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Synthesis and Study of Modified Nanostructure Porous Silicon Layers for Chemical Gas Sensing

Abstract- *In this work, We prepared a modified nanostructure porous silicon (PS) layers for effective chemical gas sensing. Nanopore covered microporous silicon gas sensor has been fabricated using electrochemical etching in an HF acid and ethanol solution. A porous silicon (PS) surface has been modified using selective depositions formed from metal to enhance the response to Sensing of CO_2. (PS) has been interest for gas sensing because of the exceptional* gathering *of importent* features. *By setting the process parameters,the porosity, pore size, and the morphology can be modifid and practically controlled. The modified porous silicon layers were characterized using different techniques such as scanning electron microscopy(SEM)and a series of electrical characterizations to study the structures in the contact of the carbon dioxide was achieved.*

Keywords*- Electrochemical synthesis, Porous silicon, Gas sensors*

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1.Introduction

Porous silicon(PS)is a nano structured material, which offer abundant advantages to first rate the produce nano structure size material area As the name suggests PS is similar to a quantum sponge ,including a net like construction consisting of nano crystallites and pores[1]. Not only Porous Silicon but Si has an important and valuable material. Any device contains silicon is bound to be a doing well device as silicon is common offered, not expensivev and without difficulty attuned with the recent IC manufacturing. There are some exclusive characteristics of silicon which are clear when its structure decrease to nano- size. These modify in properties are the result of Quantum Confinement Effect. Therefore PS demonstrate better surface to volume ratio, high surface reactivity and luminescent properties at RT due to its flexible character, Porous Silicon has a large number of applications in sensing, optoelectronics, micromachining, biotechnology, wafer technology etc .[2][3]. Porous silicon get significant interest for sensor applications, Its luminescence properties, large surface area and compatibility with silicon based technologies have been driving force for this technology development [4]. Moreover ,porous silicon gas sensor exhibit important proprties for broad purpose they could be run over abroad range of environmental temperature, pressure and humidity fluctuation as it is possible to eliminate response variations due to such environmental factor by operating in gas pulsing mode[5]. The important characteristic of sensing for the responsive detection of biological or chemical is the surface features of the substance itself such as huge porosity, topography, surface area, morphology and surface textures which effect on the detection capability of detection template and its interface with the adsorb media . One of the detection requirements must be chemically attaché the bio-active sample on the Porous silicon surface. chemical modification on porous surface is very impotent For achieving good selectivity [6]. That control of the high surface area within a small volume of the pore sizes given an increase in sensor characteristics.

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The ability to modulate dielectric constant as a function filling molecules makes of the PS a suitable dielectric material for the gas detection process [7]. All these features lead to consider the PS as one of the most valuable materials in the field of gas sensor technology. The PS sensor is simple and cheap method as compared to other gas detectors [8]. On the other hand, PS sensitivity is dependent also on the chemical adsorption and the physical adsorption of the gasses [9].

2 Experimental

I.porous silicon fabrication

Electrochemical etching (ECE) method is One of the familiar, easy and capable techniques for production of Porous Silicon. In the etching method must be pre-cleaning of silicon wafer by sonication method for remove any unnecessary particles on the Si wafer. This cleaned silicon applied in a electrochemical galvanostatic etching method which uses of an Teflon cell by place platinum grid as cathode in an electrolyte solution and a silicon as anode with a regular current source [10]. PS layers were performed on p-type, (100)-oriented Si wafers (thickness: 500 µm) of 15 Ω cm resistivity. The porous silicon samples were prepared by using electrochemical etching (ECE). It has been the solution of HF: Ethanol by rate (1:1) in the etching process of the silicon. The metal touch with silicon sample placed as the anode between the upper and the lower part of Teflon cell (container cavity). The Platinum used as cathode mish and dipped in Hydrofluoric acid electrolyte solution. The cathode inserted through the Teflon cell and textured by O-ring Plastic. by anodic etching with a current density of 10mA/cm^{2}at different etching times of (5,10 ,15and 20 min) were used as shown in figure (1).

