ISSN : 0974 - 7494 Volume 8 Issue 7

Nano Science and Nano Technology

An Indian Journal

Full Paper

NSNTAIJ, 8(7), 2014 [279-283]

Synthesis and characterization of nano crystalline porous silicon layer for solar cells applications

Nadir F.Habubi[1]*, Raid A.Ismail[2], Ahmed N.Abd[3]

[1]Physics Department, Education Faculty, The University of Mustansiriyah, Baghdad, (IRAQ)

[2]Department of Applied Sciences, The University of Technology, Baghdad, (IRAQ)

[3]Physics 3 Department, Science Faculty, The University of Mustansiriyah, Baghdad, (IRAQ)

E-mail : nadirf61@gmail.com

ABSTRACT

Porous silicon (PS) layers were fabricated on P-type crystalline silicon (c-Si) wafers of (100) orientations using electrochemical etching (ECE) process at a different etching time (7, 15 min), current density of 7 mA/cm^2, and fixed electrolyte solution HF:C_2H_5OH (1:1). Nanopores with an average diameter of (19.47, 22.70nm) were formed in the p-PS (100) layer. The lowest effective reflectance was obtained with the p-PS/CdSe layer that exhibited excellent light-trapping at wavelengths ranging from 400 to 1000 nm. Solar cells were fabricated based on the PS anti-reflection coating (CdSe) layers. The current-voltage characteristics of the solar cells were examined under 127W/cm^2 illumination, A highly efficient (3.5%,6%) for ps in (7, 15min) then The objective of the present study was to fabricate highly efficient solar cell (6%, 12.25%) respectively using Al/c-Si/ p-PS /CdSe/Al.

KEYWORDS

Porous silicon;
Quantum dots;
Solar cell.

BACKGROUND

Porous silicon is well-known and useful material for many applications, such as for photodiodes[1-3], solar cells[4,5], etc. Stain etching of silicon provides a spontaneous, self-limiting chemical method to produce nanocrystalline silicon films (porous Si), which exhibit photoluminescence (PL) properties[6,7]. PS has attracted attention due to the property of PL in the visible light range. Over the past fifteen years many different models have been elaborated interpreting the visible light luminescence in PS, several overviews have been published to weigh arguments for/against to understand this phenomenon[8].

Semiconductor nanoparticles have attracted much attention during the last few years because of their unique optical and electronic properties, which might have a great potential in many applications, such as light emitting diodes, lasers, luminescent nanocomposites, diagnostic agents in medicine and solar cells[9-13]. In recent years, quantum-dot (QD semiconductors such as CdS[14,15], PbS[16,17], and CdSe[18-21] have been employed as sensitizers due to two specific advantages. First and foremost, the size quantization effect allows one to tune the band energy and visible response by simply varying the QD size[22]. Another advantage is that these QDs open new ways to utilize hot electrons or generate multiple electron-hole pairs with one single proton through the impact ionization effect[23].

The present work deals with the fabrication of Al/ p-PS/c-Si/CdSe/Al solar cell prepared by formation of porous silicon on p-type silicon wafers with the aid of electrochemical etching and study the structural, electrical, optoelectronic, and figures of merit of porous silicon layer and solar cell devices synthesized at different conditions.

EXPERIMENTAL DETAILS

The p-PS layers were fabricated by anodic etching where a p-type silicon substrate was placed in the Teflon etching cell using a mixture of aqueous hydrogen fluoride (purity 40%) and ethanol (purity 99.99%), 1:1 by volume. The sample was anodized at a current density of 7mA/cm^2 and at different etching time (7,15min).No further chemical or thermal treatment was carried after etching. The CdSe core- shell colloidal QDs absorbed on the internal pores within PS were then prepared by dipping the PS using CdSe QDs (1mg) dissolved in toluene (100 ml) and evaporating toluene at room temperature for 50 min.

