Study of the Characteristics of Porous Silicon by Electrochemical Etching

Hasan Hadi Hussein
University of Technology, Department of Applied Sciences/ Baghdad
Email: hhh_alkadhimy@yahoo.co.uk

Received on: 25/4/2012 & Accepted on: 24/6/2012

ABSTRACT

In this work, the nanocrystalline porous silicon layer is prepared by electrochemical etching of p-type silicon wafer. The morphological films characterized have been studied of the by atomic force microscopy, XRD and FTIR spectroscopy.

The atomic force microscopy investigation shows the average diameter pore is increasing with increase of etching time.

The X-ray diffraction investigates of the porous silicon layer is shown the broadening the width of the peak compare with the bulk silicon is directly correlated to the size of the nano-scale. The FTIR spectra for porous silicon are shown that the dominant bonds being Si-H groups.

Keywords: porous silicon; Electrochemical etching; morphological; FTIR

دراسة خصائص السليكون المسامي بواسطة التنميش الكهروكيميائي

الخلاصة

في هذا العمل تم تحضير طبقة السليكون المسامية بتقنية القشط الكهروكيمياوي لشريحة سليكون نوع موجب (حاملات الشحن الاغلبية هي الفجوات). درست خصائص الاغشية المورفولوجية بمجهر القوة الذري وحيود الاشعة السينية ومطياف تحويل فورير للاشعة تحت الحمراء.اظهرت اختبار مجهر القوة الذري زيادة معدل قطر تجويف السليكون المسامي مع زيادة زمن القشط.

اما نتائج حيود الاشعة السينية لطبقة السليكون المسامي اظهرت توسع عرض القمة بالمقارنة مع السليكون الحجمي حيث يشير الحجم بمقياس النانو.اظهرت اطياف تحويل فورير للاشعة تحت الحمراء هيمنة مجاميع اواصر سليكون – هيدروجين الفعالة.

الكلمات المرشدة:السيليكون المسامي, التنميش الكهروكيميائي, القشط الكهروكيميائي

INTRODUCTION

Porous silicon can be considered as a silicon crystal having a network of voids in it. The nanosized voids in the Si bulk result in a sponge-like structure of porous and channels surrounded with a skeleton of crystalline Si nanowires

https://doi.org/10.30684/etj.31.1B.5
2412-0758/University of Technology-Iraq, Baghdad, Iraq

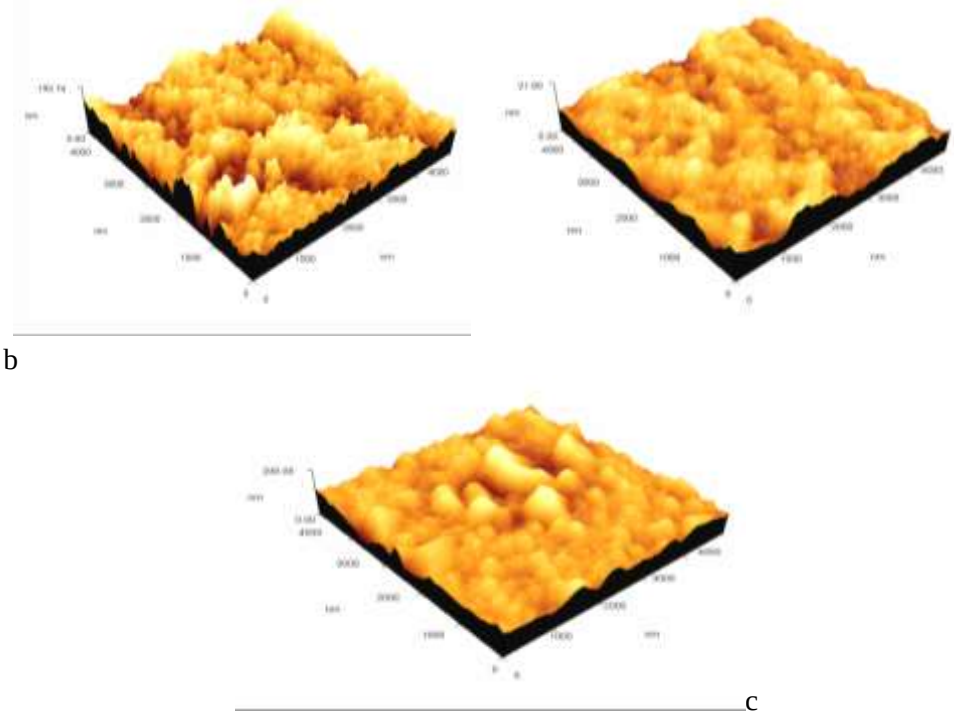
[1]. The physical properties of porous silicon are fundamentally determined by the shape and diameter of pores, the thickness and the relative content of Si, voids, and in some cases with existing silicon technology therefore has a wide area of potential applications such as waveguides, 1D photonic crystals, chemical sensors, biological sensors, photovoltaic devices etc. [5]. PS can be a bioactive, a bioinert or a resorbable material, depending on the morphological, chemical and electrical characteristics of the surface layer and those of the biological environment in which it is inserted [6].

