Study of Some Structural Properties of Porous Silicon Preparing by Photochemical Etching

N.A.A.AL-Temeeme, Ghaida.S.M

Department of Physics, College of Science, University of Baghdad, Jadiriya, Baghdad, Iraq

Abstract

Porous Silicon (PSi) has been produced in this work by using Photochemical (PC) etching process by using a hydrofluoric acid (HF) solution. The irradiation has been achieved using quartz-tungsten halogen lamp. The influence of various irradiation times on the properties of PSi material such as layer thickness, etching rate and porosity was investigated in this work too.
The XRD has been studied to determine the crystal structure and the crystalline size of PSi material

Keywords
Porous silicon, Photochemical, Structural properties

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دراسة بعض الخصائص التركيبية للسليكون المسامي و المحضر بأستخدام طريقة التنميش الكيميائي –الضوئي

د. نذيرة عباس، غيداء سلمان

قسم الفيزياء – كلية العلوم – جامعة بغداد – الجادرية – بغداد – العراق

الخلاصة:

في هذا البحث، تم تحضير السيلكون المسامي بأستخدام طريقة التنميش الكيميائي –الضوئي وباستخدام حامض (HF). لقد تم استخدام المصدرالضوئي(كوارتز-تنكستن هالوجين) . وكذلك تم في هذا البحث دراسة تأثير زمن التشعيع على بعض خصائص السيلكون المسامي مثل سمك طبقة السيلكون المسامي ،معدل التنميش والمسامية . وكذلك تم دراسة حيود الأشعة السينية لمعرفة البناء البلوري لكل من السليكون والسليكون المسامي.

Introduction

Porous silicon is the material obtained by anodic oxidation of monocrystalline silicon in past three decades, a great deal of studies have been concentrated by using a hydrofluoric acid which was first reported by Uhlir and Turner. Most interest was concentrated at its characterization and measurements of various properties mostly because of its promising application in the silicon-on-insulator technologies [1]. Porous silicon (PSi) can be considered as a silicon crystal having a network of voids in it. The nanosized voids in the silicon bulk result in a sponge- like structure of pores and channels surrounded with a skeleton of crystalline silicon nanowires [2]. Porous silicon is usually prepared by anodization in aqueous hydrogen fluoride (HF). It is also possible to employ a photochemical technique, which does not involve an externally applied bias [4]. Porous silicon has attracted great deal of interest due to efficient room-temperature visible photoluminescence, which for the first time was observed by Canham in 1990[4]. Various explanations have been proposed for the strong visible luminescence from porous silicon, the most popular being quantum confinement in nanometer-size silicon crystallites [5].

Since the most important parameters of the PSi layers are its porosity and thickness, our investigations were focused on how these properties change on varying of etching times. In this paper, the dependence of these parameters on the etching times is presented.

Experimental Work

A commercially available mirror- like n- type (111) oriented wafer of (3.84x10^{-4} Ω.cm) resistivity was rinsed with ethanol and distilled water to remove any dirt on the surface, and then immersed in electronic grade HF acid. The immersed wafer was mounted on two Teflon plates and irradiated at normal incidence in such a way that the current could pass from bottom surface to light irradiation area on the top polished surface through the electrolyte as shown in Figure (1). The light beam of quartz Tungsten halogen lamp of power density (0.56 W/cm^2) integral with dichroic ellipsoidal mirror has been focused on a silicon wafer.

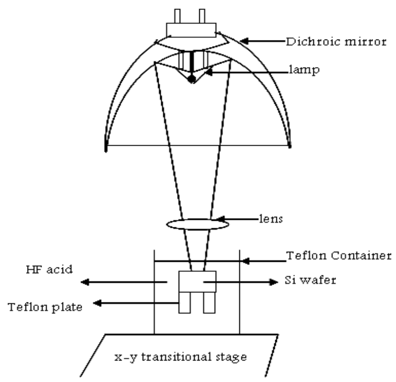

Fig. (1): The schematic diagram of thephotochemical etching process.

The wafers were etched of (16%wt) HF concentration, light power density (0.56 W/cm^2), and at different etching times.

The value of the mean porosity over the thickness of PSi layer and the thickness of PSi layer were determined gravimetrically.

Results and Discussion

Porous silicon layer thickness has been measured at various irradiation times (15-90 min) , HF concentration (16 % wt), and for power density (0.56 W/cm^2) for n -type Si wafer with resistivity(3.84x10^{-4} Ω.cm).

Figure (2) shows the relation between PSi layer thickness and etching time. From this figure, one can observe two distinct regions, at short irradiation time in which the thickness increases with increasing etching time, whereas the thickness of the PSi layer decreases with increasing the time at long irradiation time. Also, we can observe from this figure that the maximum value of the thickness is at irradiation time (t=30 min) which is equal to about (16 μm).

This exponential relation between the irradiation time and PSi layer thickness is due to the reduction in the photo-generated carriers' concentration in the porous region, and then increasing the concentration in the bulk. Therefore, the etching process and excessive etching lead to the dissolution of the porous silicon layer itself and the decreasing of the PSi layer thickness. This behavior is close to the result obtained by Fekih et al. [6].

