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Enhanced the response time of the P-N junction Photo-detector

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Abstract

In the present work, the response time of p-n junction photo-detector has been achieved by using the rapid thermal annealing (RTA) technique in which the annealing time has been ranged from (5-25) s at (773 K) the result shows a good improvement in the time constant of the detector and it has beast result at (15) s which reach to (26.81) ns for (905) nm wavelength of GaAlAs laser

الخلاصة

في هذا البحث ، تم تحسين زمن الاستجابة لكاشف ضوئي نوع (p-n) باستخدام تقنية التلـــدين الحراري السريع (RTA)، وبأزمان تتراوح من(5-25)عند درجة حرارة(773K) . ومـــن النتائج لوحظ تحسن جيد في ثابت الزمن للكاشف وكانت أفضل نتيجة عند 15s ، أذ وصل زمن الاستجابة الى 26.81ns باستخدام ليزر أشباه الموصـــلات (GaAlAa) وبطـــول مـــوجي (905nm).

Introduction

The p-n junction detector is one of the most important junction because of the wide available technique that can be used to fabricated it , beside the wide rang of radiation could be detected by using these devise [1]. It can be made easily by changed the conductivity of the surface layer of the silicon wafer by using the implementation technique, which can be achieved thermally ,by using electron gun, or ion implementation ,and other many technique [2]. The idea of it detected ability is depended on the developing of internal voltage with the depletion layer which used to separate the electron –hole pair resulting from the absorption of the light energy on the device surface [3]. This mechanism

take a specific time depended on the device characteristic and on the preparation condition, this beside ether parameters greatly affected the response time of the detector [4]. This is one of the most important parameter as it can limit the number of application that a given detector can use in. And it define as the time required for the detector voltage to increase from 10% to 90% from it final value and can be given by the following equation [5,6]

$$tr = \left[tc^2 + \left(RdC \right)^2 \right]^{1\backslash 2} \quad ..1$$

where $R_D = R_s + R_L$ **&**

$$C = C_s + C_d$$

Where t_c= charge collection time, R_c= series resistance, R_1=load resistance, C_s= capacitance result because of electrical contact.

The time constant is greatly effected by [7]:

1- Carrier diffusion time

2 – Carrier drifts time from depletion region

3-Depletion region capacitance

The response time can greatly enhanced by using some enhancement mechanism which use to reduce the defect and imperfection that inversely effected the response time of the detector also these mechanism enhanced the junction characteristic [9], one of these mechanism is called annealing which can be defined as the thermal treatment lead to eliminate the stress, vacancies, defect that present in the material their by rearranged or rediffused the imperfection the imperfection to improve the electrical activities [8 ,10,11] ,the annealing process is divided in many type one of there refer to as rapid thermal annealing in which the sample is irradiated to thermal radiation in a very short time ranged between(102-10-8)sec.

Experimental

A-Sample preparation

(5*5) mm square p-n junction sample could be obtained by using a wirecutting machine. It had bean cleaned by use alcohol with ultrasonic machine (cerry pul 125) for 15 min .The clean water has bean used with ultrasonic device to about 15 min. Ohmic contact had bean made by deposition a thin layer of (Al) and bounded to the Al wire by using silver paste.

B-measurement

1-The studying of (RTA) has bean done on the detector for optimum temperature (500^oC) and for different time (5-25) sec .The following figure (1) Shows the system use to obtain the result where a quartz tube of (2cm) diameter With one closed end had bean connected to rotary pump to achieved vacuum environment of (10^{-3}) torr, the (NiCr/NiAl) thermometer had been

use to monitoring the sample temperature**.**

Halogen lamp with (650 w) power was used to give thermal radiation with a controlled output achieved by using a variable power supply.

2-the rise time of the detector is measured by using (GaAlAs) with wavelength (905nm) and pulses duration 200-nsec and average power (1W). The output signal is achieved by using a storage scope type (8300-DCS) (programmable digital Scope) with speed (100 MHz) from (Kenwood company) the following figure (2) Shows the system.

3- The response time give by the following relation:

$$t_s = \frac{t_r}{2.2} \quad \ldots\ldots 2$$

where t_r= rise time

Result and Discussion

As we record before for this parameter a special important as it describes the specific application for a given detector the use of the (GaAlAs) is due to the suitable wavelength for this laser which lies in the peak response region of the p-n junction silicon detector. Figure (3) describe the recorded pulse from the reference sample (Standard Sample) before made any treatment and we can recognize that the rise time is (114.5) nsec which is so large that the response time is (52.04) nsec is reduce the response speed of the detector, and this belong to the imperfection and defect in the active region which work as capturing center and just a restriction prevent the carrier from arriving to the external circuit [7]. Figure (4) and (5) give a clear information about the enhancement achieved by using the (RTA) with (5), (10) sec as annealing time, we can recognize the large reduction appear with rise time which reach to (75.5) nsec and (63) nsec respectively which mean larger response speed. A further reduction can achieved with (15sec) as annealing time, where the result appear in figure (6) and this ensure the great elimination of the defect and stress with the material structure which lead to greatly effective the impurities (electrically effectivities) and as a result lead to decrease the carrier collection time and reduce the response time [5].The response time is depended on the depletion region width plus it capacitance and the external resistance and since the resistance is constant this lead to the response time dependent on the detector capacitance and the nature of the irradiation region, figure (7) give the result of annealing time of (20)sec and figure (8)of (25)sec which lead to produce an imperfection and defect which effected the carrier diffusion time out side the depletion region and on the drift time with in the depletion region [5] .

