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The Fabrication of Porous Silicon by Electrochemical Etching with Photo Assisted

Ahmed Kheralla Shaheed Al-kadumi[1], Mohammed Refat Sharif[2]

[1]Physics Department, Faculty of science, Zakho University, Iraq

[2]Chemistry Department, Faculty of science, Zakho University, Iraq

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Abstract: The properties of porous silicon was studied by using photo-electro-chemical etching to prepare porous silicon from available mirror-like n-type (111) oriented silicon wafer with resistivity (ρ=(1.5-4)Ω.cm), under illumination of100W of Tungsten Lamp with anodization (5,10,15)min, The gravimetric measurements were used to find the layer thickness of porous silicon.

Key words: Electrochemical Etching, Fabrication, Nanotechnology, Porous Silicon, Photo Assisted.

INTRODUCTION

It is argued that through nanotechnology, it has become possible to create functional devices, materials and systems on the 1 to 100 nanometer (one billionth of a meter) length scale[1]. Silicon is a wonderful material for modern electronic devices and there has been intense research on various aspects, both fundamental as well as applications. The continuously shrinking size of silicon devices (currently around 65 nm) has raised interest about the properties of silicon at the nanoscale, either in the form of clusters and nanoparticles or quasi-one-dimensional structures such as nanowires. These nanosilicon forms add a new desired feature to silicon that it becomes useful as an optical material[2]. Porous silicon (PS) has become the material of favor for sensing applications recently, because of the low cost, low power consumption, and its compatibility with silicon-based technologies. Beside optoelectronic applications [3], PS layers have been used in environmental sensors like gas detectors [4] and humidity sensors [5].

It has been proven that the sensitivity of PS depends upon the morphological characteristics of pores, including the pores diameter and uniformity, regularity of the surface and the layer thickness [6]. The optical properties of a porous silicon (PS) layer produced by electrochemical etching are determined by the thickness, porosity and by the shape and size of pores [7]. These structural parameters strongly depend on the manufacturing conditions such as current density, etching time, electrolyte composition, and also on the do pant type and concentration of the original Si wafer [8].

EXPERIMENTAL PART

Commercially available mirror-like n-type (111) oriented silicon wafer with resistivity (ρ= (1.5-4)Ω. cm) this silicon wafer has been cut off into small which the interaction circle of the pieces with acid have radius (0.6cm) this pieces was cleaned by (1:10) HF: ethanol and by using photo electrochemical etching with 48% concentration of HF, figure (1) illustrated the setup of this systematic, 100W of Tungsten Lamp was illuminated the sample over area nearly (1.1309cm^2), and photo-electrochemical etching was performed in mixture 48% HF and ethanol (1:1) at room temperature by using (Pt) electrode at various etching time (5,10,15) minute.

Figure (1): systematic of Photo-electrochemical-etching process

After photo electrochemical etching process the samples were rinsed with dionized water and lift in the environment for a few minute to dry and then stored in a plastic container filled with ethanol to prevent the formation of oxide layer on the samples. After photo electrochemical etching, layer thickness and porosity had been studied by using gravimetric measurements and using these equations [9]:

$$P=\frac{W1-w2}{w1-w3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$d=\frac{w1-w3}{\rho s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where w_1, w_2 are the weights of sample silicon before and after etching w_3 is the weight after removed porous silicon layer, then the correlation with duration time will be studied.
The relative permittivity of porous silicon was calculated by this relation[9]

$$\varepsilon_{psi}=\varepsilon_{si}-P(\varepsilon_{si}-\varepsilon_{pore}) \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where ε_{si} is relative permittivity of C-siand $\varepsilon_{pore}$is the relative permittivity of the air. The refractive index can be calculated from the square root of the effective dielectric function[10]:

$$n_{psi} = \sqrt{\epsilon_{PSi}} \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Then it can be calculate the capacity of porous silicon by using this relation [11]:

$$C_{psi}=A^* \varepsilon_{psi}{}^*\varepsilon_o/d \ldots\ldots\ldots\ldots\ldots(5)$$

Where A is the area of porous silicon (area of etching) and ε_o is the permittivity of free space.

