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Preparation and Characterization of Porous Silicon for Photodetector Applications

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Abstract

Photoelectrochemical etching (PECE) was used to prepare porous silicon (PS) layers of polished surfaces of (100) n-type silicon wafers with a resistance of 0.1-100 μm and thickness of 600 ± 25 μm. The directed slices are to be catalyzed at different etching times (5, 15, 25 min) with a constant Hydrofluoric acid of 20% and with a fixed current density of 20 mA/cm². The porous silicon morphology was investigated using scanning electron microscopy (SEM). Samples were formed by different engraving times. It revealed that the silicon surface has a layer of sponge-like structure, with the average pore diameter (740±1 nm, 550±2 nm,460±3 nm) of the porous silicon increasing as the etching time increased. PS Al PS /Si /Al photodetectors were found to work as a photodetector over a wide wavelength responsivity.

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1. Introduction

The synthesis of nanoparticles has sparked a lot of research over the last few decades. These materials have physical properties that their crystalline semiconductor counterparts do not [1]. Obtaining and studying porous silicon as a new morphological type of monocrystalline silicon is of interest due to its unique physical properties. [2,3]. Electrochemical (p-Si) or photoelectrochemical (n-Si) etching with anodic bias [4]. In general, PS was utilized to prepare. The term "pore diameter" refers to the size of a hole inside porous material, and is classified according to the pore diameter, which can vary from a few nanometres to a few microns depending on the configuration parameters. The micropores and nanopores are used when the diameter of a pore and its spaces are equal to or less than 2 nm. Mesopores are also taken into account. When the pore diameter is between 2 to 50 nm, while Macropores are considered when the pore diameter is greater than 50 nm [5]. PS is used in a variety of applications, including solar cells, sensors, and detectors. The PS photodetector is used to detect ultraviolet rays and has many advantages over other materials, including high absorption coefficient of UV absorption spectra field, no anti-reflective coating required, low impact, and easy manufacturing technology [6-8]. PS is a popular and interesting material due to its nanostructure. It has a wide area of influence on the morphology and interaction of high light. This impressive platform enables PS to develop gas sensors, as well as biometric and optical sensors [9-12]. Silicon is not widely used, particularly in the optoelectronic devices, because silicon is and the indirect energy (indirect semiconductor bandgap); hence, optical emission yield at room temperature is very small. Porous silicon is a new material of great scientific and applied interest, given that it has strong quantitative confinement properties. PS is mainly prepared by electrochemical etching on the surface of crystalline silicon wafers [13] this study is to prepare porous silicon by etching method with different etching conditions and studying some of its morphological, optical, and electrical properties.

Experimental Details

PS specimens were made using the photoelectrochemical etching technique on (100) focused n-type silicon wafers with a resistivity of 0.1-100 Ω.cm and a thickness of 600± 25μm, with a constant HFC of 20%. Si wafers were cut into small pieces for accurate measurements in the etching process. After that, soaked for 5 minutes in ethanol to cleaner and remove any residues. The contraction of Hydrofluoric acid (48%) has been diluted by using high purity ethanol C2H5OH (99.9%) to reduce hydrogen bubbles at different etching times with a fixed current density of 20 mA/cm2. Figure (1) shows a schematic diagram of the PECE setup. Finally, the sample is washed in ethanol for 2 minutes to relieve stress on the sample and avoid cracking.

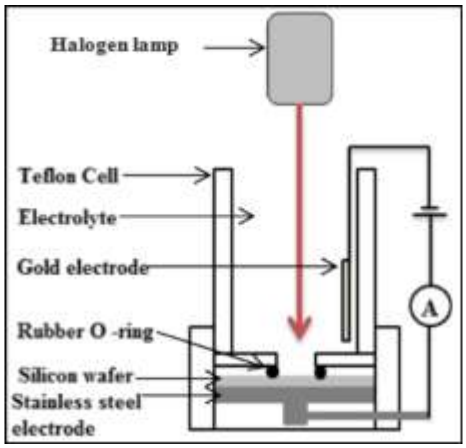

Figure 1: PS photoelectrochemical etching technique schematic diagram.

