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The properties of porous silicon with different acids

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Abstract--This paper study the characteristics of nano crystalline silicon prepared by using electrochemical etching with etching time {5,25} min for Hydrofluoric acid (HF) acid and Nitric acid (HNO₃) and etching time {5,25} min for Ethanol and Hydrofluoric acid; and study the effect of this solutions on the of features porous silicon(P-Si) will use electrochemical etching for preparation from p-type silicon wafer with resistivity (1-10 Ω.cm) with different time. after that, make a comparison for the morphological properties for porous silicon.

Keywords--nano technology, porous silicon, morphological properties, electrochemical etching, porosity.

Introduction

Nanostructure technology is a large and diverse field of research and development that has grown a lot around the world in the last few years. Nano is the study of the basic rules of molecules and structures with one dimension and a size between 1 and 1000 nm. Nanostructures are groups of these molecules. So, nanotechnology is a set of tools, techniques, and applications that are used to make and install a structure on a very small scale¹. In the 1950s, P-Si was found by Uhler (1956) and Turner (1958)² while they were polishing silicon wafers with an electrolyte that contained HF. They found that when the current and solution

were just right, the silicon didn't dissolve evenly, but holes were made. Spot etching (also called chemical etching) of silicon wafers in (HF) is one of the most common ways to make psi. With this method, you can make porous silicon that has optical and electrical properties that can be used in photodetectors and solar cells. P-Si layers are very attractive from a sensor point of view because they have large internal surface area, unique combination of a nearly perfect monocrystalline structure, and often very high activity in surface chemical reactions.

Only 0.1 to 0.3 m²/cc of monocrystalline silicon is used to make a single crystal³. Psi has many uses, such as in optoelectronics, sensing, energy conversion, optical sensors, and biomedical applications⁴. Ganham⁵ used electrochemical etching to make a sample of porous silicon, which he used to study the luminescent properties. His study improved our knowledge of the optical features of P-Si. Nano ceystalline silicon is a type of silicon that has holes made of porous nano silicon built into its microstructure. This gives it a high ratio of surface area to volume. Lehmann et al. came up with the first model to explain how the P-Si layer forms in 1991. Wiesner⁸ did a study in 2005 to find out how rough the surface of oxidized porous silicon layers was⁶. P-Si is a very important material for the future because it has good mechanical properties and good properties like being cheap, having a large surface area in a small volume, and being easy to work with on the surface⁷. In this study, you can look at the optical and structural properties of P-Si made from p-type bulk wafer silicon using SEM and XRD. The scanning electron microscopy (SEM) is a popular method of analyzing small samples, useful tools for looking at and analyzing the shape and microstructure of a material as well as its chemical composition⁸. X-ray diffraction (XRD); It has been used a lot to get accurate information about the physical and chemical properties of materials (such as amorphous/crystalline structures, crystal lattice parameters, configuration profile, etc⁹).

Experimental part

This content describes the tools and devices used to prepare and study psi layers, as well as their properties. In this work, P-Si is made by electrochemically etching a p-type (111) bulk silicon wafer with a 125mm diameter and 575mm thickness in California, USA. (1.5*1.4)cm silicon wafers were cut. These pieces were washed using ethanol as a means of cleaning by mixing ethanol and HF acid (10%) using the systematic –in figure 1 – creates P-Si with electro chemical etching for p-type silicon wafer with varying time (5,10,15,20,25 and 30) min for both solutions. The sample is then cleaned with ionized water and permitted to dry. After that, samples are stored in ethanol-filled plastic tubes to avoid room-temperature oxidation.

The mensuration

In this work, the composition of the layer P-Si was verified by making some measurements as below:

Porosity

The porosity of the P-Si layer was figured out by taking a tally of the mass of the samples both prior to and following etching $\{m_1 - m_2\}$, in addition to the sample's mass after P-Si layer removal from the sample $\{m_3\}$ by dunk it in 1 M KOH solution for 30 min¹⁰; This equation was used to figure out how porous the material was:

$$p = \frac{m_1 - m_2}{m_1 - m_3}$$

This method is called Gravimetric measurements.

Scanning electron microscope (SEM)

Direct imaging of the layer (Psi) with a mobilized emission scanning electron microscope is used to perform structural measurements of the layer (P-Si). The FESEM method was used to investigate it¹¹. The University of Tehran is where the SEM images were procured.

X-ray Diffraction (XRD)

XRD is a technique that can be used to investigate the crystalline structure of porous silicon. In this paper, XRD measurements were taken at the University of Tehran. These methods are dependent on being able to see the scattering of the intensity of a beam of X-rays that is falling on the sample as a function of the angle of incidence and polarization, scattering, wavelength, or power¹².