RESULTS AND DISCUSSIONS

The PS is produced by anodisation of Si wafers in a solution HF: C_2H_5OH (1:1). With current density (7mA/cm^2) and two different times (7,15min), this imposes that the PS formation does not cause any damage to the electrical contacts. The PS formation mechanism in chemical etching depending on solution concentration, temperature, and etching time.

The porosity was controlled by gravimetrical methods and calculated by equations[24]:

$$p(m)\% = \frac{m_1 - m_3}{m_1 - m_2} \quad (1)$$

Where m_1 is initial substrate weight, m_2 weight after anodisation, and m_3 weight after removing the PS layer in the NaOH mixture.

Figures 1,2 demonstrates the AFM images of the PS layer formed on the p-PS (7,15min) samples. Pores with sphere-like appearances and thick walls were evidently randomly distributed on the PS surface. A modest density of pores was observed, and porosity was approximately (45%,72%), the surface of the p-PS samples cracked, and numerous new pores evidently formed inside the cracks.

The average pore diameter (d) for two samples of PS layer formed on the p-PS (100) wafers were (19.47&22.70nm) and calculated using AFM. Then the optical energy gap E (eV) was calculated using equation[25-28]:

$$E_{(eV)} = E_g + \frac{h^2}{8\,d^2}\left\{\frac{1}{m_*^2} + \frac{1}{m_h^2}\right\} \quad (2)$$

Where $E_{(eV)}$ is the energy band gap of the p-PS layer, E_g is the energy band gap of bulk c-Si= 1.12eV, h is Planck's constant = 4.13×10^{-15} (eV. s), Whereas m_- and m_h are the electron and hole effective masses, respectively (at 300 K, m_- =0.19 m_0, m_h = 0.16 m_0, and m_0 = 9.109×10^{-31} kg.

The absorption spectra of PS, PS-QD samples and PS/CdSe are shown in Figure 5. Measured absorption of both PS and PS-QD samples was very similar, and it was the same at 550 nm, where PL peak in PS-QD sample was detected. The absorption maxima of PS

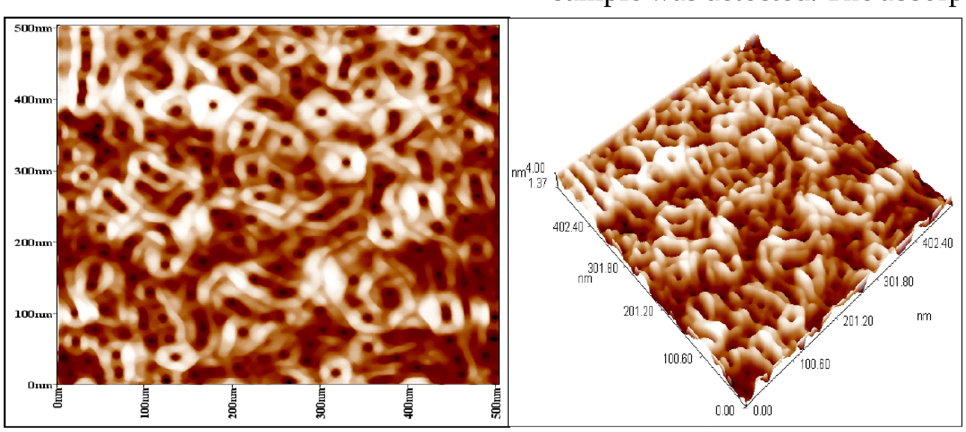

Figure 1 : 2D&3D AFM images of PS surface at constant current density 7mA/cm^2 and at 7min etching time for p-type (500nm×500m)

