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Short Communication

Change of diffused and scattered light with surface roughness of *p*-type porous Silicon

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ABSTRACT

Porous silicon samples were prepared by electrochemical etching method for different etching times. The structural properties of porous silicon (PS) samples were determined from the Atomic Force Microscopy (AFM) measurements. The surface mean root square roughness (σ rms) changes as function of porosity were studied, and the influence of etching time on porosity and roughness was studied too. UV-Vis-NIR Spectrophotometer with integrating sphere accessory used to measure the specular reflectance (R_{spec}) and scattered light (D_{sca}) for all samples. Changes of scattered light intensity with σ rms were studied. Theoretical and measured values were compared and they were almost the same.

Keywords: *Porous silicon (PS); Porosity p%; Electrochemical etching time; Specular reflectance* R_{spec}*; Scattered light* D_{sca} *; Surface mean root square roughness* (σ_{rms})*; Atomic force Microscopy (AFM).*

INTRODUCTION

Porous silicon nanostructures have attracted a great interest during the past few years, due to their many remarkable properties. Luminescent properties, nanostructure porous silicon shows a variety of other interesting properties such as tunable refractive index, high internal surface and high chemical reactivity [1]. Also surface of the PS being highly textured can enhance light trapping and reduce reflection losses of a solar cell, and the tenability of the band gap of PS may be used to optimize the sunlight absorption [2]. By adjusting the formation parameters of electrochemical etching method [3], porous silicon can achieve all porosities according to scientific application. And information about the pore size and their distribution and surface chemistry and their dependence on the fabrication conditions plays a decisive role [4]. In this paper, Surface roughness and diffused and specular reflection were measured using AFM and Spectrophotometer with integrating sphere accessory. The relation between them was investigated as function of etching time.

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EXPERIMENTAL

Porous silicon samples were prepared by electrochemical etching method [3-12], of p-type cubic silicon wafers (c-Si), (100) orientation with resistivity of 0.01-40 Ω·cm, electrochemical dissolution of Si wafers is used: HF-ethanol (measured by volume) aquas concentration 20%. The current density was Constant during sample etching (20mA/cm^2). Etching time changes for each sample (Table1). The Fabricating process was done by etching Teflon cell. After anodization, PS samples are carefully removed from the bath and cleaned in deionized water. Then the samples to be imaged by atomic force microscopy (AFM) "nano scan easy surf 2" .The AFM measurements were performed in contact mode. Then scattered and specular reflectance was investigated by UV-Vis-NIR "carry 5000" spectrophotometer. See Table1 Fabricating process parameters.

RESULTS AND DISCUSSION

Structural Properties

In (Figure 1) few examples of AFM measurement are presented to show differences between samples according to preparation time. They show surface changes with etching time. The pores become more condensed with time because of porosity increasing. We calculate porosity as in our work in [3], and we use gravimetric measurements too [7, 8, 12]. The relationship between porosity and etching time is shown in (Figure 2). This graph shows how the porosity of samples increases with increasing etching time. AFM allows us to calculate Surface mean root square roughness (σrms). We found that it increases with porosity in liner manner Figure 3.