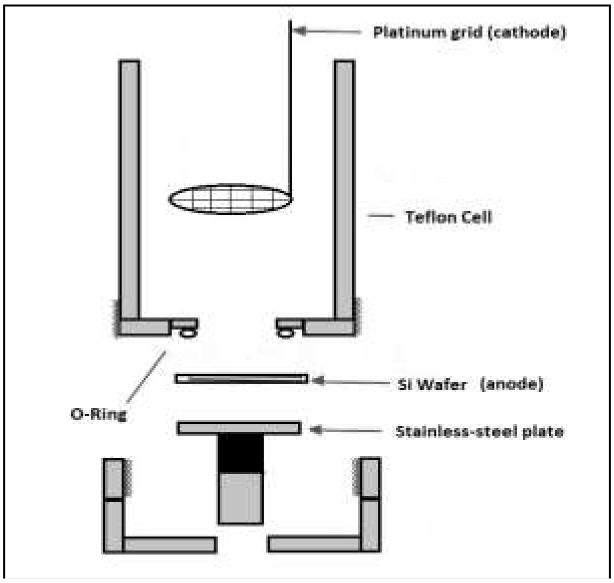


Figure1:Show the schematic of ECE Teflon cell.

II.Device synthesize

Aluminum thin film as the electrode was chosen to be deposited onto PS layer which prepared as the final formation process just before gas sensor application. Due to some properties of aluminum It has been chosen like as good conductivity, oxidization resistance, and simplicity preparation. The thickness of deposited thin film was (5-20nm)on the upper interface of PS, and the back side of silicon wafer surface also Aluminium as an electrode to obtain on a sandwich structure of (AL/nPS/n-Si/AL) as shown in figure (2).

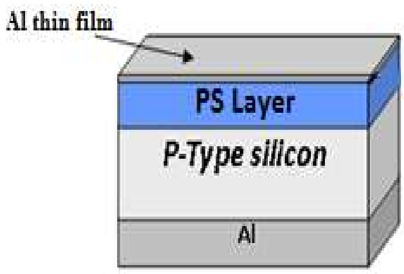


Figure 2: (AL/nPS/p-Si/AL) cross section structure of gas sensor.

3 Results and discussion

I. Layer thickness and porosity

The Layer thickness and porosity are the most important parameters, among the characteristic of PS. in our work We studied the etching time effect on both the porosity and layer thickness. Fig.(3) explain the relation between the process time and the PS layer thickness, this figure show the increase of PS thickness layer value with increasing time as a result of etching process proceed, further holes get to the exterior going to further dangle of the Si, shows the correspondence connecting layer thickness and etching time of the synthesized PS layer at several irradiation times (5, 10,15 min and 20 min.) for the long time the carriers will confined in the slim spick goingto break up these spicks and take place excessive etching until the carriers regenerate over on the entire surface and begin a new layer as explain in Figure (4) by increasing the etching time (5-20min.) the porosity increased to more than50%.

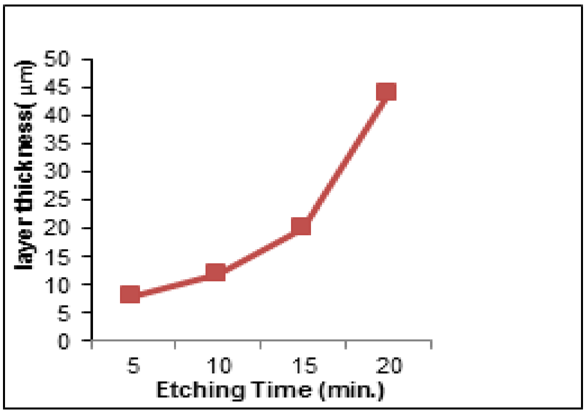


Figure 3: shows the relationship between etching time and prepared PS layer thickness at different irradiation times (5, 10,15 min and 20 min.)