3. Results and Discussion

Figure 2 shows the XRD pattern of an n-type porous silicon, the thin film was created using a 15-minute etching time, a 20mA/cm^2 etching current density, and a 20% HF concentration. As a result, we can confirm that the PS layer is still crystalline, but with a lesser diffraction angle This is due to the effect of pressure, which causes an extended lattice parameter, which causes the PS peak to be displaced to the right When the crystalline size of PS is smaller than the bulk Si peak, the diffraction angle is small.

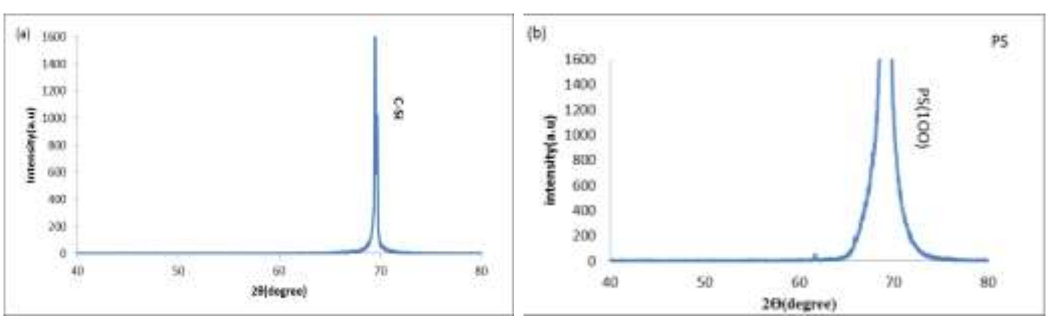

Figure 2: (a) bulk-Si, XRD pattern (b) porous Si was prepared at 20 mA/cm^2, with a 15-minute etching time and a 20% HFC concentration.

The surface morphology in Figure 3 shows the image of SEM to at varied etching times at 5 minutes, small pores start to create on the bulk-Si sheet, indicating that the etching technique can begin. When this point is raised to 15 minutes be seen through the Si layer's surface area, a larger diameter pore is formed. While another time is increased to 25 minutes, some of the walls of the pores are broken, are, and the next bottom surface is exposing and the surface roughness, i.e. we've noticed that as time passes, the surface roughness increases.

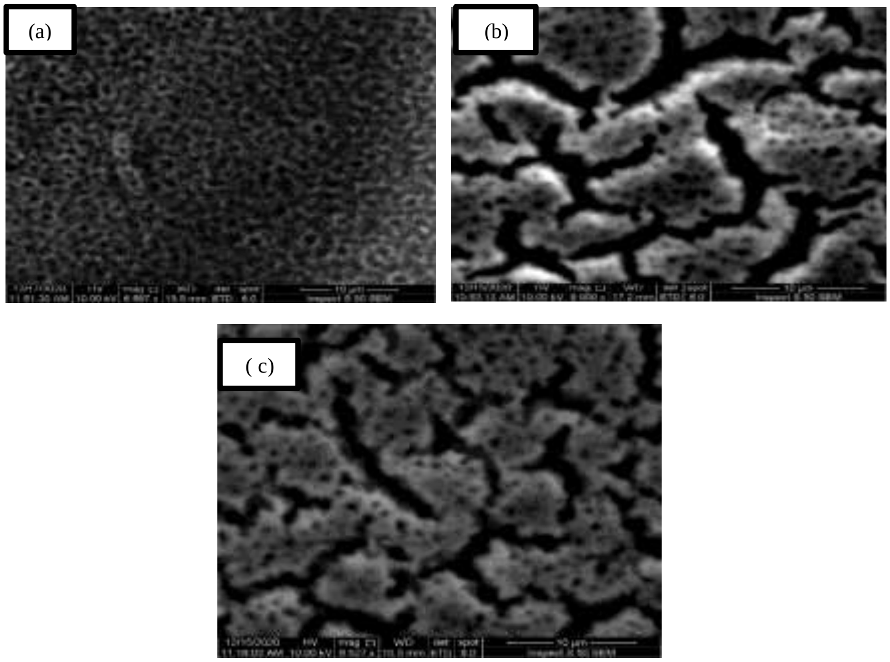

Figure 3: SEM images taken at various etching times of 5, 15, and 25 minutes, with an etching current density of 20mA/cm^2 at HF concentration 20%.