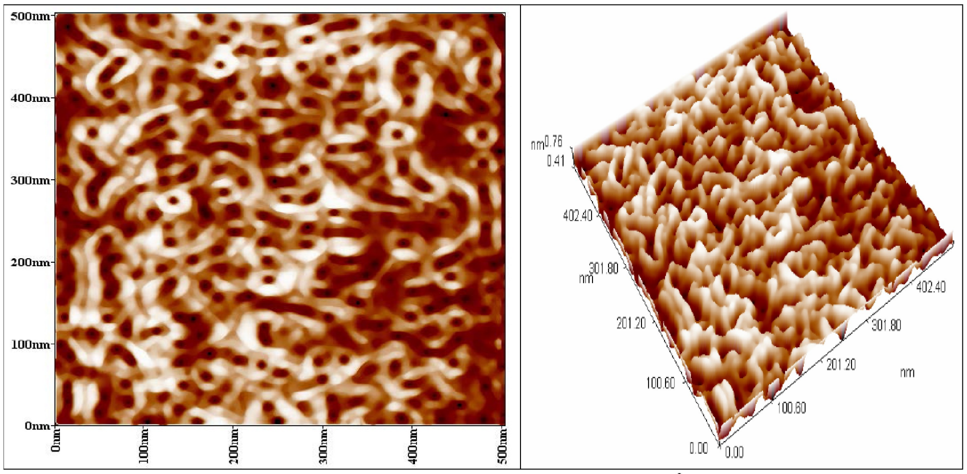

Figure 2 : 2D AFM images of PS surface at constant current density 7mA/cm² and at 15min etching time for p-type (500nm×500m)

and PS/CdSe samples were found at 610nm. Detected absorption of PS is very similar to ps/CdSe absorption, the absorption investigation of QDs in the range from 400 to 900 nm.

The maximum absorption of the PS/CdSe layer formed on the P-type c-Si (100) has been observed at 639 nm (1.940 eV) with a full-width and half maximum of approximately 145 nm as a result of the high porosity and completely etched PS layer of this sample. This phenomenon indicates that PL intensity is proportional to the number of emitted photons on the PS surface.

The lowest effective transmission was obtained from the PS layer formed on the P-type c-Si (100) sample, which evidently reduced light reflection and increased light-trapping at wavelengths from 400 to 1000 nm. Figure 4 shows dark current – voltage in forward and reverse directions of three samples measurements carried out by applying voltage supplied to the most of the sample from (0-25)V.

Figure 4, represented (I-V) characteristics of the junction in the figure can be explained as in the following observations; nonlinear behavior: (at low voltages), that's mean under the forward bias condition; it shows the exponential increase in current,. Under reverse bias, for all cases, it is clear that the curves contain two regions; in the reverse bias and at the same values of the voltage, reverse current is slightly increased with the applied voltage and this leads to generate electron-hole pairs at low bias (for zero applied voltage exactly balances the diffusion current).

The efficiency of a solar cell is the ratio of the electrical power it delivers to the load, to the optical power incident on the cell. It can be seen from Figure 4 that the solar cell with the CdSe layer based p-PS