RESULTS AND DISSCUSSION

To understand the mechanism of PS formation, it has to be taken into account that the electrochemical formation process of porous silicon consists of a non-aggressive process which removes silicon atoms without greatly disturbing the surrounding crystal matrix [12]:

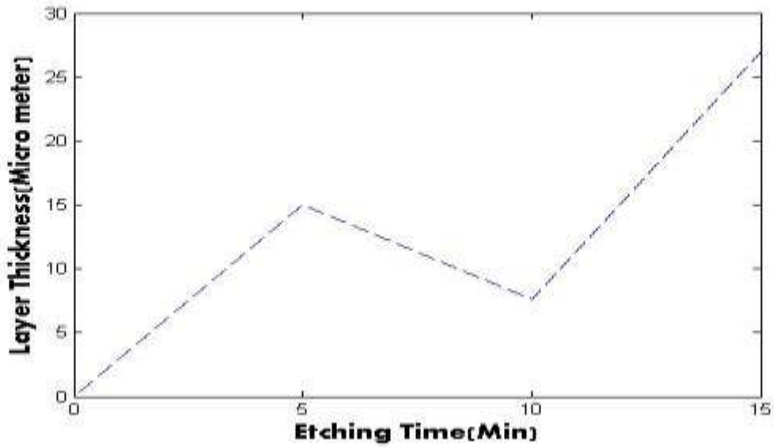

Figure (2) the relationship between layer thickness and Etching time

Figure(2) show the relationship between layer thickness of porous silicon and anodization time, In general one can show the fluctuation of the layer with respect to the time and this may be from the type of illumination in small area this causes fast formation of porous silicon and removing the silicon atoms[13]. The increased in the porous silicon layersin the beginning of anodization time but the rapid reduction in the layer thickness of porous silicon due to removing the layer and make a new layer[14].The tip which made in the beginning anodization time make the charge accumulated in the sharp ends and then increased in the chemical reaction and enlarge the rack inside the bulk silicon in the bottom of intermediate between the acid and silicon[13],in adding to that the increased in temperature from the radiation of tungsten lamp share with photons of the light to generated the carriers from valance to conduction band[15, 16], from that one can say the increased in the charges carries causes the increased in the chemical reaction and then fast formation nanostructure surface of silicon and removing the layer thickness to make a new layer thickness of porous silicon.

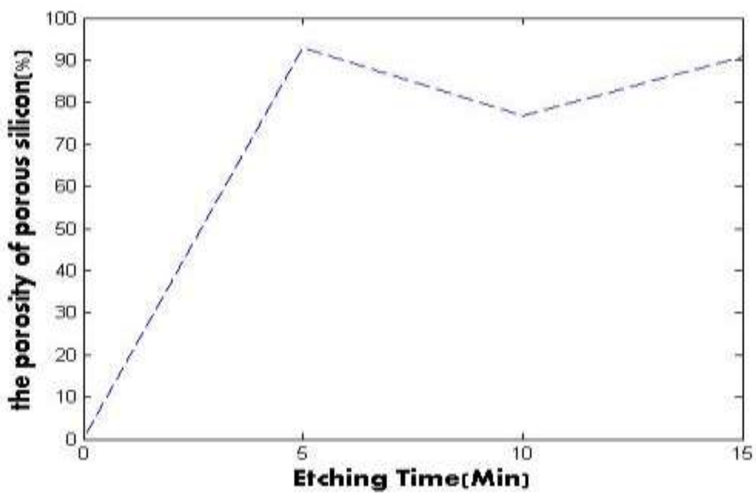

Figure (3) the relationship between porosity and Etching time

The porosity of the porous silicon as a function of the anodization time is showing in the figure(3),one can see the corresponding between figure (2) and (3) for example for the sample with etching time(5min) the layer thickness is (15µm) which have porosity(92.8%) this give us to that in this time the minority carriers in the surface of silicon would be fast generation with high absorption energy and secondary generation for the charge carriers and after duration time the nearest pores would be combined, leading fraction a mission of void from porous silicon layer continuously until losing all pores would be vanished after then initiating new pores with narrow width[14].From that centrally the refractive index will be

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decrease according to equation (4) as show in figure(4) and physically this due to the mixture between the air and nanostructure of silicon then the refractive index of silicon convert to a new substance consist of two matters.