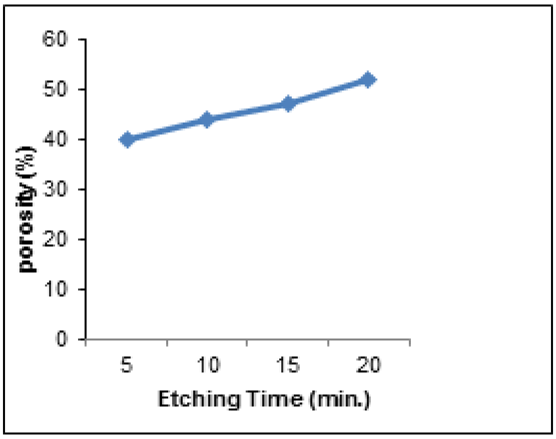
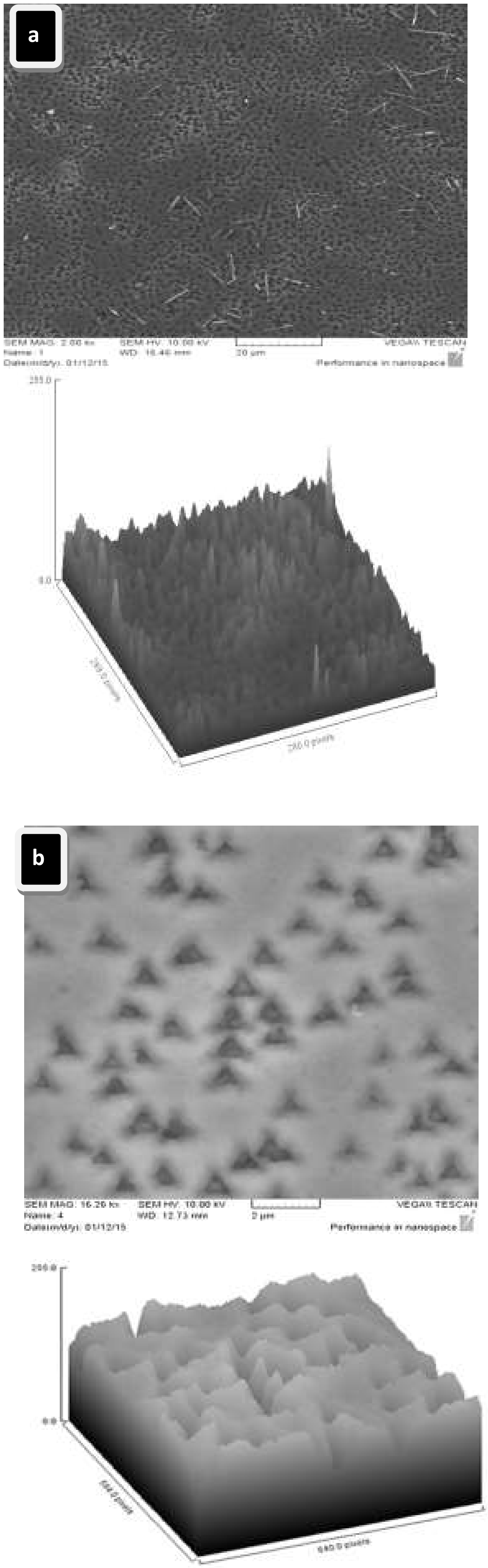


Figure 4: shows the PS porosity relationship to the etching time.

II.Surface Morphology:

The synthesized porous layer had surface morphology was extensively examined by SEM, The surface morphology of PS sample with variant etching times (5-20 min) as shown in figure(5). By compare the SEM images it is obvious that at short etching time 5min the layer morphology of PS appear as a pore shape profile .The shape of the pore were almost triangle outline these result indicative of that for short time, the E.C.E process should begin in short rate, As shown in Fig. (5 b) The growth with growing the etching time to 10 min surface morphology of the PS layer ,the size and density of the completed growth pores was larger than that of the non finished, as well the surface morphology of PS still look like as a pore like structure with triangle pore profile. more increasing of the etching time to 20min guide to enlarge the density of the finished pores and also the pore sizes and the pore profile was nearly sphere-shaped and rectangular .

As shown in Figure (5 c) by growing of the E.C.C time will progress the silicon dissolution process because of enhance pore formation.