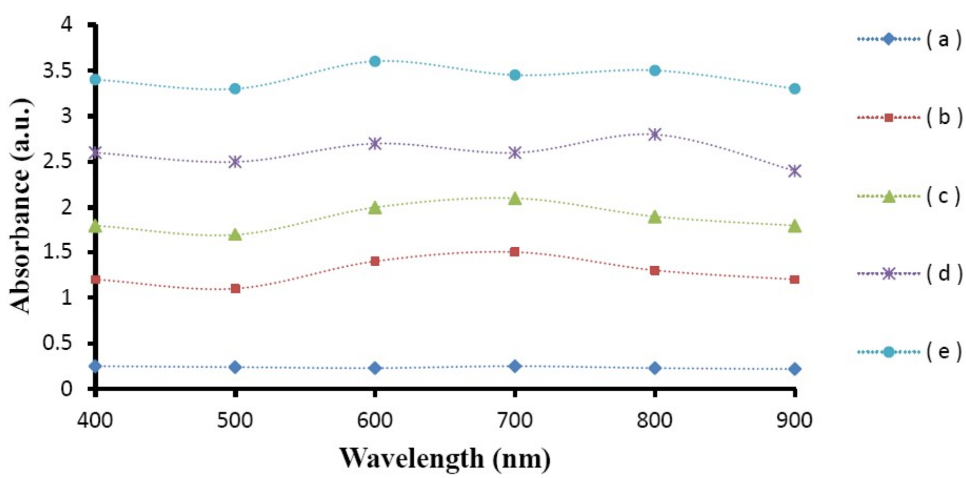

Figure 3 : Spectral absorption for, (a) c-Si, (b) p-PS at 7min etching time, 7mA/cm² current density, (C) p-PS at 15min etching time, 7mA/cm² current density. (d) p-PS /CdSe at 7min etching time, 7mA/cm² current density and (e) p-PS/ CdSe at 15min etching time, 7mA/cm² current density

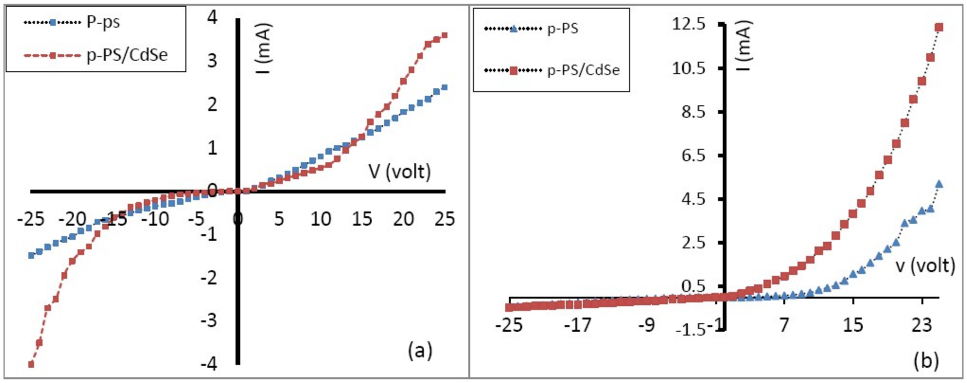

Figure 4 : I –V curves in 7mA/cm^2 current density, (a,b) at etching time (7, 15min) respectively

displays an increased short-circuit current (Isc) from 4.5 to 12.5 m A in open-circuit voltage (Voc) 25 volt in PS/CdSe mV, leading to an increased conversion efficiency from 8.8 to 12.25% for etching time 15min and from (3.5 to 6%) for etching time 7min.

CONCLUSIONS

Porous silicon (p-type) has much different structures and its pore diameter varies from nanometer to micrometer, according to the etching conditions as shown by the experimental results of AFM.

The C- V measurement revealed that the junctions are abrupt and the biotin- potential values are strongly dependent on the etching conditions. The porosity of silicon changes the response spectrum region of the detector.

All the solar cell is working for visible and near infra-red (400-800) nm regions. The Al/c-SI/p-PS/CdSe/Al exhibited has good efficiency at 7mA/cm^2,15 min etching time.

REFERENCES

[1] W.J.Aziz; Simulation, fabrication and characterization of multilyer coated solar cells, in: School of Physics, University Science Malaysia, Penang, **(2011)**.

[2] V.Torres-Costa, R.J.Martín-Palma, J.M.Martínez-Duart; J.Appl.Phys., **96**, 4197 **(2004)**.

[3] P.Vitanov, M.Delibasheva, E.Goranova, M.Peneva; Sol.Energy Mater.Sol.Cells., **61**, **(2000)**.

[4] M.Rajabi, R.Dariani; J.Porous Mater., **16**, 513 **(2009)**.

[5] S.I.Na, S.S.Kim, W.K.Hong, J.W.Park, J.Jo, Y.C.Nah, T.Lee, D.Y.Kim; Electrochim.Acta, **53**, 2560 **(2008)**.

