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Study the compatibility between four detectors manufactured on one silicon chip

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ABSTRACT

The tin oxide was deposited by using a vacuum thermal method on one silicon base to form four detectors , each of 0.25 cm^2 in size and separated by 0.15mm. Differences in the properties of manufactured optical detectors were studied in the same method, conditions, and at the same time . The results indicated that the thickness of the films (200nm, 200nm, 170nm, 180nm). And the results haven't changed much when trying to grow another membrane. The results of the electrical properties showed a convergence in the voltage barriers (0.74, 0.75, 0.76, 0.77)V for thickness (200nm, 200nm, 170nm, 180nm) respectively, but the ideal factor between a large difference in one of the detectors (5.9, 6.1, 6, 3.5). The lighting current increases with the incident of the optical power. The results showed that the rise time of the thinnest thickness reached (0.096μs), which is the fastest among the detectors. While the thickest film has off time (8.2μs), it is the fastest time for relaxation among other detectors.

1- Introduction

The tin oxide is one of the most important semiconductor materials because of the availability of salts and easy sedimentation, in addition to many other advantages [1]. SnO_2 white material it is a semiconductor of (n-type) [2], it has tetragonal crystal structure [3], the energy gap ranges between (3.5- 4) eV [4]. It is widely used in the manufacture of photovoltaic devices and solar cells [5], in gas detectors [6], and many other uses in the industry. Silicon is a widespread semiconductor where its effective energy gap is an indirect type and its value (1.1 eV), and doping with pentavalent atoms to get silicon (n-type) [7]. The aim of the study is to manufacture four SnO_2 detectors on one silicon slide and study the electrical properties of the prepared film, and Study the degree of compatibility between the four detectors.

2- Theoretical Part

(SnO_2/n-Si) detector is an isotype heterojunction, it consists of a thin layer of (SnO_2), its (n-type) semiconductor has a large energy gap and silicon (n-type) has small energy gap [1], the figure (1) shows the energy bands for each layer and for junction:

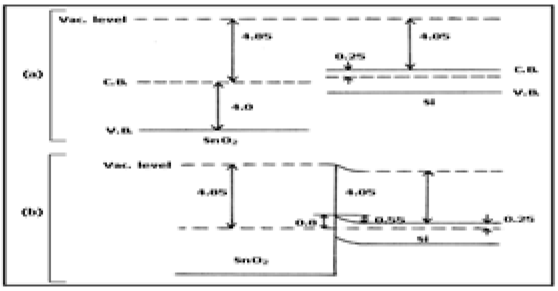

Fig. 1: a- (n-Si) and (SnO_2), b- (SnO_2/n-Si) [8].

Quadrant detector is usually used to locate a light spot or the location of a celestial body by determining the location of the spot on the quadrant detector (tracking system) [9], as in the figure (2). Quadrant detector operates in the visible light area and is used to manufacture solar trackers.

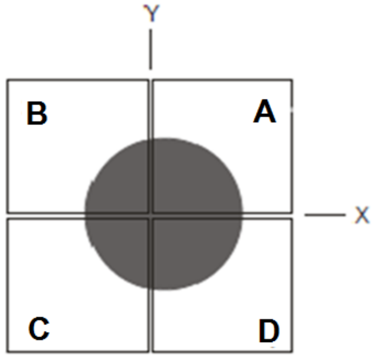

Fig. 2: The spot location on the quadrant detector.

The following equation represents the current flowing in the diode in the forward direction [10]:

$I = I_s \, e^{\frac{qV}{K_B T}}$ ... . (1)

Where I: The current passing through the diode, I_s: The saturation current of the diode, V: Applied voltage, q: Electron charge, T: Absolute temperature and k: Boltzmann's constant.

The ideal factor (n) can be calculated as in the equation [11]:

$n = \frac{q}{KT} \times \frac{v}{\ln I / I_s}$ ... . (2)

The height voltage barrier (Φ_b) for the diode is calculated from the equation [7]:

$\Phi_b = \frac{KT}{q} ln \frac{A^* T2}{Is}$ ... ... (3)

Where A*: Richardson's constant and equal ($120 A/Cm^2.K^2$) for n-Si.

3- Experimental

1- SnO_2 thin films were prepared by vacuum evaporation method by using a high vacuum system which works to empty the room in two stages, the first is mechanical and the second is diffusion, where the pressure reaches (2.2×10^{-4} mbar).

2- The pure tin was Thermal evaporation in vacuum using a boat made of tungsten, this method is one of the best methods in terms of purity and regularity. Deposited on a silicon slice (n-type) with crystal direction (111) after Cleaning. And the distance between boat and silicon slice is (15cm).