Results and Discussion

Through the usage of nanoscale crystalline silicon, porous silicon has found widespread application in the realm of technology. Figure 2 shows the relationship between the amount of etching time and the porosity of the P-Si material. Included are the signals for the HF and HNO₃ samples. Discover some facts about the structure of psi by analyzing this figure. The number of porosity measured between 5 and 30 minutes is displayed on the graph. It has been observed that the porosity of the layer increased by 0.7 at 5 minutes, which is evidence of the formation of nano crystalline silicon. However, in the 10 minutes that followed, the porosity of the layer decreased due to the polishing and removal of the P-Si layer. This was then followed by a dramatic rise to 1 at 15 minutes, which was an indicator of a very good P-Si layer (formed a new P-Si layer later on). The fluctuation continues after this point¹³.

Figure (3) shows that at 5 minutes, a scanning electron microscope image of the sample of HF and HNO₃ can be observed, It is possible to see In the five minutes, the P-Si layer is in the process of forming, so the X-ray Diffraction appeared to be close to bulk silicon as shown in figure (5). However, as time progressed, the porous layer did indeed form, as can be seen in the 25 minute sample in figure(4), It is plain to see that the porous layers are developing, and at the same time, nanowalls are coming into being¹⁴. This sample has a nanoscale that measures

39.99 nm. It is possible to notice the appearance of the porous silicon layer in X-ray diffraction figure (6).

It is possible to make a description of the reaction between HF acid and ethanol for 5 minutes about P-Si formation from the middle of the area in the sample by using figure (7). The reaction between acid and silicon may be stronger than terminate area of sample due to the difference in the loss of chemical charges in the two regions. Additionally, the interaction with the ends became stronger than the center region, which remained columns because the reaction was slow. Over time, the layer is formed and goes. In a period of 25 minutes, as can be seen, the P-Si layer will begin to form; Nanowalls and a sponge-like structure¹⁵. This picture, which is labeled "figure(8)," is a particularly good illustration of the nano crystalline silicon. Figure 9 shows an X-ray diffraction pattern for HF and ethanol. When the X-ray beam is directed at this sample, the region that contains the porous material reflects the rays, while the flat region absorbs the rays without reflecting them. This indicates that there is a diffraction pattern of rays present in the region that contains the columns. Figure 10 shows that after 25 minutes, the porous layer was homogeneous, which means that the nanosize was the same throughout the entire layer. As a result, both the reflection and the absorption became uniform, and the image only displayed a single pattern.¹⁶.

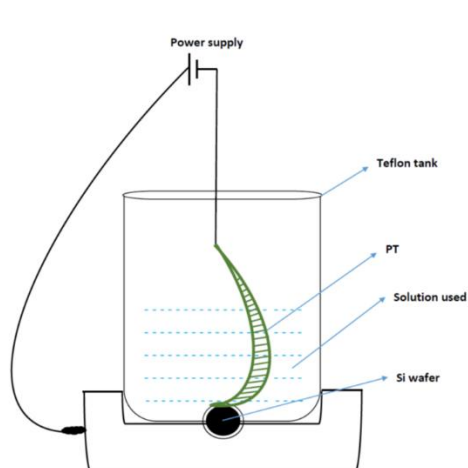


Figure 1. The systematic for the electro chemical etching which used in this study

