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Improvement the efficiency of SnO_2/n-Si detector by engraving method using a CNC machine

Wlla M. Mohammed

Physics Department, College of Education for Pure Science, Tikrit University, Tikrit, Iraq

E-mail: rahafwlla@gmail.com

Abstract

Tin oxide was deposited by using vacuum thermal method on silicon wafer engraved by Computer Numerical Controlled (CNC) Machine. The inscription was engraved by diamond-made brine. Deep 0.05 mm in the form of concentric squares. Electrical results in the dark were shown high value of forward current and the high value of the detection factor from 6.42 before engraving to 10.41 after engraving. (I-V) characters in illumination with powers (50, 100, 150, 200, 250) mW/cm^2 show Improved properties of the detector, Especially at power (150, 200, 250) mW/cm^2. Response improved in rise time from 2.4 µs to 0.72 µs and time of inactivity improved 515.2 µs to 44.2 µs. Sensitivity angle increased at zone from 40^o to 65^o.

Key words
Tin oxide, CNC machine, diamond-made brine.

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تحسين كفاءة كاشف SnO_2/n-Si بأسلوب الحفر باستعمال ماكينة CNC

ولاء محفوظ محمد

قسم الفيزياء، كلية التربية للعلوم الصرفة، جامعة تكريت، تكريت، العراق

الخلاصة

تم في هذا البحث ترسيب أوكسيد القصدير على قواعد من السليكون المحفور بواسطة ماكينة مسيطر عليها رقمياً بالحاسبة الالكترونية CNC. تمت عملية الحفر بعمق 0.05 mm على شكل مربعات بواسطة برينة من الألماس. الخواص الكهربائية في الظلام بينت زيادة في قيمة التيار الامامي بالنسبة للتيار العكسي مع ارتفاع في قيمة عامل الكشفية من 6.42 قبل الحفر الى 4.10. اما الخواص الكهربائية عند الاضائة بقدرات (50, 100, 150, 200, 250) mW/cm^2 فبينت زيادة في قيمة الكشفية وخصوصاً عند القدرات (150, 200, 250) mW/cm^2. زمن الاستجابة لنهوض الإشارة تحسن من 2.4 µs الى 0.72 µs وتحسن زمن الخمود من 515.2 µs الى 44.2 µs. اما بالنسبة الى زاوية التحسس للكاشف فبينت النتائج الى زيادة ملحوظة في المنطقة المحصورة بين 40^o الى 65^o.

Introduction

Tin oxide, in its volumetric state, is one of the insulators, but it turns into a semiconductor if it is deposited form thin film [1]. The transition from the insulator to the semiconductor occurs due to deviation at valence in oxidation preparation [2]. SnO_2 thin film can be prepared in a variety of ways physical and chemical. The interest in heterostructures with silicon as one of the components is due to the practical significance of multilayered structures of materials in modern electronic engineering. Along with semiconductor heterostructures, it is also interesting to investigate liquid crystal (LC)–semiconductor interfaces [3]. Properties of SnO_2/n-Si heterojunctions of the symmetric type, it acts as a solar cell or detector [4]. Thin films of SnO_2 which are growing on silicon surfaces have possess certain characteristics which make them interesting for photovoltaic applications [5]. The efficiency of the detector depends on the surface area exposed to radiation [6] . The area can be increased by chemical etching using hydrofluoric acid to obtain nano structure in the silicon surface [7], or by developing nanoparticles of tin oxide on flat surfaces of silicon [8]. The research aims is making engraving in a silicon chip in a mechanical manner using CNC and coating the tin oxide to manufacture a detector.

Experimental

1- CNC machine

Computer Numerical Control (CNC) a machine that can be controlled by computer. It is an innovative addition to cutting and drilling operations, especially for operations that need high accuracy [9]. The CNC machine used in the research of the type used for drilling circuit boards and working on three axes this machine is works by program written in high level language known G-cod. In this research a program was written to make concentric squares and a depth of 0.05mm as follows:

```
G00   F3000 X-0.5 Y-0.5
G00   F155 Z0
G01   F60  Z-0.05
G01   F300 X0.5
G01  Y0.5
G01  X-0.5
G01  Y-0.5
G00 F3000 Z1
```

The program was repeated four times, and the length was reduced to x-axis and y-axis by 1mm at every time. In the engraving process a diamond-made brine was used. The machine is set to rotate the cutter speed up to 4200 rpm, and quickly engraving up to 1 cm per minute.