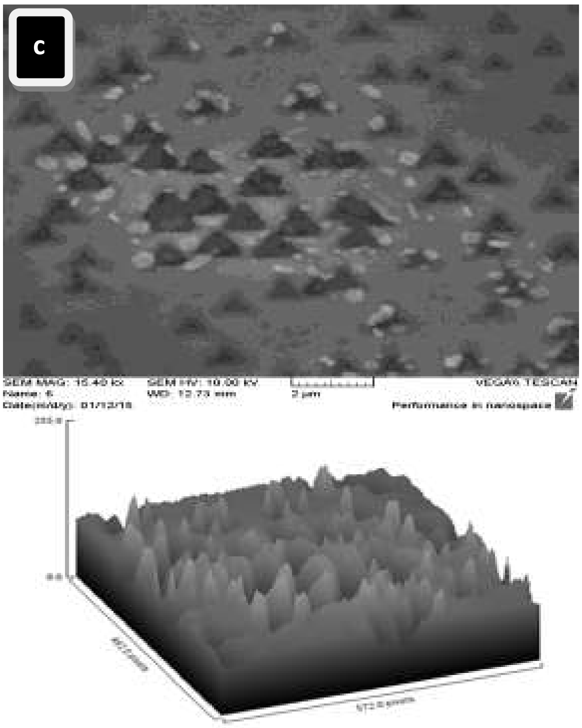
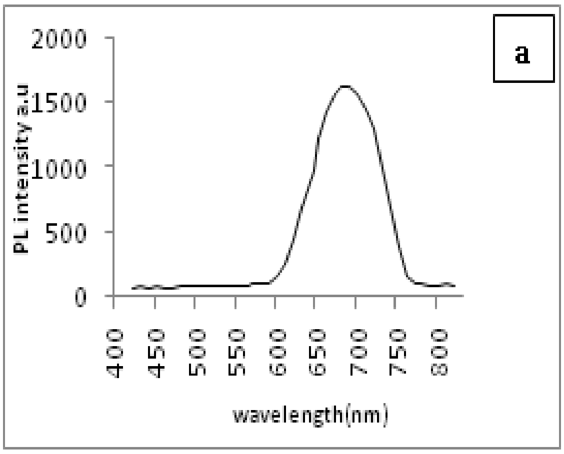
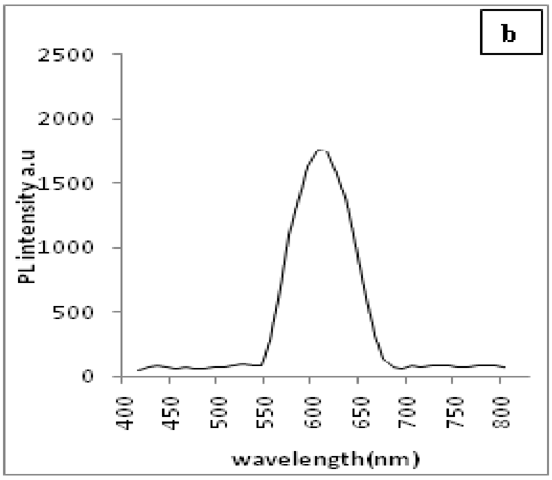


Figure 5: shows the SEM image of the P.S with variant etching time(a)5 (b)10and(c)20min.

4. Photoluminescence study

For studying the optical properties of porous silicon the Photoluminescence spectroscopy has come out as an significant tool materials appropriate for gas sensing process. Photoluminescence was conducted by using He-Cd laser system operating at wavelength 325nm . The PL spectra of PS synthesized with etching times increased from 5 to 20min) are shown in figure (6).The spectra of PL for PS had been dominated by intence and broad emission peak at visible region from (500-750). the spectrum of PL notecied in an emission peak at a wavelength of 680,630, and 600nm , The PL intensity is increasing by growing the time of etching would a blue shift in the PL peak position. The PL spectra with low PL intensity are due to the presence of bigger PS structures size in the porous layer.





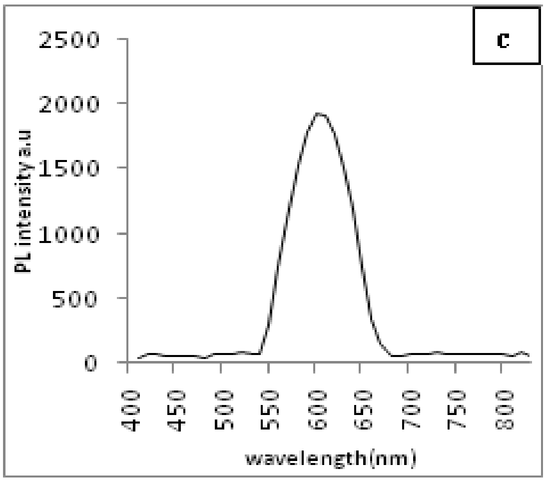


Figure 6:show the spectra of PL for PS at etching times, (a) 5min,(b) 10min and(c)20min.