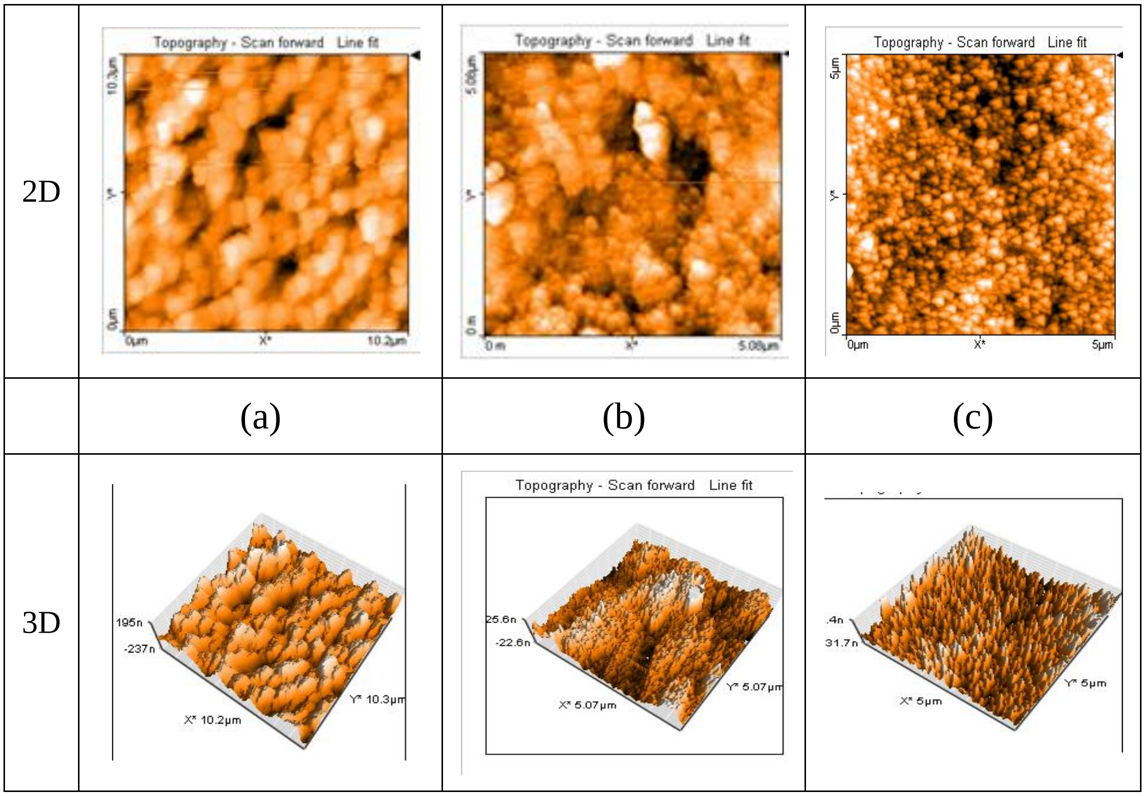

Fig. 1. 2D and 3D AFM image of porous silicon samples prepared with HF concentration 20%, and current density of 20 mA·cm^{-2}, at different etching time (a)5min, (b) 15min, (c) 25min.

Table 1. Fabricating condition of porous silicon samples

Sample	HF concentration (%)	Current density (mA/cm^2)	Anodization Time (min)
S01	20	20	5
S02	20	20	10
S03	20	20	15
S04	20	20	20
S05	20	20	25

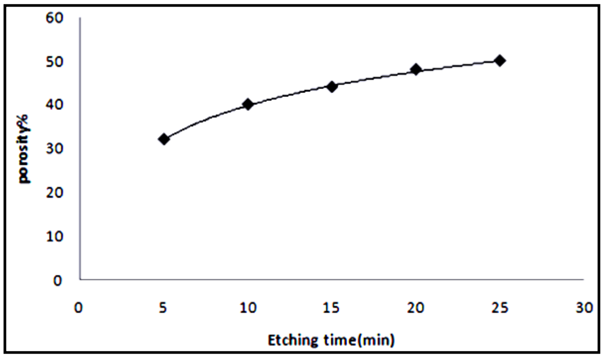

Fig. 2. changing of porosity% with etching time Type-p. porous silicon samples prepared with HF concentration 20%,current density 20mA/cm^2, with different etching time

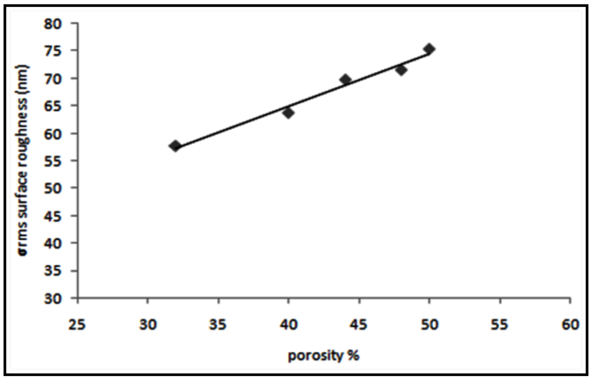

Fig. 3. Root mean square roughness (σrms) measured using AFM as a function of porosity

Optical Measurements

The reflectance response is well accounted for in porous silicon using a homogeneous thin layer with a given thickness and a complex refractive index strongly depending on the wavelength [12-15]. There are three possibilities for the origin of the scattering in porous silicon thin film: air/PSi interface, the volume or the inner surface of the material and the PSi/bulk Si interfaces [7]. The specular reflection (R_{spec}) and scattered light (D_{sca}) of porous silicon are measured. Figure 4 gives example of the results for sample S01.