2-Silicon wafer

In this research's n-type Silicon wafer was used with (111) direction. Silicon was cleaning by washing using distilled water Then wash with methanol for 10 minutes because it is a strong solvent and then wash with water then wash with ethanol for 10 minutes and then with distilled water [10]. The silicon was cut into 1.5 cm^2 pieces. Then put it in CNC machine to be engraving in four concentric squares. Some samples were left without engraving to use them as reference.

3- Thin film of SnO_2

Tin oxide thin films were prepared by using vacuum thermal method. A quantity of pure tin powder 99.9% was put in boat of tungsten, at height of 10 cm from silicon pieces. The pressure inside the chamber was reduced to 1.4×10^{-4} mbar, then tin was evaporated tin to growing on silicon wafer. It was then put into a 650-degree oven for 1 hour, the tin then oxidizes and becomes tin film produces our SnO_2/ n-Si device. Fig.1 shows the x-ray analysis of SnO_2 films deposited on the glass and oxidate in the same way, confirming the tin oxide to the tin oxide. Fig.2 shows the image of the detector used in this research.

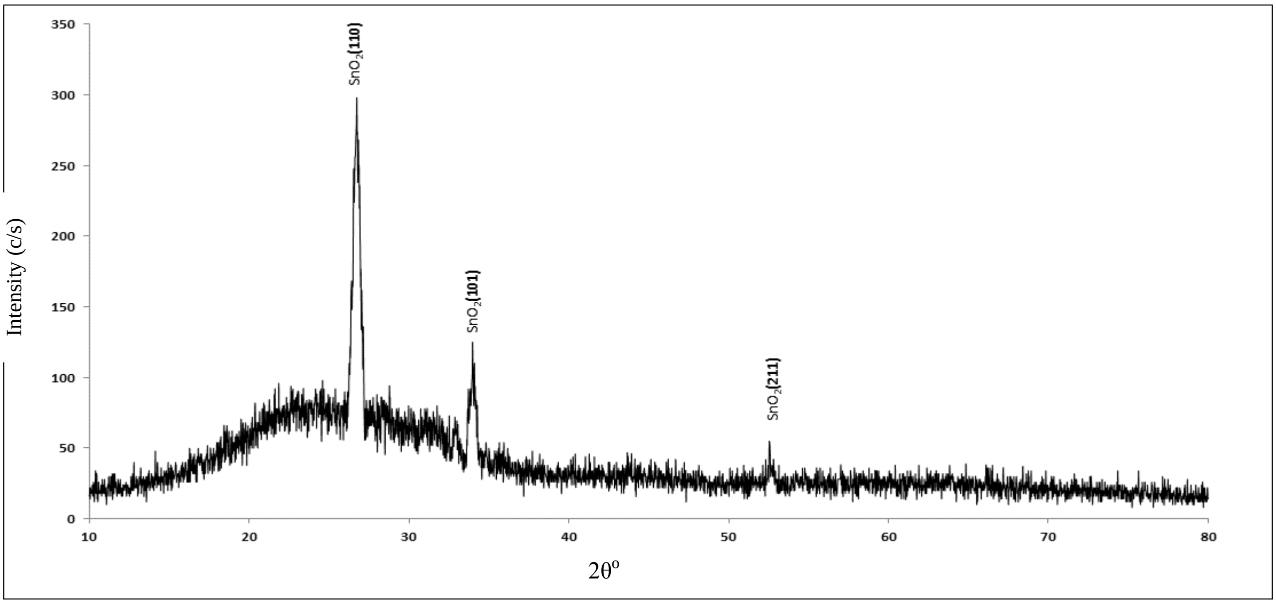


Fig.1: X-ray analysis of a SnO_2 films.

