Optik 161 (2018) 161–165

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

Experimental study of n-type porous silicon obtained under illumination

M.R. Beghoul[a,b,*], N. Boutaoui[b], H. Bouridah[a,b], R. Remmouche[a,b], M.H. Arada[b], H. Haoues[b]

[a] Département d'Electronique, Université de Jijel, Ouled Aissa 18000, Jijel, Algeria
[b] Laboratoire d'Etudes des Matériaux (LEM), Université de Jijel, Ouled Aissa 18000, Jijel, Algeria

ARTICLE INFO

Article history:
Received 7 January 2018
Accepted 30 January 2018

Keywords:
Porous silicon
Anodization
Crystallite size
Nanocrystals
Reflectance

ABSTRACT

Porous silicon (PS) has been prepared from n-type (100) silicon substrate by using electrochemical etching under He-Ne laser illumination. The PS was produced within several etching conditions. The morphological, structural and optical properties were studied by using atomic force microscopy (AFM), X-ray diffraction (XRD), Raman analysis, and reflectance measurements. Results show that the evolution of the obtained nanostructures is strongly related to anodization conditions. The optical analysis results show that a low reflectance was obtained for samples anodized by increasing current density. This is correlated to morphological results showing the strong dependence of the obtained nanoporous structure in terms of crystallites sizes and porosity, on the anodization conditions.

1. Introduction

Porous silicon obtained from single crystal silicon substrates has attracted considerable interest taking into account the possibility of modulating its porosity and correlatively its refractive index, which is a highly appreciated quality for photonics applications (optical waveguide, photonic crystals) [1–3]. Similarly, in the photovoltaics field, porous silicon represents very attractive potential, and can be used as an antireflection layer for solar cells [4–6]. Porous silicon can also be used in sensitive elements of various sensors [7]

From the experimental point of view, the morphologic proprieties in terms of nanocristallite sizes and porosity are controlled while exploiting the current density and the etching duration of the substrates [7–11].

Indeed, by a judicious choice of these anodization conditions, the morphology of single-crystal silicon can be transformed in order to reduce considerably its reflectance [12,13].

It is in this context that the work presented in this paper was accomplished. The characterization of the obtained n-type porous silicon was carried out using several methods of investigation in order to correlate the crystallographic, morphological and optical properties.

* Corresponding author at: Département d'Electronique, Université de Jijel, Ouled Aissa 18000, Jijel, Algeria.
E-mail address: beghoul@univ-jijel.dz (M.R. Beghoul).

https://doi.org/10.1016/j.ijleo.2018.01.118

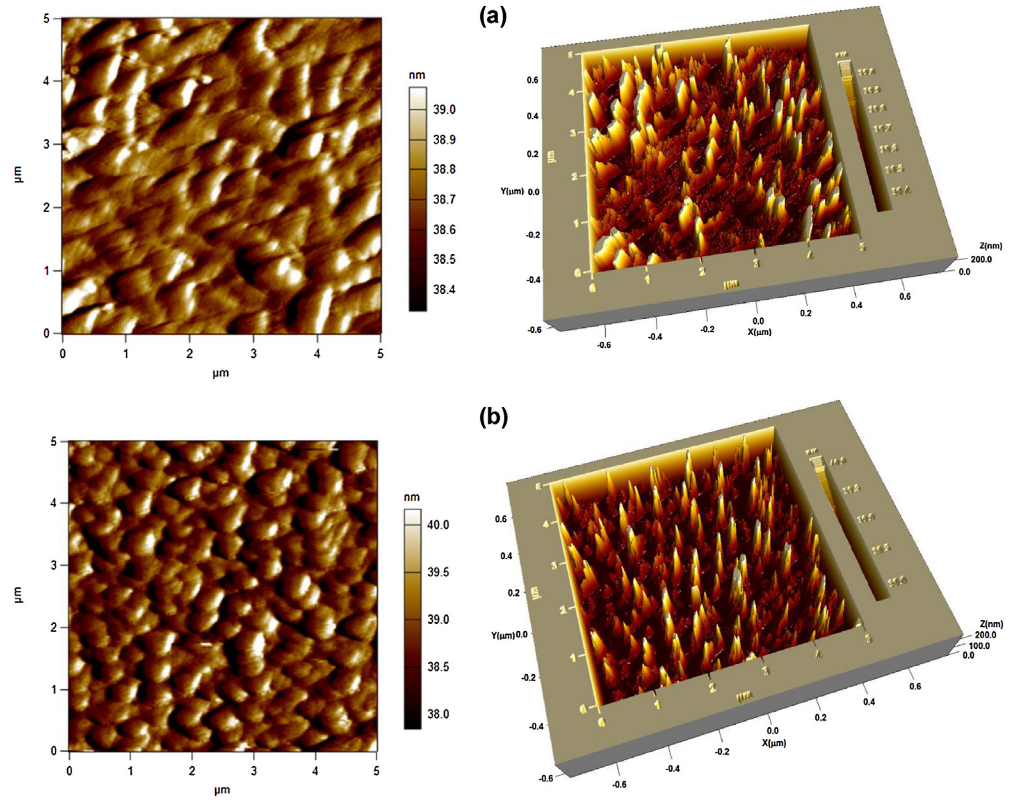

Fig. 1. 2D and 3D AFM images of Porous Silicon (a) Current density 20 mA/cm^2, time 40 min, (b) Current density 40 mA/cm^2, time 20 min.

2. Experimental

Porous Silicon samples were prepared from n-type cleaned Silicon wafers with (100) orientation, thickness of 525 µm and a resistivity of (1–10) Ω cm. The method consists in varying the current density J from 20 to 40 mA/cm^2 and etching duration from 20 to 60 min in a cell with two-electrodes system, a cathode and n-type Si (100) anode separated by a distance of 3 cm. The electrolyte used was 48% HF:C_2H_5OH taken in the mole ratio of 1:2:1. The small cell of anodization was conceived to carry out chemical attacks of silicon surfaces of dimension (1 cm × 1 cm) illuminated by a red laser beam delivered by a low power He-Ne source (λ = 632.8 nm, P = 5 mW). The use of ethanol makes it possible to increase the wettability of the acid solution, this allows the diffusion of the fluoride (F^-) ions at the bottom of the pores. The ethanol limits the accumulation of the hydrogen bubbles formed during the chemical reaction and thus increases the homogeneity of the layers.

During the anodization of an n-type silicon substrate, the electron-hole pairs are generated by illumination [14]. The minority carriers diffuse towards the electrochemical interface. They can cross the depletion region to be consumed by the electrochemical reaction at the end of the pores where the electric field is maximal. In the case of n-type silicon, the use of a light source is necessary in order to illuminate the samples and to activate the anodization process.

Surface morphology, structural and optical properties of the obtained nano-structures were characterized by using various techniques. The atomic force microscopy AFM images of the porous silicon layers were performed with an Asulym Research-Model MFP-3D.

The Raman spectra were measured using Jobin Yvon's Labram Dilor Raman spectrometer. X-ray diffraction analyses of the samples were carried out using the PANalytical X'Pert Pro diffractometer. The incident X-ray beam originates from a copper anticathode using the radiation Kα = 1.5405980 Å, it is supplied by a stabilized generator operating at a voltage of 40 KV with current intensity of 30 mA. Reflectance measurements were obtained at room temperature in the range wavelengths between 400 and 700 nm

3. Results and discussion

The AFM images presented in Fig. 1a and b were obtained on two samples anodized under completely different conditions. The 2D AFM images reveal a presence of nanostructures surrounded by irregulary shaped pores randomly distributed over the whole analyzed surface.