Responsivity, Rise Time for Bi_2O_3 /Si Photo Detector

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Received on: 22/11/2012 & Accepted on: 11/6/2013

ABSTRACT

In the present work, three different active layer thicknesses of Bi_2O_3 filmswas employ for fabricated n-Bi_2O_3/p-Si heterojunction detector, using reactive pulse laser deposition technique as preparation method, detector parameter was carried out,responsivity, detectivity quantum efficiency and rise time in order to investigated the performance of the fabricated devise .

Key word: Reactive Pulse Laser Deposition, Bismuth Oxide, Heterojunction, Responsivity, Rise Time, Active Layer Thicknesses**.**

الاستجابية وزمن النهوض لكاشف ضوئي Bi_2O_3/Si

الخلاصة

في هذا البحث, تم تحضير ثلاث اغشية باسماك مختلفة من اوكسيد البزموث والتي استخدمت لاحقا في تصنيع كاشف من نوع مفرق هجين ذو تركيب n-Bi_2O_3/p-Si, باستخدام تقنية الاقتلاع بالليزر النبضي الفعالة كوسيلة ترسيب تم دراسة معلمات الكاشف كلاستجابية, الكشفية, الكفاءة الكمية وزمن الاستجابة لكي يتم التحقق من اداء الكاشف المصنع.

INTRODUCTION

Bismuth oxide is material known with its wide band gap ranging between (1.73-3.98eV) [1, 2] remarkable photoconductivity and photoluminesces [3, 4], these characteristic made this material good candied for devise dependent on light detection. Several workers used Bi_2O_3 in heterojunction devise using different preparation method such as sputtering, rapid thermal oxidation [5, 6]. Up to our knowledge there are few workers fabricated Bi_2O_3/Si as detector one of them isRaid A. Ismail [6] using rapid thermal oxidation where dark and illuminated I-V, CV, and spectral responsivity of Bi_2O_3/Si heterojunction were investigated and discussed. In the present work we used reactive pulse laser depositions as preparation method for fabricating our device.

Theoretical part

Responsivity is an important factor that one could determine from it the spectral range of the detector works through, it was calculated from the following equation.

$$R_l = \frac{I_{ph}}{P_i} \quad \text{A/W} \qquad \dots (1)$$

Where I_{ph} is the measured photocurrent and P_i is the incident optical power, while the specific detectivity considers one of the most important parameter .The detectivity is calculated from the following equation [7]:

$$D_l^* = \frac{R_l}{I_n}\sqrt{A\Delta f} \ \text{cm. Hz}^{1/2}.\ \text{W}^{-1} \qquad \dots (2)$$

The idea of the rise time depending on the developing of internal voltage with the depletion region which is used to separate the electron-hole pairs resulting from the absorption of the light energy (led with wavelength of about (810nm) and pulse duration of about 0.1 msec) on the device surface. This mechanism takes a specific time depended on the device characteristic while the response time could be found from the following equation [8].

$$t_r = \frac{t_{ris}}{2.2} \qquad ...(3)$$

Thus rise time (t_{ris}) and response time (t_r) consider one of the most important parameters in determining the efficiency of the detector.

EXPERIMENTAL WORK

An isotype hetero junction of n-Bi_2O_3/p-Si structure was fabricated; whereBi_2O_3 layer with high purity of 99.999% was deposited on (1×1 cm^2) square-shape p type silicon samples, of (1.5-4Ω) .cm resistivity. Wafer were etched with cleaning solution consisting of (HNO_3, CH $_3$COOH, HF) of ratios (2:1:1:10) [9], to remove oxides by placing wafers in the ultrasonic machine (Cerry PUL 125 device) for 15 minutes, then cleaned by ethanol and ultrasonic machine for 15 minutes, and cleaned by water and ultrasonic waves for 15 minutes also. Ohmic contacts were fabricated on the cleaned silicon wafers using a mask to specify the contact area of the front and back surfaces on the Si wafer. Reactive pulse laser deposition was used to deposited bismuth oxide layer at 7.8J/cm^2 laser fluence , 200 mbar and 250K,devise was fabricated at threeactive layer thicknesses of about (180, 210 and 240) nm. Thicknesses measured using Fizeauinterferometric method,then characterization for detector parameter was carry out for the three fabricated detector.

RESULTS AND DISCUSSION

Figure (1) shows the spectral responsivity for devices fabricated at different active layers thickness as a function of spectral wavelength.