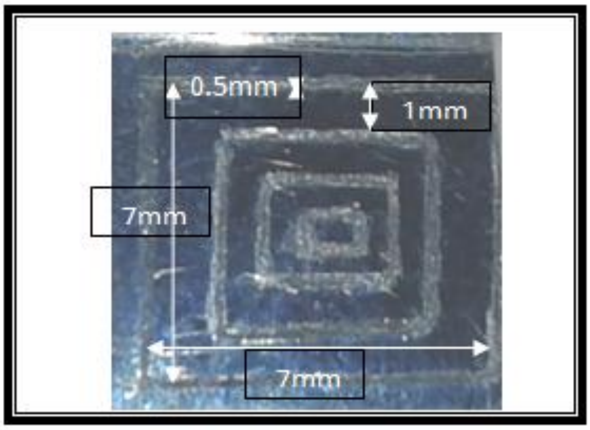


Fig.2: Detector SnO_2/ n-Si with engraving.

To calculate thickness, the weighted method represented by Eq. (1) [11].

$$t = \frac{m_2 - m_1}{A.\rho_{SnO_2}} \quad (1)$$

when t: thickness, m_2-m_1: difference weight between m_2 and m_1, ρ: density of material, A: The area is added to the increase due to engraving.

Results and discussion

1- (I-V) Characterization in dark

Fig.3 show the (I-V) characters of SnO_2/n-Si in the dark using (digital multimeter (Victor VC97). The forward current shows an increase in the current value of the detector, and this increase is due to the increase of the detector area. The value of the voltage barrier V_b has not changed significantly. In reverse, the reverse current of the detector is also increased in engraving detector especially when increasing the voltages. Rectification factor is equal to the ratio between the forward current to the reverse current at a same voltage [12], reaches to 6.42 for smooth and equal to 10.41 for engraved detector by an increase of 61.18%.

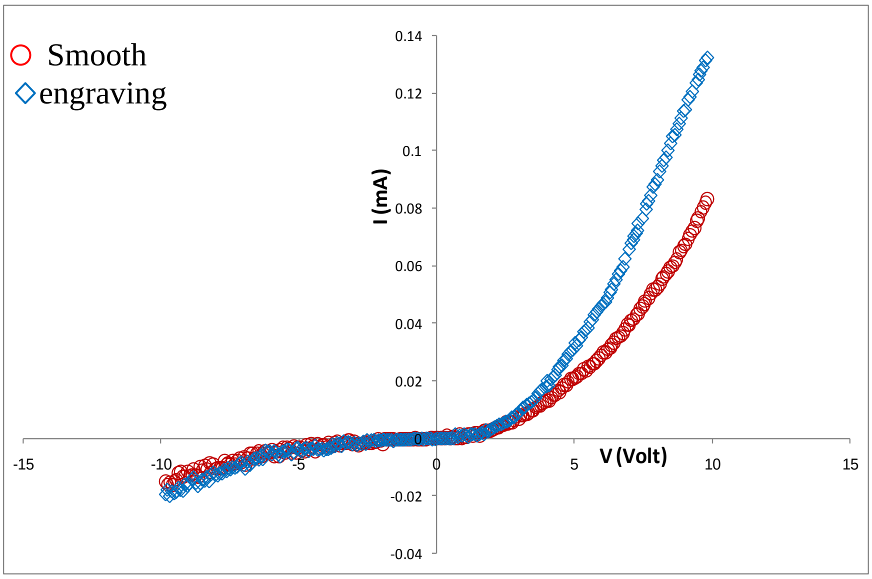


Fig.3: (I-V) characters of SnO_2/n-Si detector in the dark.

2- (I-V) Characterization in illumination

The effect of the incident light on the detector was studied in power (50, 100, 150, 200, 250) mW/cm^2. Fig.4(a, b, c, d, e) shows the increase reverse current when illumination for the engraving detector compared with smooth detector, and came higher than the results of the researcher (a) [12]. The Fig.4(f) shows the variation of photo current and power intensity with constant bias at 9 volt, smooth detector reached to Saturation current after 150mW while engraving detector continue to rise. The increase in the area of the detector led to an increase in the photo current, in addition to the fact that the engraving has caused a rough surface reduced the value of the reflection. The results of the engraving detector in general were inferior to the detector deposited by the SnO_2 thin film of the nanoparticle [13] or the SnO_2 thin film deposited on the porous silicon [14]. The reason for the engraving detector being that the increase in the area of linear areas either in the porous detectors or nanoparticles, the increase in areas for all detectors.