[6] L.Hyunwoo, E.Lee, L.Soohong; Investigation of nano-porous silicon antireflection coatings for crystalline silicon solar cells, in: Nanotechnology Materials and Devices Conference, NMDC 2006. IEEE, 2006, 340-341 **(2006)**.

[7] P.L.Ossicini, F.Priolo; Light emitting silicon for microphotonics, Springer-Verlag, Berlin Heidelberg, **(2003)**.

[8] N.Jeyakumaran, B.Natarajan, S.Ramamurthy, V.Vasu; IJNN, **3**, 45 **(2007)**.

[9] C.H.Chen, Y.F.Chen; Solid State Commun., **111**, 681 **(1999)**.

[10] K.Omar, Z.Hassan, A.Ramzy, H.Abu Hassan; JOAM, **11**, 1641 **(2009)**.

[11] A.Ramizy, Z.Hassan, K.Omar; J.Mater.Sci.: Mater.Electron., **22**, 717 **(2011)**.

[12] M.A.Vasquez-A., G.Aguila Rodriguez, G.Gracia-Salgado, G.Romero-Raredess, R.Pena-Sierra; Revista Mexicana De Fisca, **53(06)**, 431 **(2007)**.

[13] V.Agrawal, J.A.del Rio; Appl.Phys.Lett., **82(10)**, 1512 **(2003)**.

[14] R.S.Dubey, D.K.Gautam; Optoelectron.Adv.Mater. Rap.Comm., **1(9)**, 436 **(2007)**.

[15] J.E.Lugo, H.A.Lopez, S.Chan, P.M.Fauchet; J.Appl. Phys., **91(8)**, 4966 **(2002)**.

[16] S.Setzu, P.Ferrand, R.Romestain; Mater.Sci. & Engg., **70(34)**, **(2000)**.

[17] P.Ferrand, D.Loi, R.Romestain; Appl.Phys.Lett., **79(19)**, 3017-3019 **(2001)**.

[18] C.J.Oton, L.Dal Negro, Z.Gaburro, L.Pavesi, A.Lagendijk, D.S.Wiersma; Phys.Stat., Sol., **197(1)**, 298 **(2003)**.

[19] Jun-Ho Yum, Sang-Hyun Cho; CdSe Quantum Dots Sensitized TiO2 Electrodes for Photovoltaic Cells, Journal of the Korean Electrochemical Society, **10(4)**, **(2007)**.

[20] Antonio Luque, Antonio Marti, J.Arthur; Solar Cells Based on Quantum Dots, MRS Bulletin, **32**, **(2007)**.

[21] Ivan Mora Sero, Sixto Gimenez; Factors determining the photovoltaic performance of a CdSe quantum dot sensitized solar cell: the role of the linker molecule and of the counter electrode, Nanotechnology, **19**, **(2009)**.

[22] W.Shockley, H.J.Queisser; J.Appl.Phys., **32**, 510 **(1961)**.

[23] R.Schaller et al.; Seven excitons at a cost of one: redefining the limits of conversion efficiency of photons into charge carriers. Nano Letters, **6(3)**, **(2006)**.

[24] Arthur J.Nozik; Multiple exciton generation in semiconductor quantum dots. Chemical Physics Letters, **3**, **(2008)**.

[25] Jeaho Park, Kwan Hyi Lee, Justin F.Galloway; Synthesis of CdSe Quantum Dots from a Non – Coordinating Solvent: Growth Kinetics and Particle Size Distribution. J.Phys.Chem.C, **112(46)**, **(2008)**.

[26] Istvan Robel, M.K.Vaidyanathan Subramanian, J.A.C.S.ChinWon, J.Leng, Y.Lai, J.R.Williams; Quantum Dot Solar Cells. Harvesting Light Energy with CdSe., **128**, **(2006)**.

[27] M.C.Hanna, R.J.Ellingson, M.B.P.Y.O.M., A.Nozik; Quantum Dot Solar Cells: High Efficiency through Multiple Exciton Generation, **(2004)**.