3- By placing capillary wires in the form of Cross to divide the slice into four detectors, the wire with a diameter of (0.15mm) will prevent the precipitation of tin in the area under it and make bars between the four detectors.

4- Heat treatment is carried out using an electronically controlled electric oven at ($400C^o$) for (40min.), the film turned from Sn (gray) to SnO_2 (transparent).

5- The electrodes were deposited by vacuum evaporation method, where the aluminum layer is deposited on the back of the detector (on silicon), while the four front poles were deposited after applying a mask of aluminum foil which punctured four holes, the diameter of the hole is (0.5mm), it was placed at the centers of the detectors, then the aluminum was evaporated, and the figure (3) showed a platform of quadrant detector:

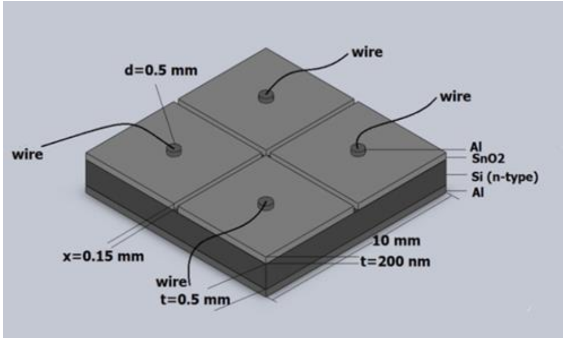

Fig. 3: Showed a platform of quadrant detector.

6- The thickness of the four Detectors was calculated by optical interferometer method used a helium neon laser with a wavelength of (632nm), and that incidents at an angle of (45^o) to the thin film after passing through a Convex lens(+100), the reflected beam falls on a screen, then the following equation was used to calculate the thickness (t) [12,13]:

$t = \frac{\Delta X}{X} \times \frac{\lambda}{2}$ ... ... (4)

where ΔX: Dark hem width, X: Luminous hem width and λ: Laser wavelength.

The thickness of SnO_2 thin films was measured as the following:

(200, 200, 170 and 180) nm for sample (A,B, C and D) respectively.

7- Study (I-V)Characteristics under dark and illumination.

8- Study the response time by Pulsed laser diode was used with a wavelength of 900 nm with wave width 2 µs with a lead 120 µs was used to find response time. The quadrant detector is connected to an external voltage of 10V across serial resistant 230 Ω ,and from them Signal received by digital oscilloscope as the figure (4).

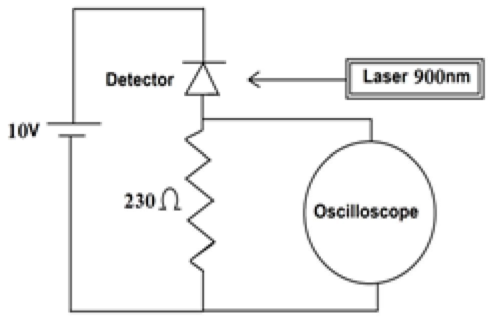

Fig. 4: Electric circuit used to study response time.

4- Results and discussion

A-(I-V) characteristics of four detectors under dark

The electrical properties of the quadrant detector were studied with 5Volt under dark. Figure (5) shows the (I-V) characteristics of quadrant detector under dark. The results showed that the detectors had properties identical to the crystalline and had equal voltage barrier (A= 0.74, B= 0.75, C= 0.76, D= 0.77)V. The results indicated a significant convergence in the value of the voltage barrier between the quadrant detector. Using the equation (4), the ideality factor (n) for the four detectors is calculated (A= 5.9, B= 6.1, C= 6, D= 3.5). The results show that sample (D) had a different value from the rest of the samples, which indicates an abundance of charge carriers[14]. Figure (6) shows the saturation current of the detectors, and figure(7) shows the slope $\left(\frac{v}{lnI/I_s}\right)$ that using in equation (2) for the detectors.

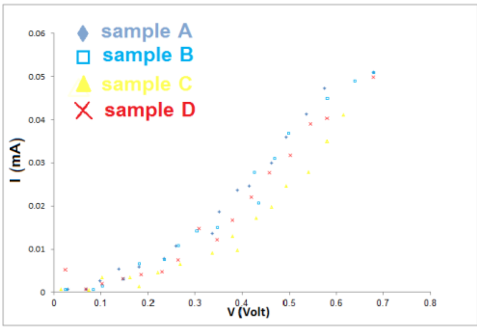

Fig. 5: shows the (I-V) characteristics of quadrant detector under dark.