3- Response time

Pulsed laser 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 detector is connected to an external voltage of 9V across serial resistant 1 KΩ, and from them signal received by digital oscilloscope. Fig.5 shows the pulse shape received. Rise time calculates from 10% to 90% of wave rise time. Time of inactivity calculates from 90% to 10 % of wave relaxation time. The results showed that the time of the rise of the smooth detector in 900 nm was 2.4 µs while the detector was faster than times 0.72 µs. Time of inactivity of the smooth detector was 515.2 µs while the detector was also faster than times 44.2 µs. The response speed in the engraving detector was slightly higher than the detector deposited by the SnO_2 tin film of the nanoparticle [13] or the SnO_2 tin film deposited on the porous silicon [14]. The results indicate crystal defects works to minimize the mobility of carriers. This means that the engraving process has caused crystalline defects due to heat generation during drilling [12].

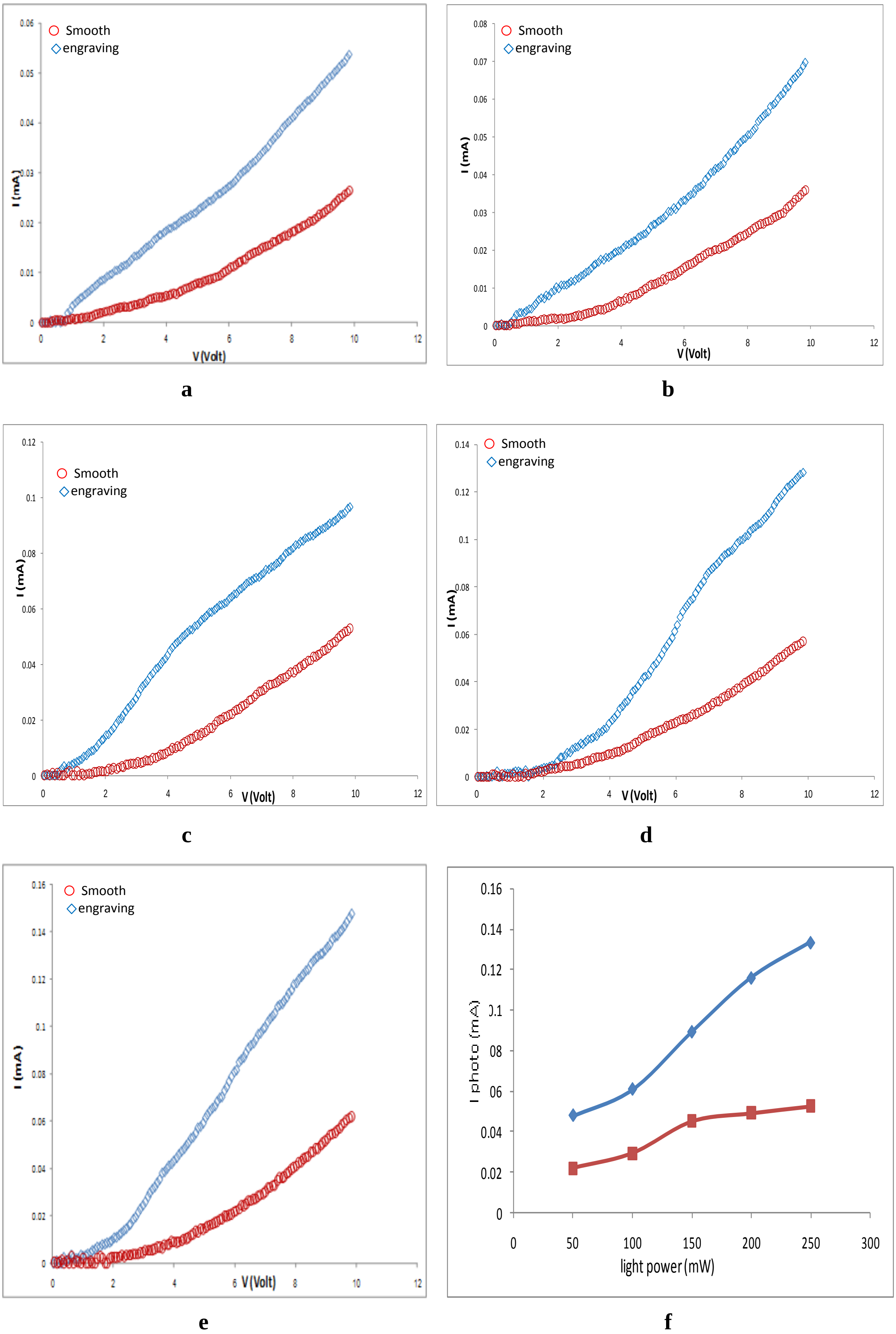
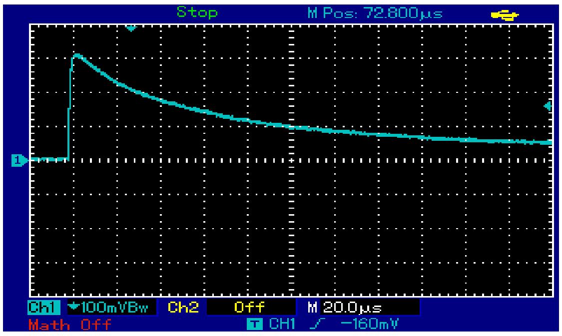
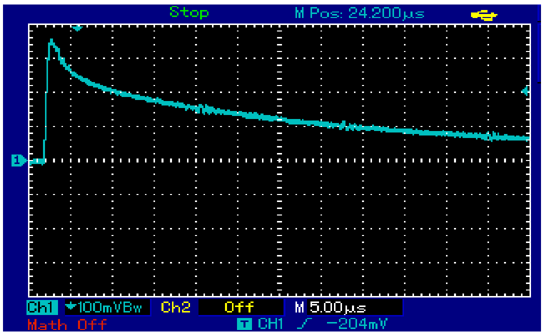