EXPERIMENTAL WORK

Samples used in this study are boron doped p-type crystalline silicon (c-Si) wafers (thickness 508±15μm and resistivity 1.5-4 Ω.cm grown by Czochralski (CZ) method in (111) orientations. Initially these crystals are characterized by XRD-6000 SHIMADZU Japan, FTIR IRAffinity-1 Fourier Transform Infrared Spectrophotometer SHIMADZU and AFM the atomic force micrographs were taken for porous silicon by AA3000 Scanning Probe Microscope Angstrom Advanced Inc/U.S.A.The porous samples were then prepared by electrochemical anodic dissolution of doped silicon in 40% hydrofluoric acid and ethanol with gold electrode as cathode. The electrolyte was prepared by mixing HF (40%) and ethanol in 1:1 ratios.

RESULTS AND DISCUSSION

When etching time increases a part of pores coagulate to larger structures. Figure (1), shows the 3D AFM image of porous silicon in which the irregular and randomly distributed nanocrystalline silicon pillars and voids over the entire surface can be seen. Table (1) gives the roughness average, root mean square and average diameter pore.



a

b

c

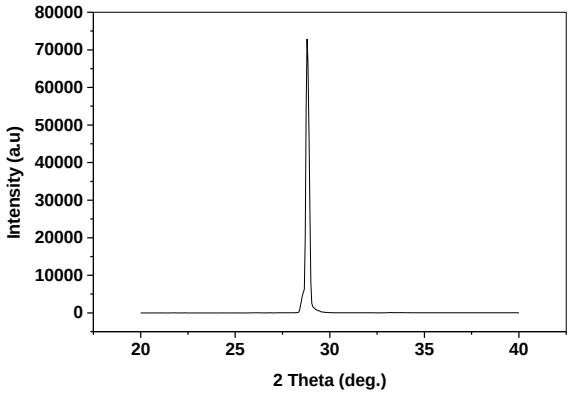
Figure (1): 3D AFM image of porous silicon prepared

at J=15 mA/cm^2 etched under different etching time (a) 10 and (b) 30 and (c) 45 min.

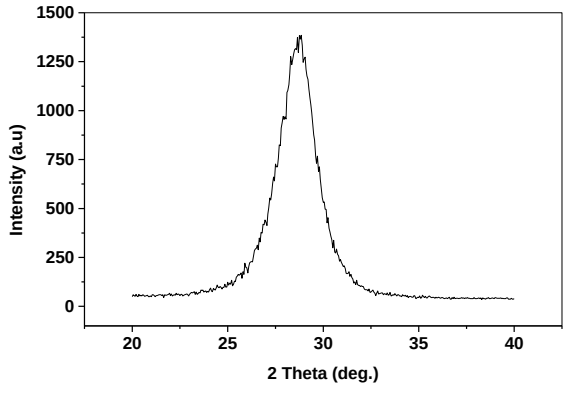
Table (1): The calculated morphology characteristics of PS samples prepared with different etching time.

Current density (mA/cm^2)	Etching Time (min)	Roughness Ave. (nm)	RMS (nm)	Ave. Diameter (nm)
15	10	1.46	1.83	29.88
	30	19.5	24.6	143.29
	45	13.1	17.6	224.67

One important property of porous silicon is that its skeleton maintains the structure of silicon crystalline after anodization, as shown by X-ray topography studies. Figure (2). When crystal size is reduced toward nanometric scale, then a broadening of diffraction peaks is observed and the width of the peak is directly correlated to the size of the nanocrystalline domains [7].



