Optik 168 (2018) 424–431

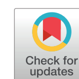
Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

High-performance nanoporous silicon-based photodetectors



Asad A. Thahe [a,b], Hazri Bakhtiar [a], Noriah Bidin [b], Z. Hassan [c], M.A. Qaeed [d], Asmiet Ramizy [e], Zainal A. Talib [f], Naser M. Ahmed [c], Khalid Omar [g], Hasan Alqaraghuli [h], M. Husham [i], Nageh K. Allam [j,*]

[a] *Physics Department, Faculty of Science, Universiti Teknologi Malaysia, 81310, Johor Bahru, Malaysia*
[b] *Laser Center, Institute Ibnu Sina, Universiti Teknologi Malaysia, Skudai, 81310, Johor, Malaysia*
[c] *Institute of Nano Optoelectronics Research and Technology, Universiti Sains Malaysia 1800 USM, Penang, Malaysia*
[d] *Hodeidah University, Al-Hodeidah, Yemen*
[e] *Department of Physics, Anbar University, 31001, Anbar, Iraq*
[f] *Department of Physics, Faculty of Science, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia*
[g] *National Chair of Materials Science and Metallurgy, Universiti of Nizwa, P.O. Box 33, PC 616, Birkat Al-Mouz, Nizwa, Oman*
[h] *Mechatronics and Automatic Control Department, Faculty of Electrical Engineering, Universiti Technology Malaysia, 81310, Johor Bahru, Malaysia*
[i] *Instituteof Advanced Technology (ITMA) Univerisity Putra Malaysia, 43400, Serdang, Malaysia*
[j] *Energy Materials Laboratory, School of Sciences and Engineering, The American University in Cairo, New Cairo, 11835, Egypt*

ARTICLE INFO

Article history:
Received 25 February 2018
Received in revised form 29 March 2018
Accepted 11 April 2018

Keywords:
Porous silicon
Etching time
Electrical properties
Photodetector

ABSTRACT

A series of porous silicon (PSi) samples was prepared using photoelectrochemical etching (PECE) method with optimum current density of 45 mA/cm^2. The as-prepared PSi samples were characterized to determine the influence of the etching time (15, 25 and 30 min) on their morphology and electrical properties. The percentage of porosity was estimated *via* gravimetric analysis. The band gap of the fabricated PSi was ≈2.22 eV. Upon their use to fabricate metal-semiconductor-metal (MSM) ultraviolet photodetectors (UVPD), the fabricated PSi revealed excellent stability and reliability under repetitive shots at 530 nm. Furthermore, very fast rise time (≈0.28 s) was obtained at a bias of 1 V under visible light (530 nm) illumination.

© 2018 Elsevier GmbH. All rights reserved.

1. Introduction

The emergent properties of porous silicon (PSi) originated from the presence of harmonious morphology of the porous layer opened a new avenue in Si-based optoelectronics. However, the performance of such devices is challenged by the ability to fabricate PSi nanostructures with the desirable characteristics. The electrochemical etching is an appropriate method to produce n-PSi with diverse morphologies. The optical and electrical properties of the grown n-PSi are greatly dependent on the porosity (size, shape, homogeneity and density distribution), morphology and fabrication conditions, which can be controlled by adjusting the etching time, current density, coating process, etc. [1]. Moreover, coating the front surface of PSi layer with n-type semiconductor material was shown to improve the crystallinity and optoelectronic properties of the material [2]. To this end, many attempts have been made to achieve PSi-based devices with optimum performance, where the

* Corresponding author.
E-mail address: nageh.allam@aucegypt.edu (N.K. Allam).

https://doi.org/10.1016/j.ijleo.2018.04.084
0030-4026/© 2018 Elsevier GmbH. All rights reserved.

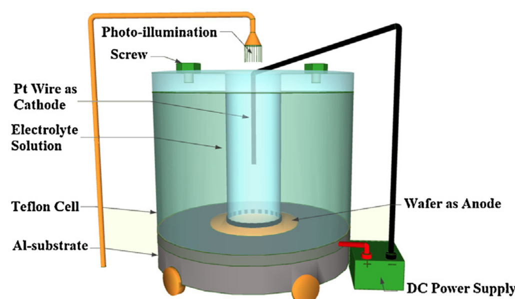


Fig. 1. The experimental set-up used for the photoelectrochemical etching of Si.

