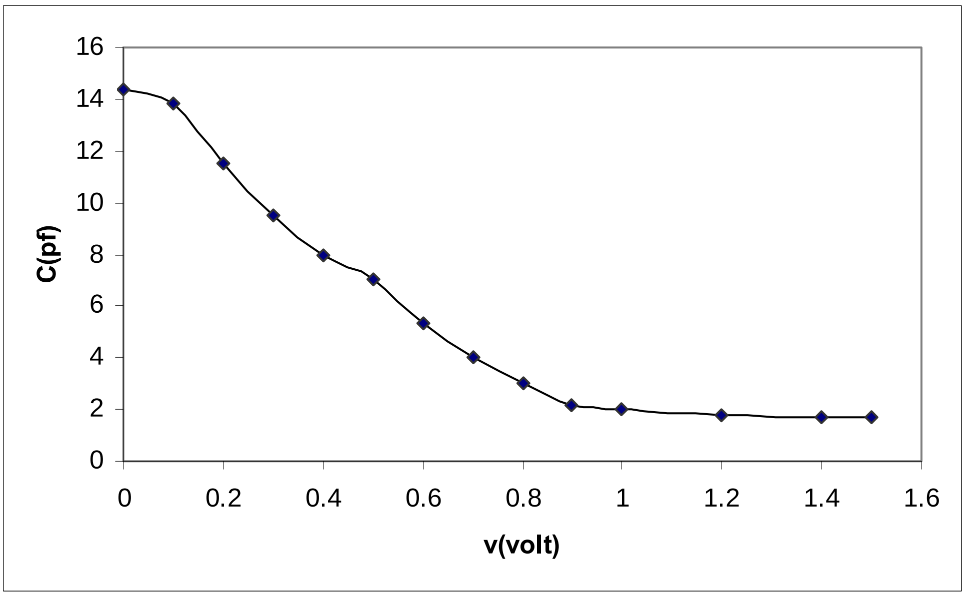

Fig. (6) C as a function of reverse bias.

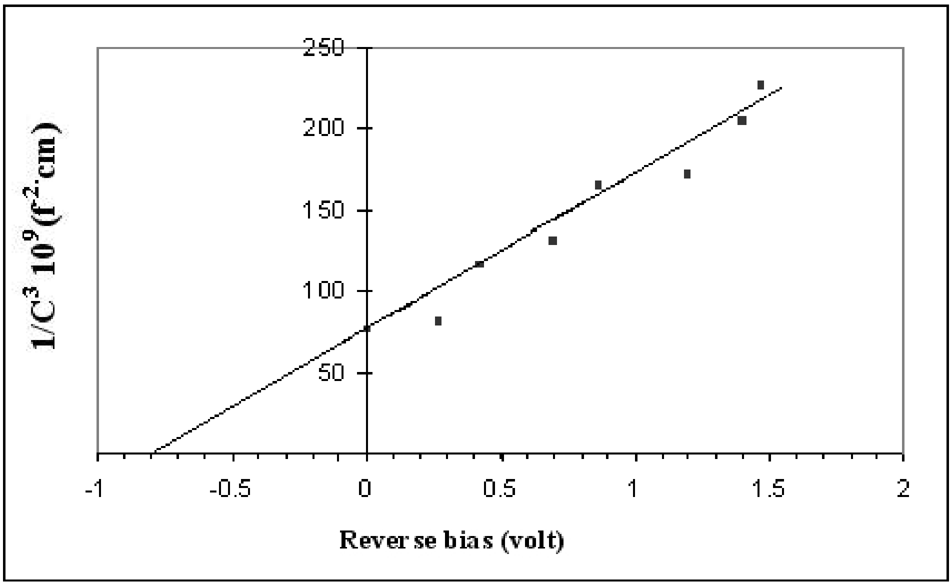

Fig.(7) C^{-3} as function a of reverse bias voltage.

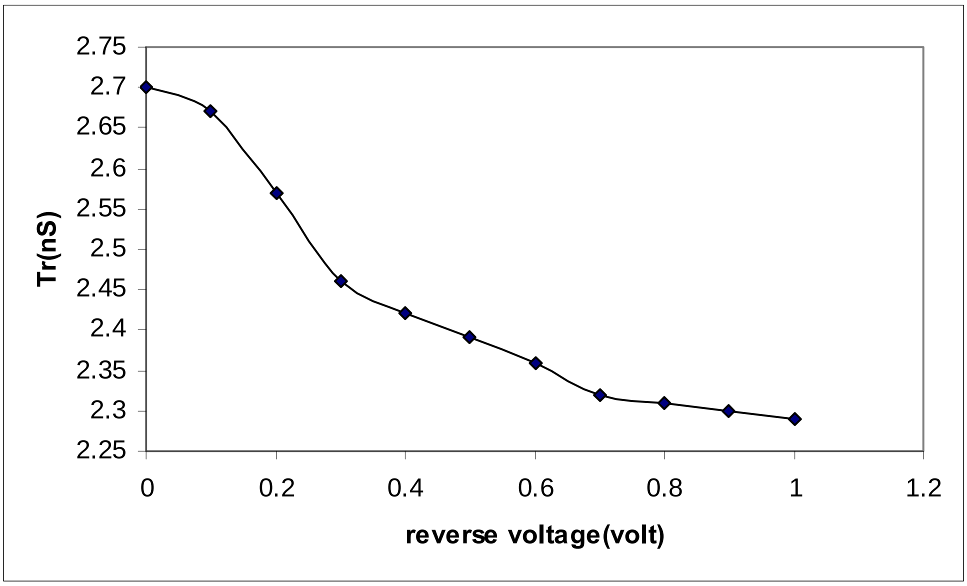

Fig.(8) Raise time detector as function of bias voltage