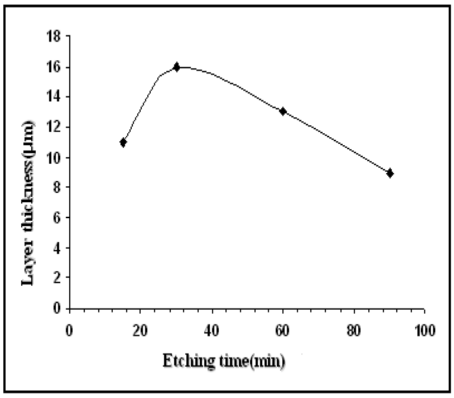

Fig. (2): The relation between layer thickness and etching time.

The relation between the etching rate and the irradiation time is shown in figure (3). In this case, the samples were immersed in HF acid with a concentration of (16 %wt) and irradiated for different durations with light power density (0.56 W/cm^2). It is observed from this figure that after a certain value of etching time and with increasing etching time the etching rate is reduced. This is due to the increasing of etching time causes the decreasing of the PSi layer thickness and the concentration of the charge carriers changes and also the etching rate decreases in the direction of silicon wafer; therefore, with increasing of etching time, the etching rate would be reduced gradually. This result is comparable with the results obtained by other researchers [7].

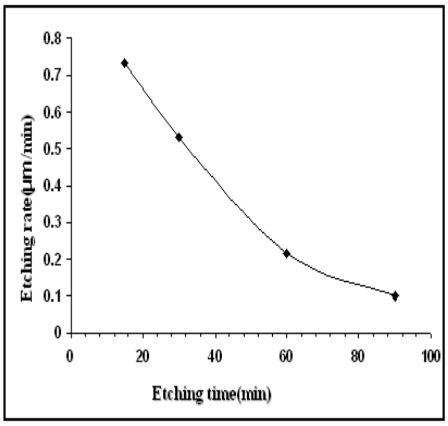

Fig. (3): The relation between etching rate and etching time.

Figure (4) shows the relationship between porosity and etching time of the prepared PSi layer at different irradiation time (15-90 min), (16%wt) HF concentration, and power density of (0.56 W/cm^2). From this figure, we can see that the values of porosity are increasing with increasing of etching time. This result is ascribed to the increasing of the number and width of the pores with increasing of etching time. Our result agrees with outcomes of [2, 8].

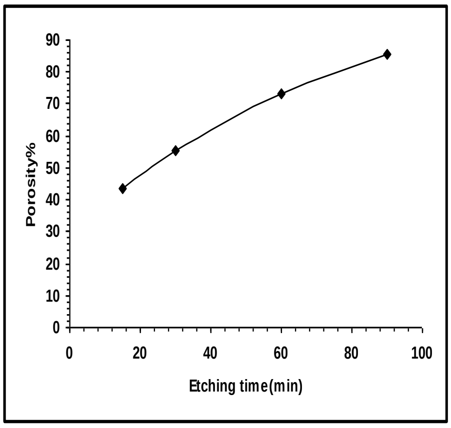

Fig. (4): The relation between porosity and etching time.

Figure (5) illustrate X-ray diffraction of crystalline silicon and PSi material respectively. It is observed from this figure that the peak of PSi has high value of intensity and expansion, compared with silicon peak. This result is caused by the ray diffraction from crystals with nano-size in the walls between pores. Consequently, we can confirm that the PSi layer remains crystalline, but it is slightly shifted to a smaller diffraction angle. This result is attributed to effect of strain which leads to a little expanded lattice parameter and then PSi peak is displaced to small diffraction angle diffraction [9].

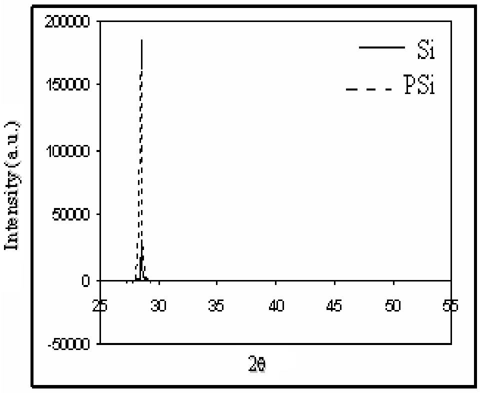

Fig. (5): The X-ray diffraction measurements of silicon and PSi layer.

The nanocrystal size for PSi was calculated according to Scherrer equation [10] and it is equal to ~29.7 nm.

Conclusion

The variation of the etching time during porous silicon formation causes dramatic change in the porous silicon parameters. We found that the relation between the layer thickness and the irradiation time is exponential**.** It is observed that after a certain value of etching time and with increasing etching time the etching rate is reduced. Also, the values of porosity are increasing with increasing etching time. It is observed from the X-ray diffraction of crystalline silicon and PSi material that the peak of PSi has high value of intensity and expansion, compared with silicon peak.

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