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2-D OF NANO PHOTONIC SILICON FABRICATION FOR SENSING APPLICATION

M. M. HASSAN[a,b], M. A. FAKHRI[a,*]
[a]*Laser and Optoelectronic department, University of Technology, 10066 Baghdad, Iraq*
[b]*Ministry of Health, Baghdad, Iraq*

Porous silicon (n-PS) with diverse morphologies was prepared on silicon (Si) substrate via photo-electrochemical etching technique. We studies the structure, surface morphology, pore diameter, roughness, based on (XRD), (AFM), (SEM) at different etching time (5, 10 min) and current ($10mA/cm^2$). In this present work we fabricate the nanophotonic Porous Silicon (PS) by the Electro photo Chemical etching method. The nanophotonic PS results show a Nano structure and the reduction of the reflection in order to improve the light conversion for optoelectronics and higher band-gap obtained from Photoluminescence (PL) analysis.

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1. Introduction

Porous silicon (PS) is a fine network of very small voids (often called pores) surrounded by thin walls (often called nanocrystallites). [1-4]PS is often synthesized from bulk crystalline silicon, the synthesis is started from surface of the crystalline silicon into the bulk [5-8], and therefore the surface of the PS is looked to be a brittle hierarchy disorder. The cross-section is seemed to be as a spongy skeleton, what is why the name Porous Silicon is used [10-16]. Fig. 2-1 shows a schematic structure of PS. The word nanoporous is sometimes used for smallest-pore regime to emphasize the nanometric dimensions [17-26].

Many preparation techniques have been adopted in synthesizing porous silicon among them is the electrochemical etching technique.

In the PS formed by electrochemical etching, pore sizes are related both to the depletion layer width (produced from the internal field of HF electrolyte/Si interface) and to the mechanism of charge transfer during etching through the interface of HF electrolyte/Si [27-29]. In highly doped substrates, the depletion width is very thin, therefore the pore size being typically around 10 nm (micropores). In lightly doped n-type substrates, the pore size is around 10 – 100 nm (mesopores). Macropores are difficult to obtain from electrochemical etching but they are obtained from photochemical etching [30-33].

Bulk crystalline silicon has a band gap of 1.12 eV, which should result in luminescence in the near infrared (1100 nm), but silicon is an inefficient optical material because it possesses an indirect band gap [34-37]. In indirect band gap, the maximum of the valence band and the minimum of the conduction band appear not to coincide. Thus, radiative recombination in silicon requires a phonon, which significantly reduces the probability and rate of radiative process [38-41].

In this work the synthesis and characterization of n-PS grown on n-type silicon wafers by using photo electrochemical etching method under varying the time etching at room temperature and studied the morphological and structural properties by using the techniques of X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM) and Atomic Force Microscope (AFM).

[*]Corresponding author: mokaram_76@yahoo.com

2. Experimental work

The layer of the n-PS was grown at room temperature (27 °C) on the 1.25 cm^2 dimension of n-type Si wafer. The electrochemical etching induced by laser method was used to prepared the layer of the nanophotonic porous silicon and performed at the room temperature in an especially cell designed as present in the Fig. 1. It was manufactured from the Teflon with a circular opening at the bottom that was stamped by the wafer of the Si as a substrate. The cell designed as a two-electrodes, the first one was connected to the Si wafer as an (anode) and the second one was connected to the wire of the platinum (Pt) acted as the cathode. The Si wafer of the used n-Si it has been submerged inside the 49% solution of the pure hydrofluoric acid (HF), connect to allow electrons within the solution. To form the n-PS layer the etching time duration was varied to (5 and 10 min), the current density was kept fixed (10 mA) and the illumination source was employed during the etching process was laser diode of 50 mW/ cm^2 and 650 nm wavelength. The synthesized n-PS samples were rinsed in ethanol and air-dried.