The current-voltage (J-V) characteristic of porous silicon as shown in figure 4 structures is introduced and discussed in the dark, as obtained by adjusting the applied bias of the Al/PS/Si/Al sandwich from -5 to +5 V. The effects of J-V experimental measurements. Curves in crystalline and porous silicon substrates are identified and analyzed at various etching times. J-V curves show the energy gap between porous and crystalline materials. silicon. It appears that J-V etching time characteristics are linked to the formation of PS pores with a smaller energy gap Growing. The etching time has increased the diameter of the pore in the PS structure, resulting in a rise in PS resistivity due to conduction band folding (quasi direct) increasing energy gab, resulting in a decrease in current for both forward and reverse bias [14].

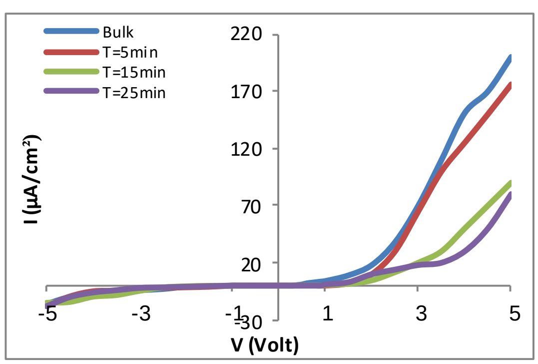

Figure 4: J-V characteristics Si/PS Al prepared with etching time 5, 15, 25 min. etching current density, 20 mA/cm^2 at HF concentration 20%.

the J-V curve in the presence of the light illumination as shown in figure 5. The increase of the reverse bias voltage leads to the increase in the internal electric field which leads to an increase in the probability of the separated electron-hole pairs. Also, the photocurrent is increased with increasing the incident power intensity 5–125 mW/cm^2 due to the increase in the number of the generated photo-carriers in the depletion region. The source of light in the I-V measurement under illumination was white light (100 mW).