Conclusion

We could conclude that the (RTA) is an attractive method in order to greatly enhance the detector parameter especially the response time. This method required specific temperature and time. For p-n junction detector with $1.2\Omega/cm^2$ sheet resistance a 15 sec and 500^oC as annealing time and temperature give the beast result.

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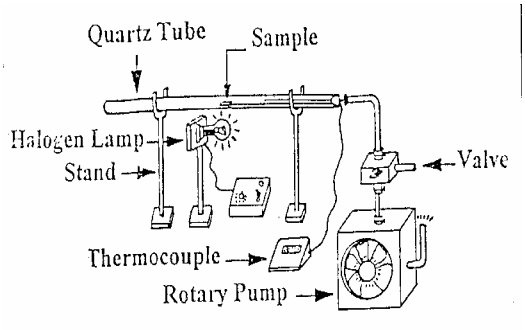


Figure (1) Schematic diagram of rapid thermal annealing

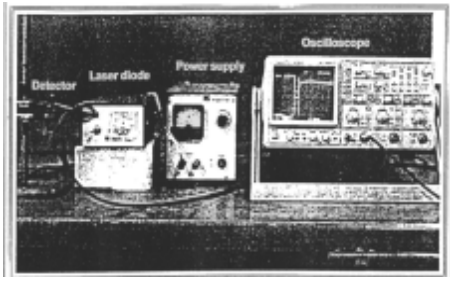


Figure (2) system used to measure rise time of detector

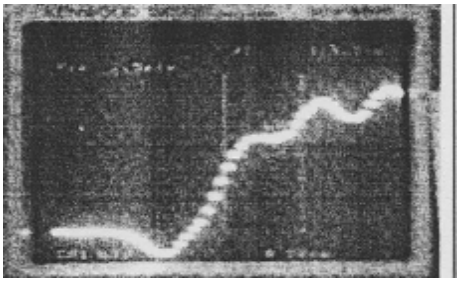


Figure (3)out put signal of standard sample

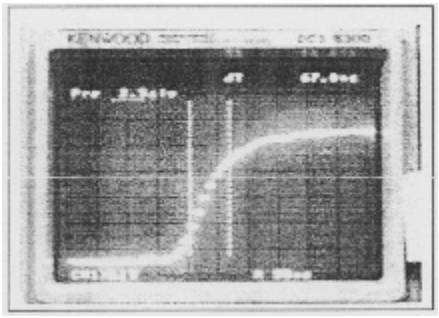


Figure (4) output signal of p-n junction silicon after RTA at 5 sec

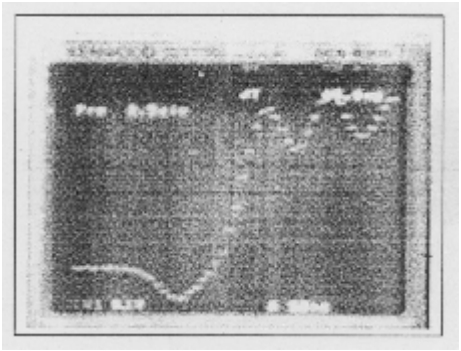


Figure (5) output signal of p-n junction silicon after RTA at 10 sec

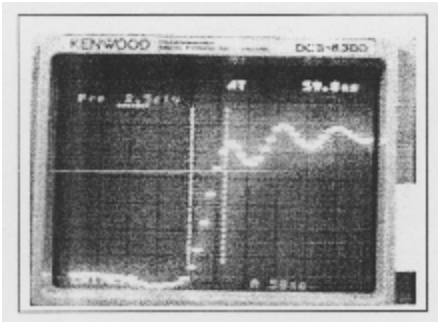
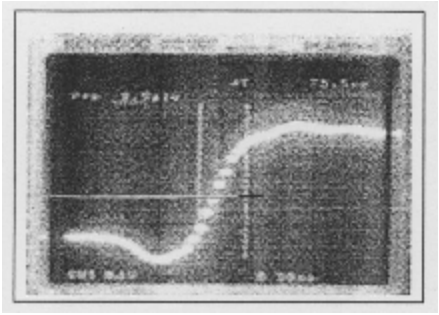


Figure (6) output signal of p-n junction silicon after RTA at 15 sec



Figure(7) output signal of p-n junction silicon after RTA at 20 sec