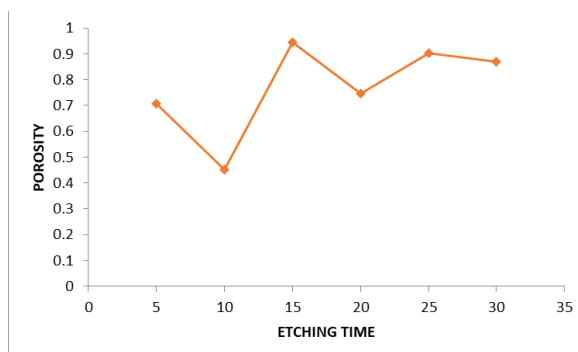


Figure 2. The relation sheep between porosity and etching time

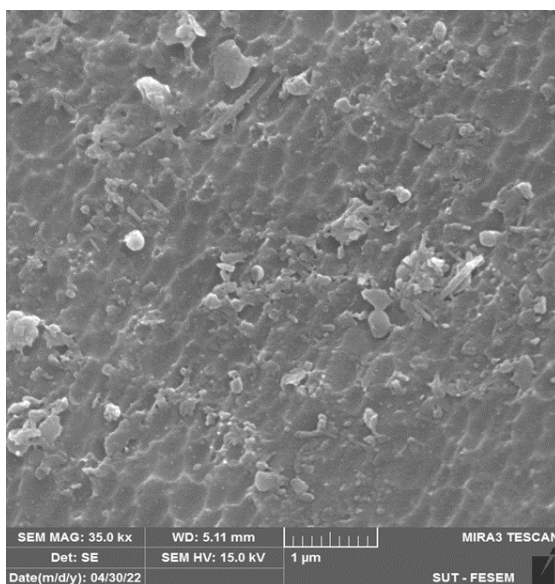


Figure 3. SEM image of P-Si layer with HNO₃+HF at 5 min

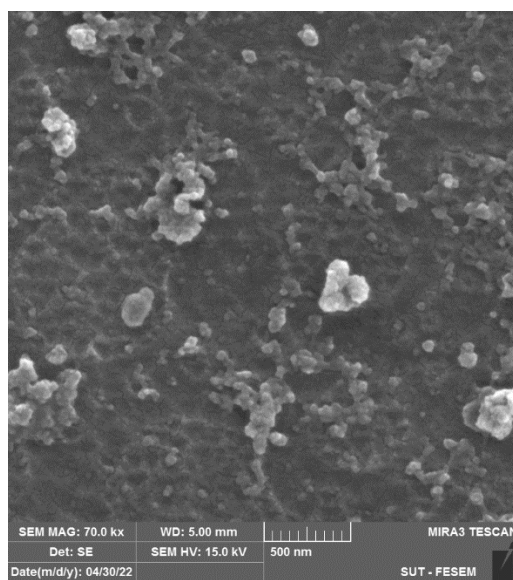


Figure 4. SEM image of P-Si layer with HNO₃+HF at 25 min

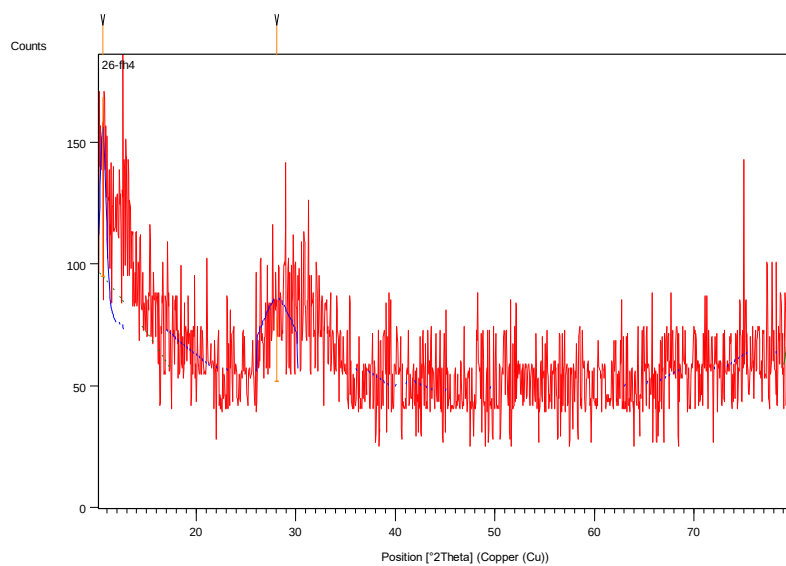


Figure 5. X-ray Diffraction of HNO₃+HF at 5 min

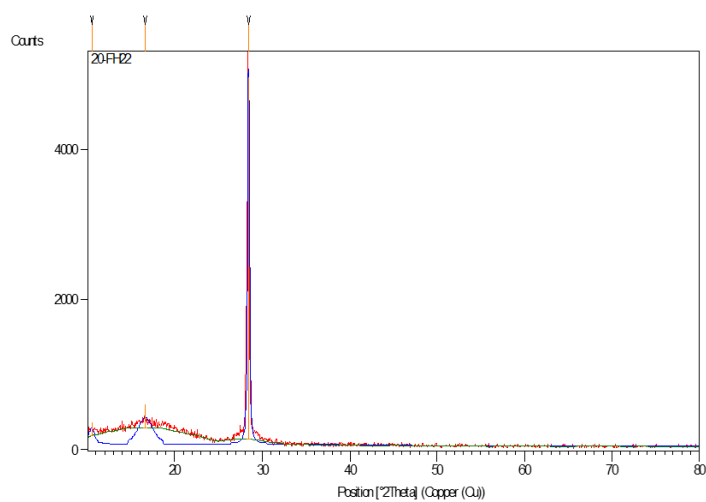


Figure 6. X-ray Diffraction of HNO₃+HF at 25 min