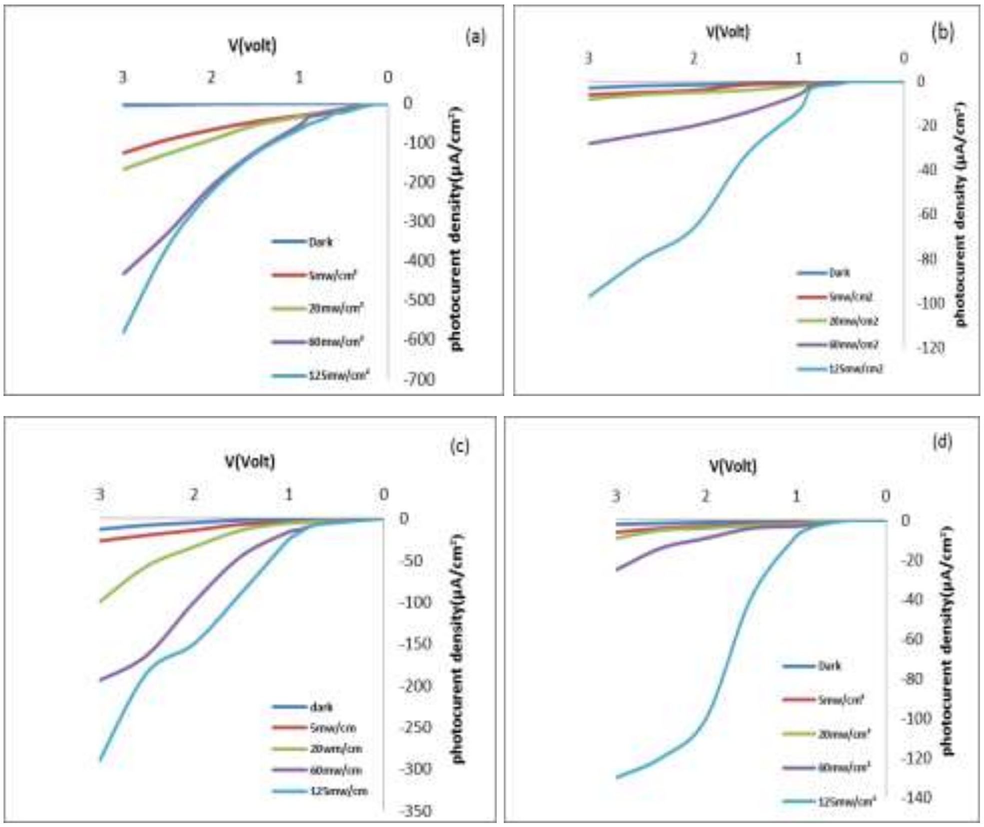

Figure 5: J_{ph}-V characteristics for (a) C-Si and PS samples with etching times of (b) 5 minutes, (c) 15 minutes, and (d) 25 minutes, etching current density of 20 mA/cm^2, at HF concentration 20%.

The spectral response of Al/PS/Si/Al in the wavelength range 400–900 nm at 2 biased eV as shown in figure 6 in the photodetector system. The response is a function used to determine the value of the detection signal in the Al/PS/n-Si/Al answer; there are two peaks, the first peak states that the 600nm wavelength is absorbed in the PS contact depletion region, the second response peak is the result of 800nm absorption in the region C-Si contact depletion The PS response is improved with increased etching time. So, when pore size of PS is changed, the responsivity of PS changes as well. whereas porous silicon is a new material of great scientific and applied interest, due to its strong quantum confinement properties [13].

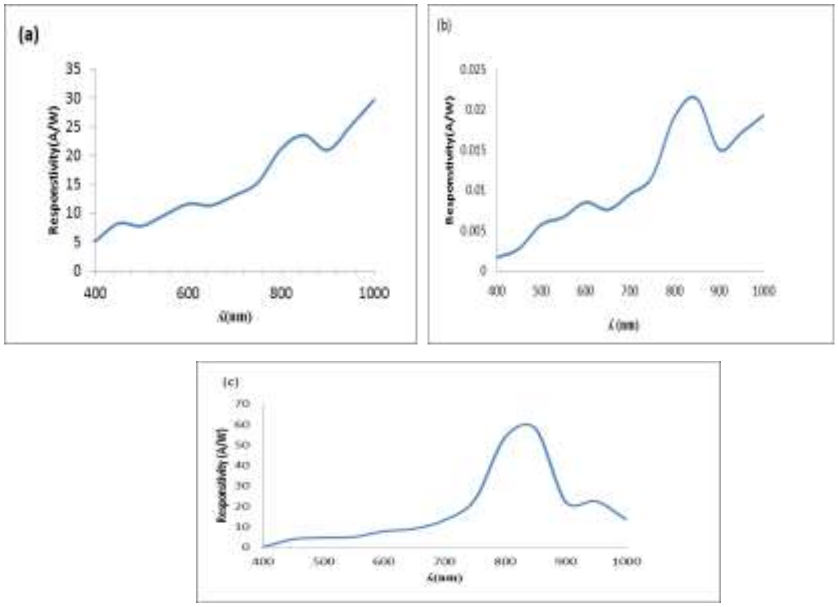

Figure 6: Responsivity of C-Si, and PS specimen at varied etching time(a) 5, (b) 15 and (c) 25, min., etching current density 20 mA/cm² at HF concentration 20%.

4. Conclusions

In summary, the pore diameter in the porous silicon layer increases as the etching period advances, resulting in good responsiveness. Based on the findings of this research, the surface stabilization of the PS layers results in high responsivity in the visible region as a photodetector device.

Conflict of Interest

The authors declare that they have no conflict of interest.

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