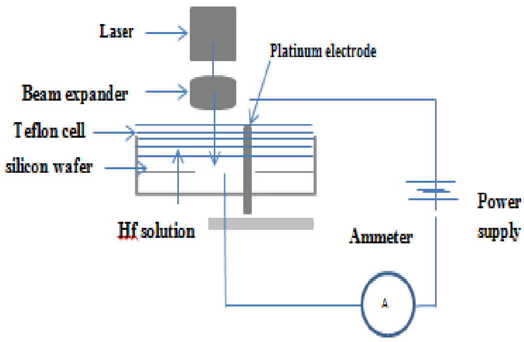


Fig. 1. The setup of photo-electrochemical etching.

3. Result and discussion

Fig. 2 shows the XRD pattern of n-Psi on silicon substrate synthesis at (5 min, 10 min) etching time has two different peaks located at 2θ = 28.45˚, 32.95˚, 70.3˚ corresponding to (111) and (400) planes respectively. The increase in etching time led to an enhancement in diffraction peak intensities. The morphologies (pore density, shapes, sizes and pore distribution) of the n-PS layers were altered with the variation of etching times as clearly reflected in the XRD pattern [16, 42, 43]. When increase the etching time we can see apparent new small peak at new diffraction angle, this may be attributed to new nanostructure which was different in morphology.

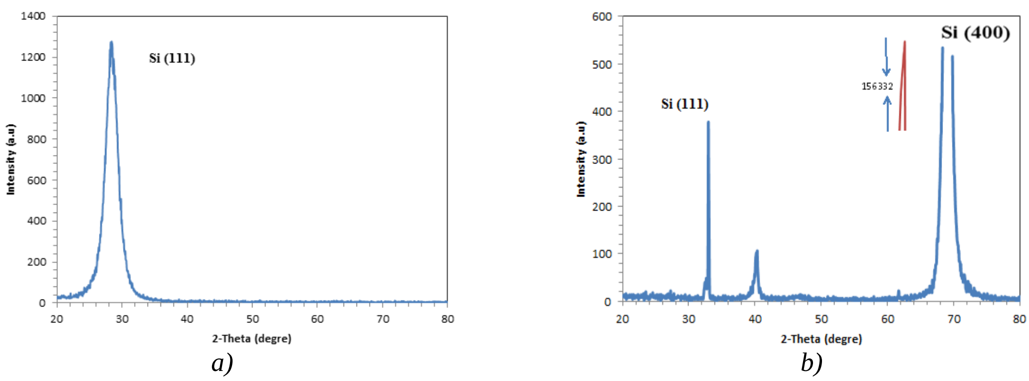
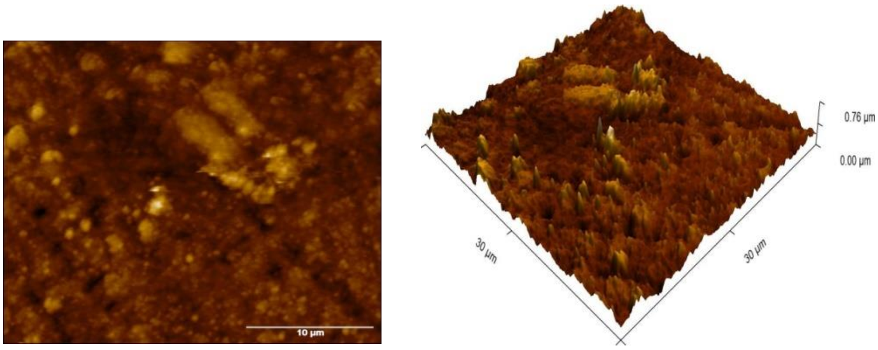


Fig. 2. XRD pattern of (a) PS prepared at (5 min) (b) PS layer prepared at (10 min) and 10 mA/cm^2.