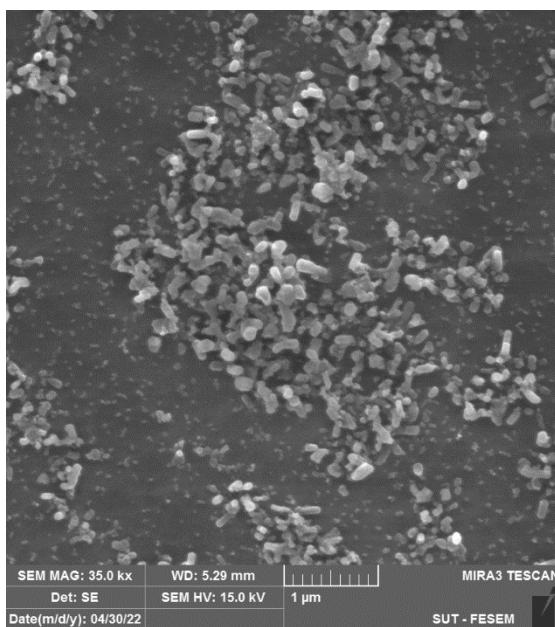


Figure 7. SEM of P-Si layer in HF+ETHANOL at 5 min

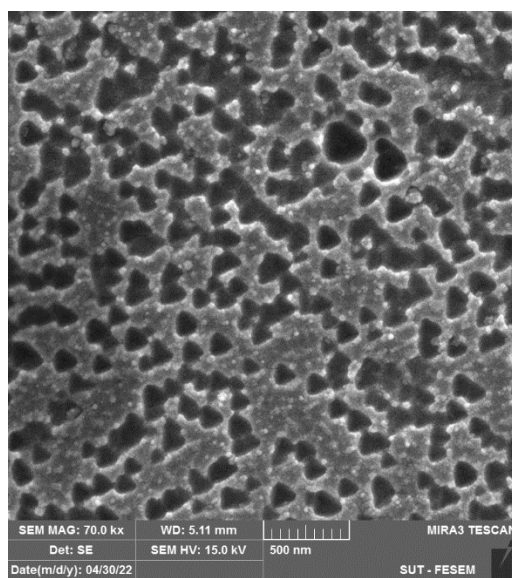


Figure 8. SEM of P-Si layer in HF+ETHANOL at 25 min

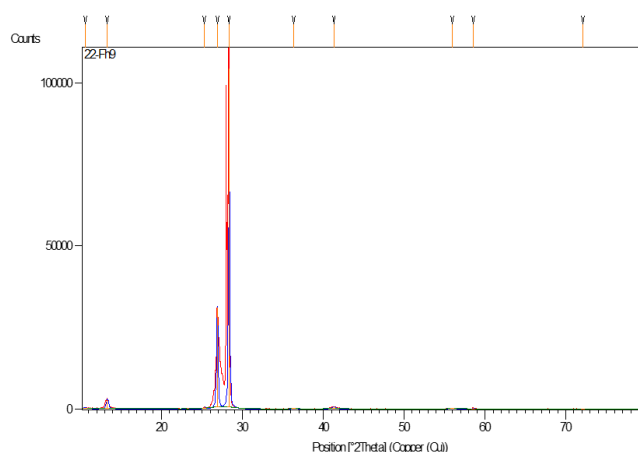


Figure 9. X-ray Diffraction of psi in HF+ETHANOL at 5 min

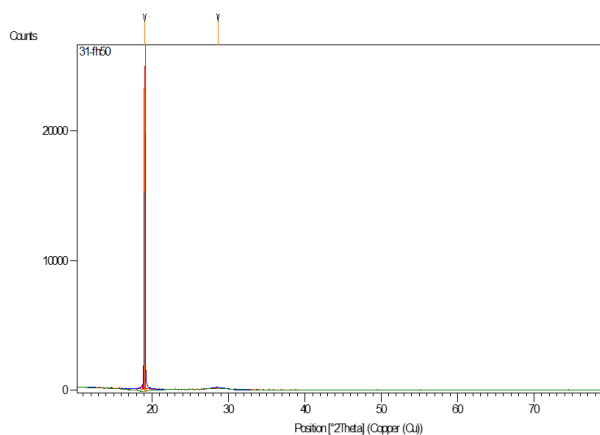


Figure 10. X-ray Diffraction of psi in HF+ETHANOL at 25 min

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