Optik 127 (2016) 10450–10456

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Study the size and distribution of thin Nano porous film of silicon substrate through chemo-thermal treatment for dry fuel cell application

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ARTICLE INFO

Article history:
Received 16 June 2016
Accepted 23 August 2016

Keywords:
Porous silicon
Fuel cell
Hydro phobic
Micro-structure

ABSTRACT

In this work, nanoporous silicon substrate is optimized and its utilization is shown through proposed porous silicon based fuel cell fabrication. Nanoporous silicon is made by electrochemical etching to form proton exchange membrane in fuel cell. Various properties of nanoporous silicon are observed such as photoluminescence, hydrophobic behavior demonstrating contact angles up to 143°. The improvement of pore quality is shown through x-ray diffraction measurement (XRD), Raman spectroscopy, reflectance measurement and surface quality is observed through the imaging of atomic force microscopy (AFM) & scanning electron microscopy (SEM). The electrical behavior is observed through the measurement of polarization (current and voltage) of fuel cell.

1. Introduction

Porous silicon is prominent for its versatile application in the semiconductor industry. Porous silicon is easily formed by electrochemical dissolution of silicon wafers in aqueous or ethanoic HF solutions [1]. Its high surface area, made it useful as a model in spectroscopic studies, as a dielectric layer in capacitance based chemical sensors and as a precursor to generate thick oxide layers on silicon in 1970s and 1980s [2]. The discovery of visible light emission from porous silicon led to the creation of silicon based optoelectronic lasers, displays and switches [3]. Porous silicon is a promising material due to its excellent optical, mechanical, and thermal properties, obvious compatibility with silicon-based microelectronics and the low cost because of which it is used in making solar cells and sensors. Also due to good optical properties and high surface area, porous silicon (p-Si) is used in a wide range of optoelectronic and sensing application [4–6]. High irradiance optical is done in structure based study on p-Si as monolayers [7–10], freestanding monolayers [11], waveguides [12], multilayers [13,14] and micro cavities [15].

In this study, porous silicon is fabricated by electrochemical etching in the presence of HF where various parameters such as etching time, type of wafer, current density and concentration of the electrolyte solution are observed and optimized. The main objective of this study is to determine the effect of the above mentioned parameters on the pore size of the electrochemically etched porous silicon and implement the fabricated porous silicon in fuel cell. Structural and morphological studies were done through FESEM and AFM.

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http://dx.doi.org/10.1016/j.ijleo.2016.08.053
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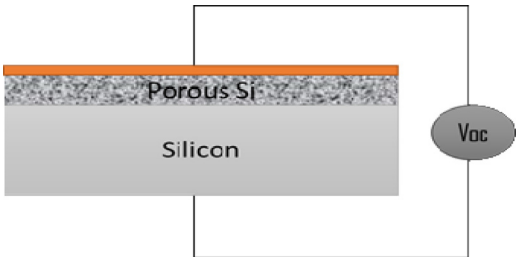

Fig. 1. Schematic representation of Fuel cell.

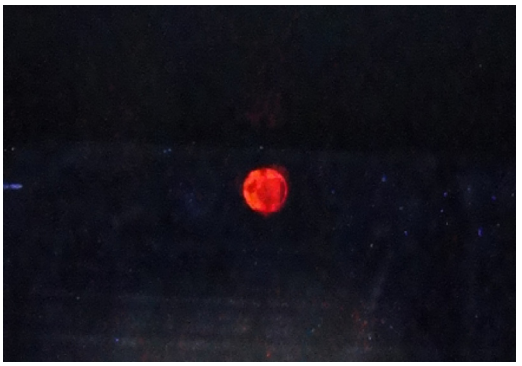

Fig. 2. luminescence of porous silicon under UV light.

2. Experimental study

Single crystal wafer of p-type (100) Si of 0.8–1 Ω cm resistance is taken as substrate. A suitable fabrication setup (anodization cell) using Teflon was made to form porous silicon. The front side of the silicon wafer is contacted with the HF-solution (HF: C_2H_5OH) and the in back side electrical connection is made through designed O-ring structure. A mixture of HF (40%) and C_2H_5OH (98%) with concentration 1:1 is making of electrolyte solution. Graphite electrode used as cathode and substrate as anode for the formation of nanopore. The maximum 30 V is applied or the experimental study. Then the etching time was varied according to the requirements. The outline of our fuel cell is: the crystalline silicon layer below the porous silicon layer is the working as anode deposited copper layer as cathode. The contact with silicon was made using e-beam deposition technique. Schematic model of proposed fuel cell is shown in Fig. 1.

Pore formation is confirmed through UV light experiment. The excitation and luminescence have been seen in porous silicon layers prepared by electrochemical anodization. Strong luminescence in the visible range of spectra at room temperature was obtained. The photoluminescence of porous silicon is due to quantum confinement effect. The porous silicon emits a reddish orange light when kept under the UV light shown in Fig. 2. It absorbs the energy in the range of UV rays and then emits the light in the visible range of spectra i.e. reddish orange color.

3. Result and discussions

There are two different aspect for the formation of porous silicon one is optimization of pores in terms of porosity, uniformity, surface roughness and contact angle. Another aspect is the formation of fuel cell. Pore distribution were studied with different current density like 10 mA/cm^2, 20 mA/cm^2, 30 mA/cm^2, 40 mA/cm^2, 60 mA/cm^2, 80 mA/cm^2, and 100 mA/cm^2.

Etching was done at low current densities (20 mA/cm^2) for 5 min in order to study their effect on the porosity and pore size. It is seen in the FE-SEM Fig. 3(a) that pores were not uniform because low current density. So from the observation it is seen that higher current density for less time is required. So for further study etching was done at 40 mA/cm^2 for 2 min and it is seen from SEM image in Fig. 3(b) that porosity is uniform but pore sizes are not uniform than the previous one. The thickness of the porous layer is large so the merging of pores has occurred and as a result the sizes of pores were formed uneven.

Fig. 4(a) & (b) shows the FESEM image of top and cross sectional view of P-type silicon wafers with electrolyte concentration (1:1) current density is kept 60 mA/cm^2 for 1 min and it is seen pore size also appears to be larger as compared to previous cases. It is may be due to less selectivity and higher current density. So the porous silicon have become very non-uniform. The merging of pores could have occurred because the defective sites on the silicon wafer might have been very closely spaced.