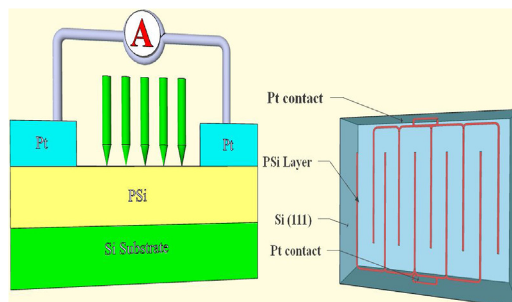


Fig. 2. Schematic diagram of the metal shadow used for the fabrication of MSM UV detectors.

emphasis was to improve the electrical and charge carrier transport properties of PSi [3]. However, the optimum synthesis conditions of n-PSi with the desirable optoelectronic properties are still far from being attained.

Based on its strong visible and ultraviolet photoluminescence at room temperature, n-PSi is recently explored for ultraviolet photodetectors (UVPDs) for medical, engineering, and technological applications [4]. Considering such demand, we attempted to optimize the electrical and optical properties of n-PSi to fabricate metal-semiconductor-metal (M-S-M) UVPDs. Specifically, the time of the photoelectrochemical etching, the applied voltage or current, the etching solution composition, and the illumination intensity were investigated to control the morphology of the grown n-PSi in a desirable manner that enhances its electrical and optical properties.

2. Experimental procedure

Single crystalline wafers of n-type Si (111) of thickness 205–306 μm were cut into squares each of an area 1.5 cm^2. Then, these wafers were cleaned following Radio Corporation of America method (RCA) prior to photoelectrochemical etching to grow n-PSi. An anodization cell made of Teflon was used, wherein the Si wafer was fixed and sealed through O-ring. The front side of the wafer was exposed to hydrogen fluoride (HF) solution (48%) containing ethanol (C_2H_6O, 99.9%) and hydrogen peroxide (H_2O_2).

Fig. 1 shows the experimental set-up for the photoelectrochemical etching process to prepare PSi. The Si wafer was immersed inside the electrolyte solution containing HF, ethanol and H_2O_2. Pure hydrogen peroxide was added to remove the H_2 gas bubbles from the sample surface that is generated during the anodization process [5]. The Si wafer was used as the anode and a platinum wire was acted as the cathode. The PSi layer was grown using the DC process inside the HF solution ($HF:C_2H_6O:H_2O_2 = 2:1:1$) at a fixed current density of 45 mA/cm^2 under external incandescent light, where three different etching times (15, 25 and 30 min) were used. The resulted PSi samples were used to design MSM UVPDs, wherein a platinum (Pt) layer of thickness ≈150 nm was deposited onto the PSi surface. The metallic Pt was suitable for developing Schottky contact because of its higher work function. The structure of MSM PD was consisted of two inter-digitated Schottky contacts (electrodes) each of a length ≈3.3 mm with finger width of 230 μm and spacing of 400 μm. Each electrode possessed four fingers as displayed in Fig. 2. The contact pad of the MSM PD array was developed after forming the metal mask fingers.

The structure of the prepared PSi samples was examined using X-ray diffraction (X-ray Diffractometer, PANalytical X'Pert Pro) in the 2θ range of 30°–80° with Cu-Kα radiation (wavelength 1.54056 Å) operated at 40 kV and 30 mA. The surface morphology of the as-prepared PSi samples was characterized using high resolution field emission scanning electron microscope (FESEM, NOVA NANO SEM 450). The metal finger mask was deposited *via* electron beam evaporator (ATO 306 vacuum coater). A Keithley electrometer (model 6517 A) was used to measure the current-voltage (*I*–*V*) characteristics and current-time (*i*–*t*) behaviour of the fabricated MSM UVPDs. The photoluminescence (PL) spectra of the PSi-based devices were recorded on a

Download English Version:

https://daneshyari.com/en/article/7223479

Download Persian Version:

https://daneshyari.com/article/7223479

Daneshyari.com