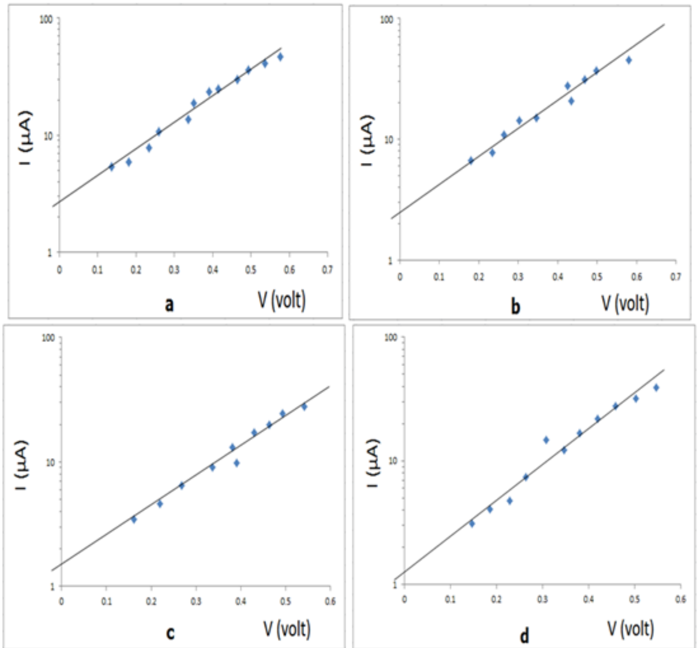

Fig. 6: shows the saturation current of the detectors: (a): sample A, (b): sample B, (c): sample C and (d): sample D.

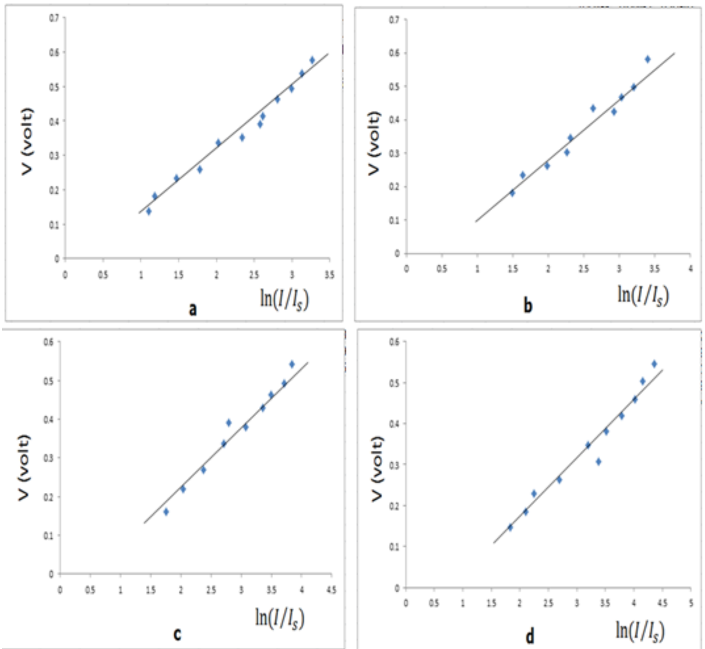

Fig. 7: Shows the relation between ln I/I$_s$ and the voltage (slope in eq. (2)): (a): sample A, (b): sample B, (c): sample C and (d): sample D.

B- (I-V)Characteristics under illumination

The effect of the incident light on the quadrant detector was studied in power (50,100,150,200,250) mW/cm^2. Figure (8) show the reverse current when illumination for the quadrant detector. The results showed that the 50 mW of the reverse current was identical and overlapping. With the increase of the incident optical power, the sample (C) had a greater current than the other samples. The reason is that the detector possesses thinner than other detectors, and therefore the photons are able to reach the depletion region [15,16].