Relative spectral response of the fabricated devices at different thickness, performed in the spectral range (200-1280) nm. it is noted that the responsivity curve shows good band-pass behavior (window effect), and it is comprised of four distinct regions, the first region (corresponding UV region in range of 160 - 280) nm shows an increase in responsivity with wavelength, attains the maximum value at wavelength of 200 nm (the absorption of the Bi_2O_3 frontal layer). The lower responsivity at the shorter wavelength region may be due to the absorption of the light near the surface (shallow absorption depth), which has large amount of surface recombination of the photo generated carriers, the second region of the plot shows a decrease in responsivity with a minimum value at wavelength of 440 nm, this could be attributed to a high degree of carrier recombination at the interface, the third region shows an increase in the responsivity passing through the maximum value at wavelength of 880 nm corresponding to light absorption at transition region on silicon side.The fourth region shows that responsivity decreases reaching the absorption edge of the silicon1.1eV. The smaller responsivity at longer wavelength is attributed to the carriers generated deep in the bulk of the silicon. At different thickness of the active layer thickness from (180–210) nm the spectral responsivity shows an increased in responsivity with increased thickness which may be attributed to the reduction of the resistance in series with increasing the thickness in addition to the location of the depletion region far from the surface, which in turns reduces the surface recombination, further increased in active layer thickness resulted in decreased in responsivity of the device fabricated at 240 nm active layer thickness.

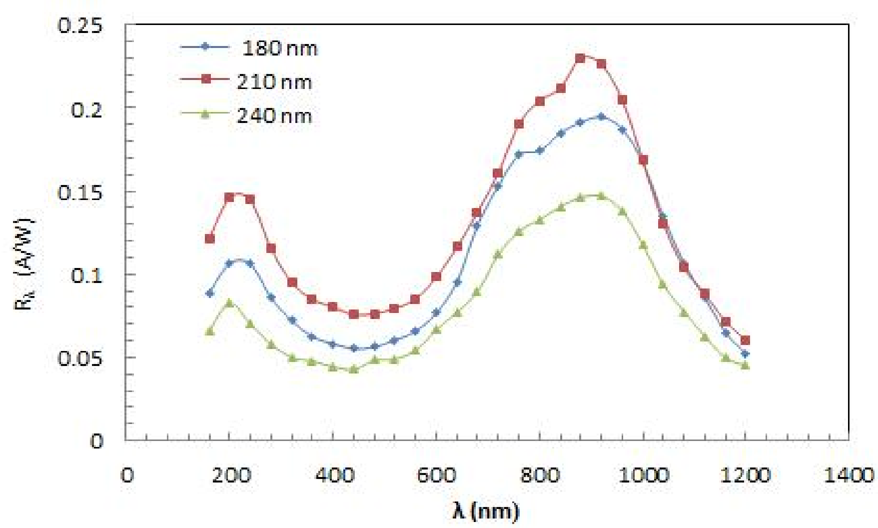


Figure (1) Responsively for n-Bi_2O_3/p-Si device fabricated at different active layers thickness.

Detectivity for device fabricated at different active layers thickness shown in Figure (2).It shows the variation in specific detectivity with increase of active layer thickness and it’s related to the responsivity value.

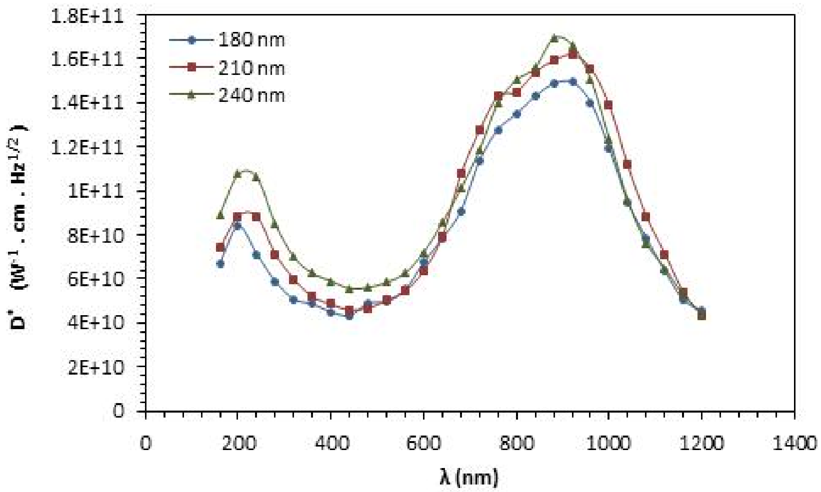


Figure (2) Detectivity for n-Bi_2O_3/p-Si devices fabricated at different active layers thickness.

Figure (3) represents the relationship between the wavelength of the incident light and the quantum efficiency (Q.E) of the device, and because the quantum efficiency (Q.E) is function of the responsivity. Therefore the result is related to the spectral responsivity because its directly proportional to it.