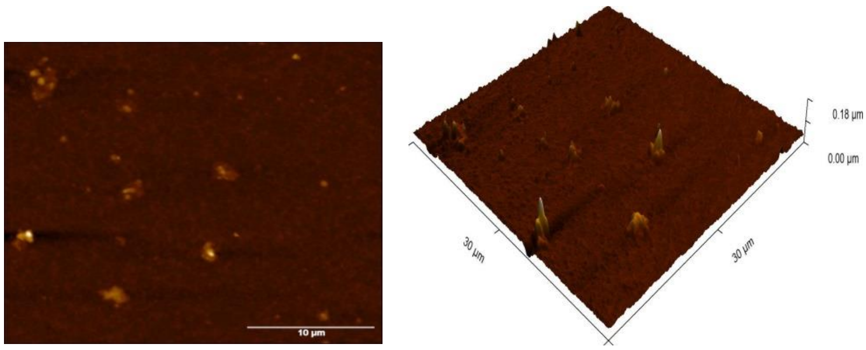
Fig. 3 obtains the surface morphology of the PS (AFM) shows the three dimensions of the PS layer. PS can be observed the structure with densely pores in which the randomly distributed Nano-crystalline silicon pillars and voids over the entire surface. Therefore, the etching time and current density can be used to control the size and shape of the final structures [44-47].

Table 1. The calculated morphology characteristics of PS samples.

Current density (mA/cm^2)	Etching time (min)	Roughness (nm)	RMS (nm)	Average dimeter (nm)
10	5	2.09584	2.62248	52
	10	14.1544	19.0080	36



a)



b)

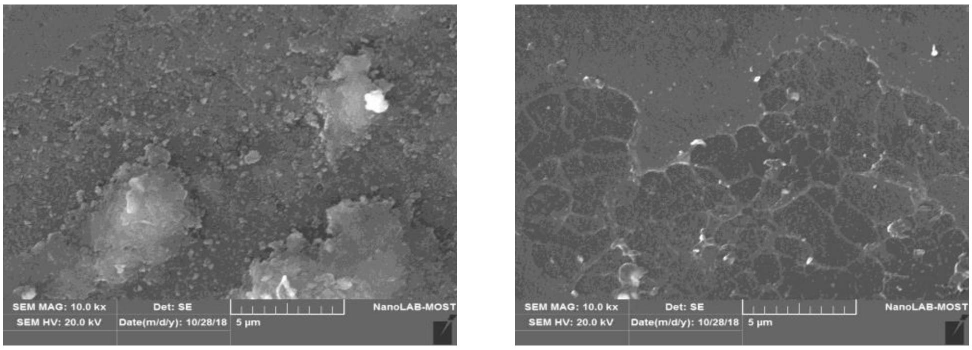
Fig. 3. AFM image for PS (a) 5 (b) 20 (c) 10 min at current density 10 mA/cm^2

When the fixed the current density (10mA) and varying the etching time (5 min, 10 min), note that the pore width increases with increasing of etching time as reported in Table 1. This because the pore width may be back to increase in holes number on surface of silicon with etching time which leads to preferential dissolution of pores, and the enlargement of the area of each pore leading to reducing the width of the walls that separate pores.

We found that the average diameter of pores reduced by increasing the etching time from 5 to 10 min, as reported in Table 1. This attributed to longer etching time caused an increasing in porosity, so increasing in an average roughness [48-50].

Fig. 4 reveals an SEM topographic image of the PS surface with magnification 5µm, The SEM image, show that the porous silicon consisted of a complicated network of pores and columns separated by very thin walls in Nano-meter sized structures having very large surface area which usually varies from 3-600 m^2 /cm^3 depending on experimental conditions [51-53].

At low time; we noticed clear distortions at the surface due to the absence of sufficient time to make pores regularly and clearly. At high time, we notice that the surface is more uniform and the pores are distributed, and the distortion appear less than they are in the low current.



a) *b)*

Fig. 4. The SEM image for PS (a) (5 min) , (b) (10 min) at 10 mA/cm^2.

4. Conclusion

Porous silicon layers are prepared by photo-electrochemical etching for different etching times. The samples are then characterized the Nano-crystalline porous silicon layer to study its structural and morphological properties, The obtained results show that the structural properties of the PS layer depend on the etching time, surface roughness, layer thickness, and pore diameter. It was found that when the etching time was increased we obtained better results than the low time in the above properties.

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