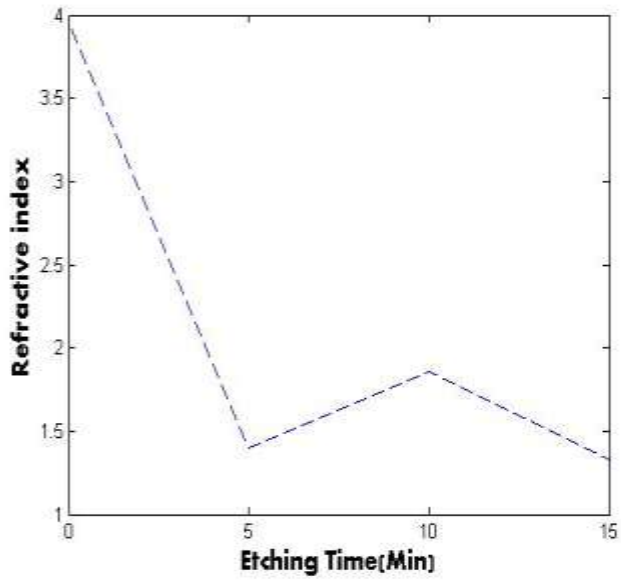

Figure (4):The relationship between Refractive index and

In the same result and reason for the relative permittivity as in the figure(5) which indicator to reduction for the relative permittivity of porous silicon with respect to the process time, this indicator to form two layer the above layer porous silicon and the bottom bulk silicon, the fluctuation in the relative permittivity for the two layers causes to form device like diode P-N junction and many researchers devoted for this application[13,17].

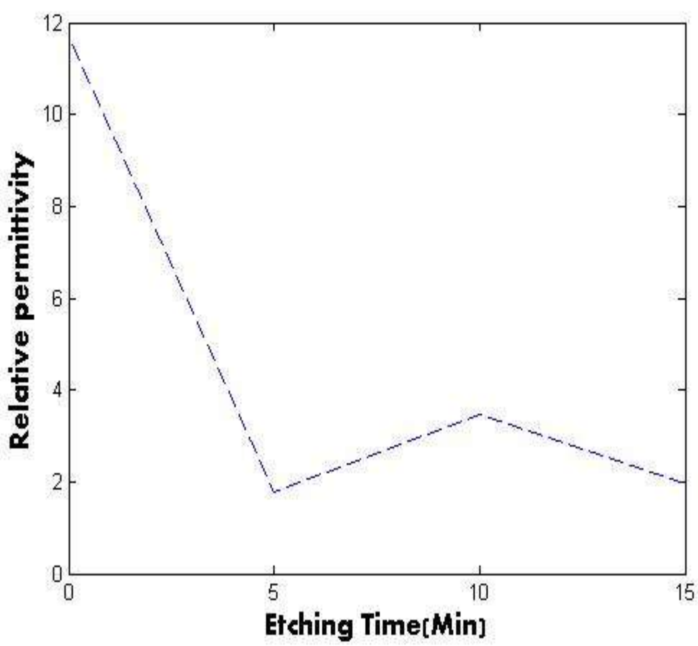

Figure (4): The relationship between Relative permittivity and Etching

Figure (5) show the capacitance for the porous silicon as a function of anodization time from this figure one can see the depending of the capacitance on the depleted of the charge carriers which correlated to the anodization time [18].

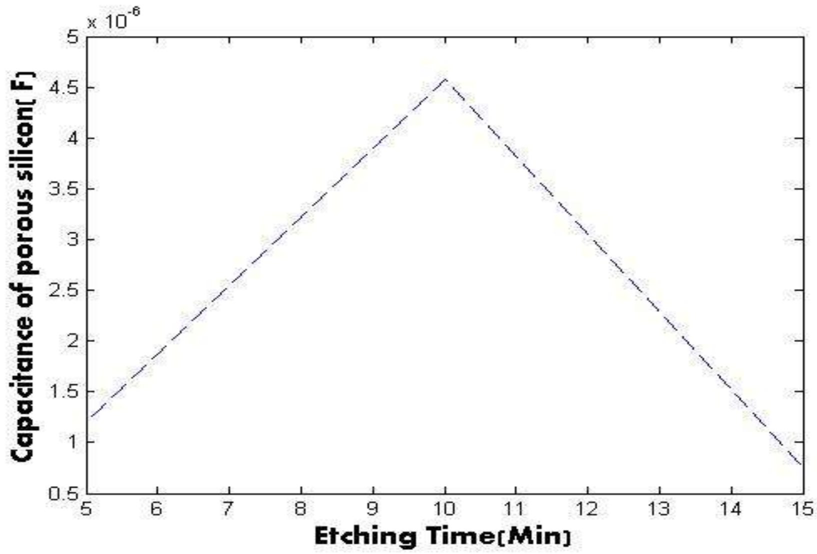

Figure (5): The relationship between Capacitance of porous silicon and

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