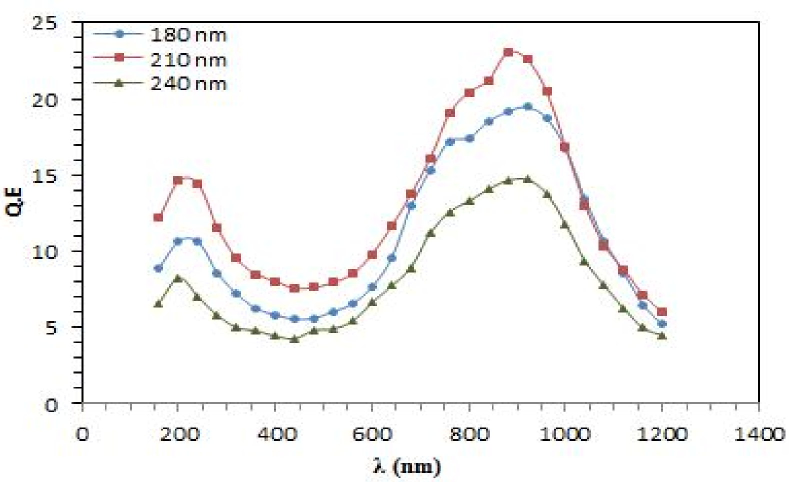
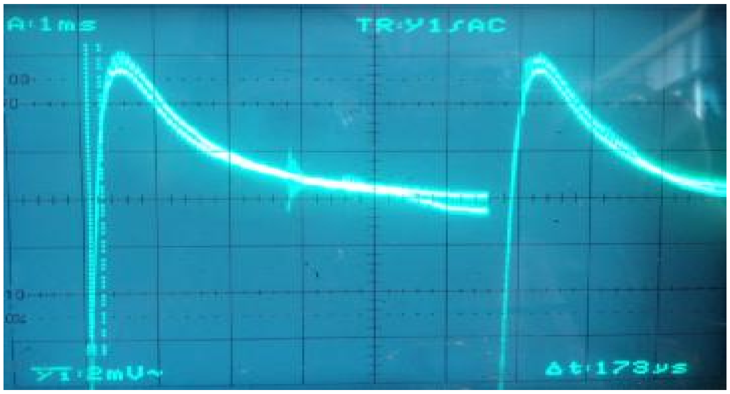


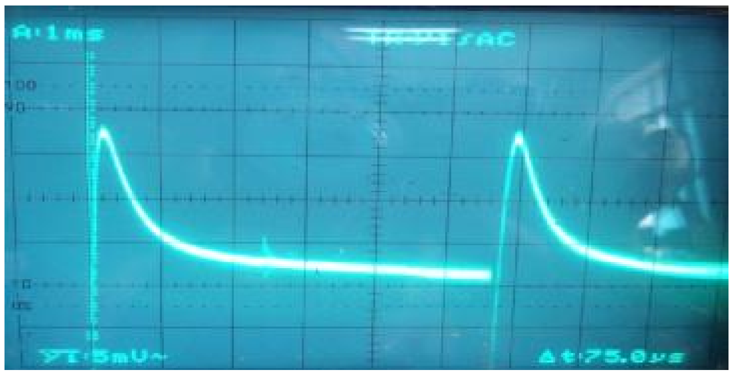
Figure (3) Quantum efficiency for n-Bi_2O_3/p-Si devices Fabricated at different active layers thickness.

Figure (4) shows the rise time pulses for the three devices Table (1) shows the found and calculated values for rise and response time for devices prepared at different number of pulses.

a)



b)



c)

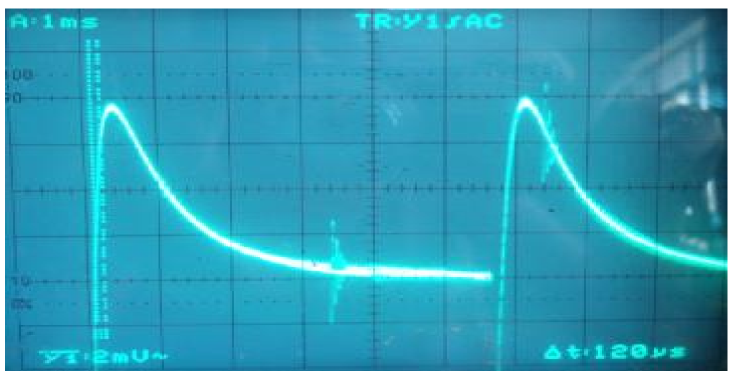


Figure (4) Rise time pulses for devices fabricated at different active layer thickness(a) 180 nm, (b) 210 nm, (c) 240 nm

Table (1) Rise and responsivity time for n-Bi_2O_3/p-Si devices.

Devices active layer thickness	Rise time (μsec)	Responsivity time (μsec)
180 nm	173	78.6
210 nm	75	34
240 nm	120	54.5

Rise and time responsivity are results tabulated in Table (1), results show decreasing in rise time with increasing active layer thickness from(180 – 210) nm then increasing again at 240 nm, lowest rise time achieve at 210 nm (i.e., the faster detector) may attributed to low lattice mismatch at this thickness, while devise fabricated at 240 nm active layer thickness shows increasing in response time this may due to negative effect for the formation of a considerably thick SiO layer an oscillatory rise and response time result achieve elsewhere [10, 11].

CONCLUSIONS

An isotype hetero junction detector of Bi_2O_3/S structure was fabricated and it's characterization was made. Device fabricated with active layer thickness of 210 nm is found to be the best thickness among the three devices, with spectral responsivity, detectivity and rise time of about 0.23A/W, 1.6×10^{11} W^{-1}. cm. $Hz^{1/2}$ and 75µsec respectively.

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