Fig.4: The (I-V) of the detector to light. a-50 mW. b-100 mW. c-150 mW. d-200 mW. e-250 mW. f-The relationship between photo current and intensity of light.



a



b

Fig.5: Received pulse .a-Smooth detector. b-engraving detector.

4- Sensitivity angle

Fig.6 show the relationship between the angle of incident light and the photo current. Helium Neon Laser was used at wavelength 633 nm / 1mW. The angle was changed from 5 degree to 95 degree. The results indicate high of photo current value from 5^o to 30^o For both detectors and the detector with engraving showed an increase in current value at the angle 40^o to 65^o The maximum angle which promise is in 55^o due to the vertical of the light incident on the edges of the engraving [12]. This increase did not occur in nanotubes or porous detectors [13, 14] because their surfaces did not contain deep reductions.

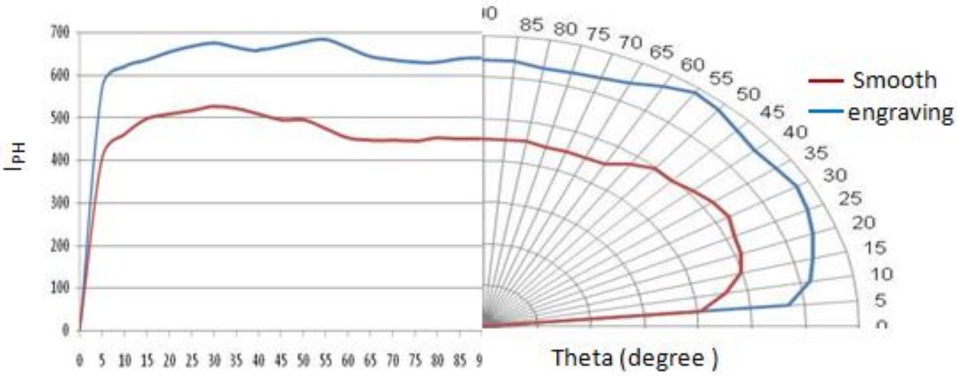


Fig.6: Photo current as a fundamental of incident light angle.

Conclusions

Silicon wafer can be engraving from CNC machine by diamond-made brine, then deposition thin films on them to fabicate a detector. The engraving detector has high sensitivity to incidence light. It has high response time compared to another detector of the same type. The detector response was able to increase with increasing the sensitivity angle. Therefore, the detector prepared in this way done quickly and have a specifications that can be exploited for industrial production. This method is characterized by non-use chemical solutions that are deactivate when used, In addition to being a safety.

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