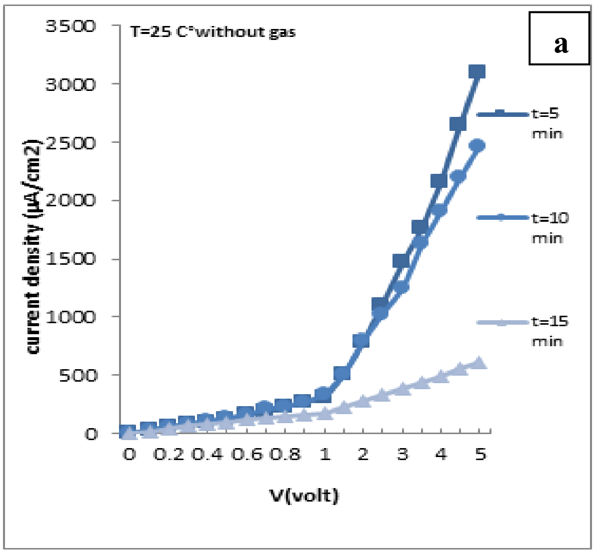
Table (1) show the PS layer energy gap, the PL peak of wavelength emission and intensity with time.

Table 1:Illustrates the etching time, PL emission wavelength, PL intensity, energy band gap.

E.C.E time(min)	Wavelength PL peak (nm)	Intensity pf PL (a.u)	E.g PS (eV)
5	680	1700	1.8
10	630	1780	1.95
20	600	1950	2.06

Gas Sensor Properties

The sensing mechanism of this mode of operation is setup on the effect of the current density -voltage value pass throw in the junction of porous silicon -crystalline silicon. according to the porosity and the porous layer the action of this junction as detection method different and the resistivity of the porous layer thickness. we can study From these curves , that the current transient in the nonexistence of gas molecule was different in relation to the porous layer the layer thickness and the porosity of as shown in figure(7a). As shown in fig.(7b). the J-V characteristics of gas sensor in the structure (AL/nPS/p-Si/AL) with exposure to CO_2 gas .The rates of the current at existence of CO_2 gas is higher than that without gas, the variation in the current signifying that the sensor is very sensitive to CO_2gas.both figure show the difference of the current at greatest applied voltage +5V at RT operation temperature the forward current passing through the modified structures deceased with increasing the etching times. Due to the growing layer thickness and the porosity this performance was observe with growing the time of E.C.E ,when the porosity increased this lead to drop off both of the mobility of the charge carrier and the dielectric constant of the PS layer.



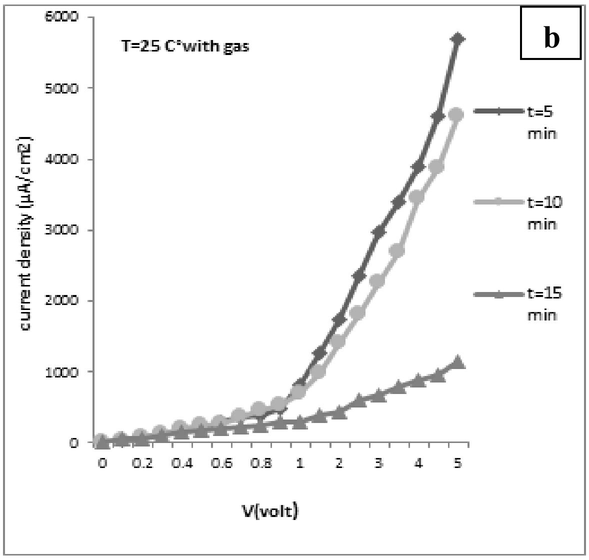


Figure 7:Illustrated the J-V characteristics for porous sample of structure at room temperatures (a) without gas ,b) ° under CO_2 gas

5. Conclusions

Electrochemical etching process could be considered as controlled technique to produce of nanostructure (PS).The surface morphology is found to be dependent on etching time. The maximum porosity and porous layer thickness was obtained with large etching time

PS layer has surface morphology of pore- like structure in different shape like triangle and rectangular at etching time ranging from (5-20min), the PS layer give the PL spectra with strong and broad emission peak at visible region and blue shift tack placed. the fabricated sensor is extremely responsive to morphological charactristic of PS layer, thickness, porosity, and the growing the etching time will enhance the area active sensitivity area. The growing of the current density for PS samples coduct to the CO_2 gas molecules was because of desorption of the PS layer for the molecule on the surface.

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