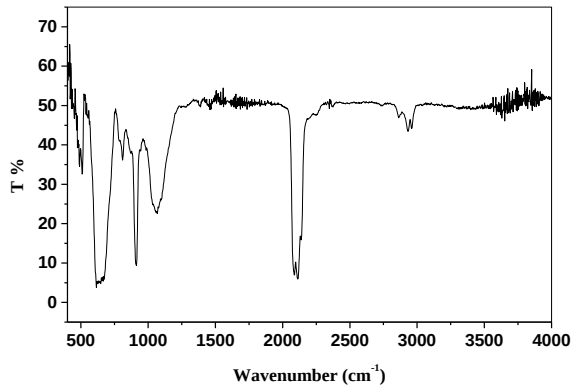
(a)



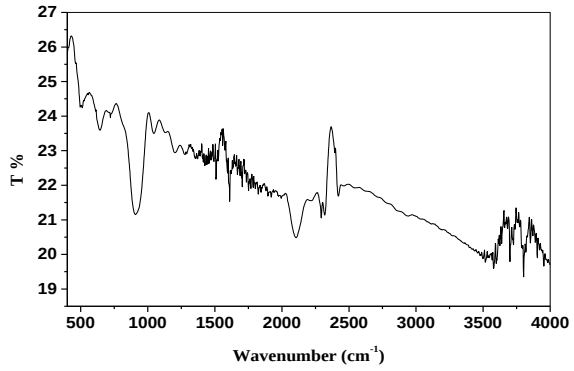
(b)

Figure (2): Shows X-ray diffraction of (a) bulk silicon (b) porous silicon prepared by current density 15 mA/cm^2 and etching time 30min

The FTIR spectra of the p-type porous silicon are shown in curve (a) and (b), in Figure (3) show the FTIR spectra measured from samples prepared at current density 15 mA/cm^2 and etching time (a) 10 min. and (b) 45 min. Chemical bonds and their infrared resonance positions detected in PS agree with some article such as [1,8,9] are shown in Table (2).



(a)



(b)

Figure (3): IR transmittance spectrum of a PS layer (a) 10 min (b) 45 min at current density 15 mA/cm^2

Table (2): Wavenumber positions and attributions of the Transmittance peaks observed in several PS (15 mA/cm^2 and 45 min) by Fourier transform infrared absorption FTIR measurements.

Peak position (cm^{-1})	Attribution
644.22	Si-H_2 wagging
908.47	Si-H_2 scissor
1045.42	Si-O stretching in O-SiO and C-SiO
1203.58	SiCH bending
1423.47	C-H_3 asymmetric deformed
1705.07	C-O
2104.34	Si-H stretch. (Si_3-SiH)

2939.52	CH stretch. (CH2)
3580.77	OH stretch. (SiOH)

CONCLUSIONS

The atomic force microscopy investigation shows the average diameter is increasing with increase of etching time. The changes of the rough silicon surface morphology due to the etching with slightly different anodic etching time.

From the XRD properties we have shown the porous structure and the decrease of the Si nanosized because a broadening of the Si peaks. The result of FT-IR show that the dominant bonds being Si-H groups.

REFERENCES

[1]. Edit Pap. A, Investigation Of Pristine And Oxidized Porous SILICON,OulunYliopisto, Oulu(2005).

[2].Uhlir.A, "Electrolytic shaping of germanium and silicon", the BellSystem Technical Journal, 35, 333 (1956)

[3].Canham, L. T, Appl. Phys. Lett. 67, 1046, (1990).

[4].Canham,L. T, "Properties of porous silicon" INSPEC, England, (1998).

[5].Dubey.R.S, Gautam.D.K, "Synthesis and Characterization of Nanocrystalline Porous Silicon Layer for Solar Cells Applications", Journal of Optoelectronic and Biomedical Materials Volume 1, Issue 1, 8-14, March (2009).

[6].Ioanid.A, Dieaconu .M, Antohe. S, "A Semiempirical Potential Model for H-Terminated Functionalized Surface of Porous Silicon", Digest Journal of Nanomaterials and Biostructures Vol. 5, No 4, 947-957 October-December (2010).

[7].Lorusso. A, Nassisi.V, Congedo. G, Lovergine. N, Velardi .L, Prete .P, "Pulsed plasma ion source to create Si nanocrystals in SiO_2 substrates", Applied Surface Science, 255, 5401-5404 (2009).

[8].Yue Zhao, Deren Yang, Dongsheng Li, Minghua Jiang, "Annealing and amorphous silicon passivation of porous silicon with blue light emission", Applied Surface Science 252, 1065–1069 (2005).

[9].Bisis, Ossicini .S,Pavesi.L, "Porous silicon: a quantum sponge structure for silicon based optoelectronics", Surface science reports 264, (2000).