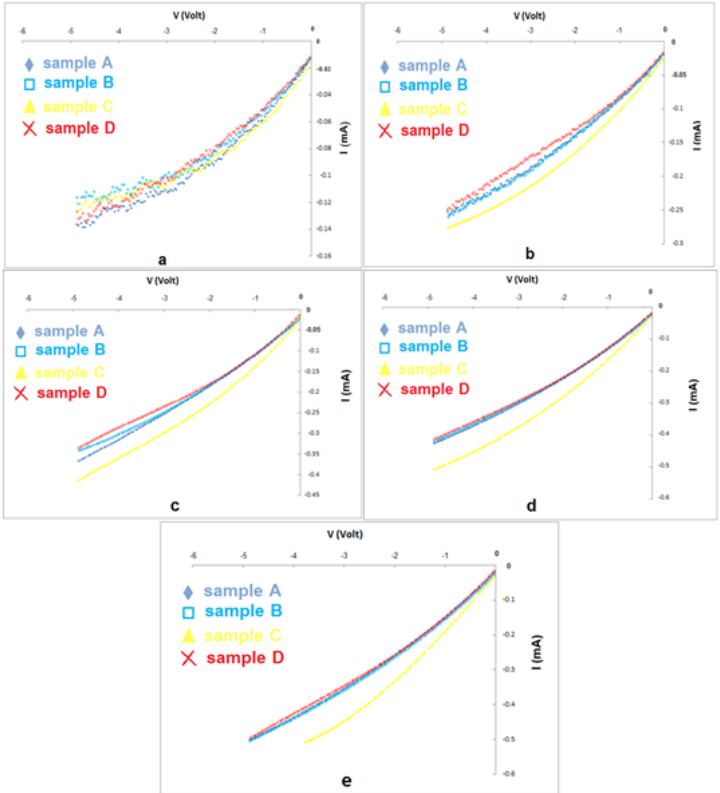

Fig. 8: (I-V)Characters under illumination: (a) 50mW/cm^2, (b) 100mW/cm^2, (c) 150mW/cm^2, (d) 200mW/cm^{2}and (e) 250mW/cm^2.

C- Response time

Figure (9) show the pulse shape received. Rise time calculates from 10% to 90% of wave rise time. time of inactivity (off time) calculates from 90% to 30% of wave relaxation time. Table (1) shows that the time of the rise and off time For the four detectors. It Indicate that the thinner detector had a higher speed than the rest of the detector and the reason is due to the ability of the (electron hole) scanned from the faster access to the valence and conduction band . As for the off time, It can be seen that the thicker membrane had a shorter dormancy time, and the reason may be that the greater the thickness of the thin film, the greater the crystal defects that work to capture (electron hole) and thus decay with less time.

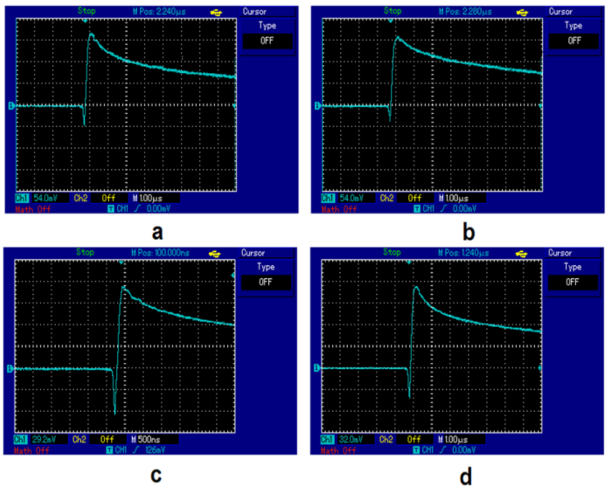

Fig. 9: show the pulse shape received.

Table 1: shows that the rise time and off For the four detectors.

Detector	Rise Time (μs)	Inactivity time (off Time) (μs)
A	0.144	8.2
B	0.160	9.4
C	0.096	9.8
D	0.140	9

Conclusion

The results showed that the deposition of a membrane of SnO_2 by The method of thermal evaporation in a vacuum on silicon (n) is not of a continuous thickness. This leads to differences in the electrical properties of factor n and the response time of the detectors . The results also showed that the difference in thickness had little effect on the barrier voltage. The electrical properties of the lights showed that the less the power of the incidence light, the smaller the differences between the detectors.

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دراسة التوافق بين أربعة كواشف منماة على شريحة سليكونية واحدة

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الملخص

تم ترسيب ثنائي أوكسيد القصدير بطريقة التبخير الحراري في الفراغ على قطعة واحدة من السليكون على شكل أربعة كواشف، مساحة كل كاشف $0.25cm^2$ مفصولة عن بعضها بمسافة 0.15mm. الاختلافات في خصائص الكواشف المصنعة درست بنفس الطريقة، الشروط، ونفس الوقت. النتائج بينت بأن سمك الأغشية (200nm, 200nm, 170nm, 180nm). ولم تتغير النتائج كثيراً عند محاولة انماء غشاء اخر وبنفس الطريقة. أظهرت نتائج الخواص الكهربائية تقارباً في حاجز الجهد V(0.74, 0.75, 0.76, 0.77) للأسماك (200mm, 200nm, 170nm, 180nm) على التوالي، لكن عامل المثالية أظهر فرق كبير في أحد الكواشف (5.9, 6.1, 6, 3.5). والتيار المقاس في الاضاءة يزداد بازدياد القدرة الضوئية الساقطة. النتائج بينت بأن زمن النهوض للكاشف الأرق سمكاً وصل الى (0.096µs)، وهو الأسرع بين الكواشف الأخرى. بينما الغشاء الأكثر سمكاً لديه زمن استرخاء (8.2µs)، وهو الأسرع بين الكواشف الاخرى.