One can note the presence of interference fringes at wave length between 200-400nm, and 600-700 nm for this sample and that refers to the relation between pore average diameter and wave length, one can expect that the average diameter is from the order of wave length and that was true when measuring pore average diameter by AFM. All three reflectance intensity increasing starting from 1000nm to 1100 nm then they become steady until 2500nm. Similar behavior was found for all samples but for different wave lengths. Scattered light changing with etching time, (Figure 5) because of porosity changing with time. Scattered light for each sample at wave length 808 nm(LASER wave length in our lab.) was studied.

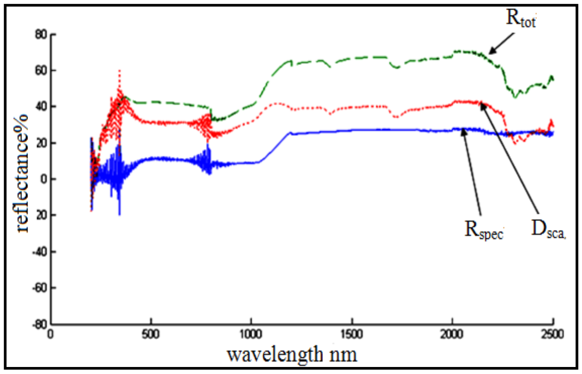

Fig. 4. specular reflectance (R_{spec}), scattered light (D_{sca}), and total reflectance ($R_{tot}= R_{spec}+ D_{sca}$) as function wavelength nm for sample S01 from UV-Vis-NIR spectrophotometer measurements

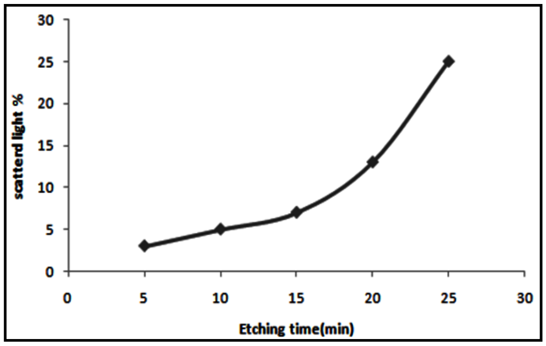

Fig.5 scattered light as function of etching time for p- type PS at wave length λ=808 nm

The mean root square roughness has been measured with AFM, and it was found that the roughness increases with time Figure 6. The theoretical result calculated from Davies-Bennett relation [5, 13]:

$$D_{sca} = R_{tot}\{1 - \exp[-(4\pi\sigma_{rms} / \lambda)^2]\} \quad (1)$$

Where D_{sca} the scattered light intensity, R_{tot} is the total reflectance, λ is the light wave length in the vacuum. When comparing theoretical results calculated from Davies-Bennett relation with measured values by Spectrophotometer, we found that they are almost the same.

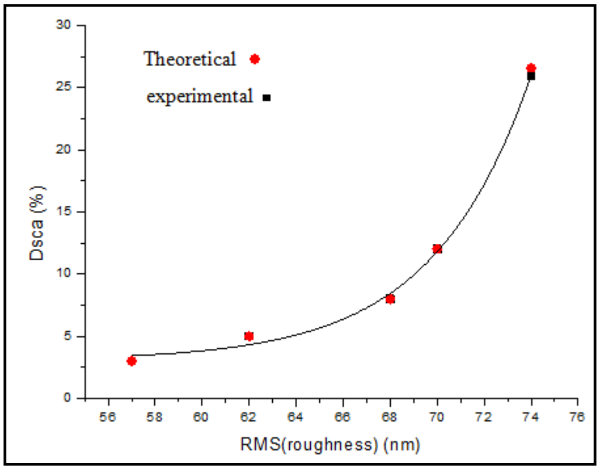

Fig. 6. Theoretical and experimental values of scattered light (D_{sca}) as a function of rms roughness (σ rms)

CONCLUSIONS

Samples of porous silicon (PS) were prepared by electrochemical etching method, with HF concentration 20%,current density 20mA/cm^2, with different etching times 5,10,15,20,25 min. porosity was calculated from gravimetric technique and from our method [2] using AFM. The scattering and the reflectance of porous silicon are measured using UV-Vis-NIR spectrophotometer with integrated sphere used to measure the specular (Rspec) and diffused (Rdiff) reflection and scattered light (Dsca) for all samples. AFM results were used to calculate Surface mean root square roughness (rms σ), and to study its changing with porosity which was liner behavior. rms σ changes with D the scattered light intensity in both ,the theoretical result calculated from Davies-Bennett relation, and measured values, were almost the same.

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