Materials Science in Semiconductor Processing 64 (2017) 71–76

Contents lists available at ScienceDirect

Materials Science in Semiconductor Processing

journal homepage: www.elsevier.com/locate/mssp

Origins of photoluminescence degradation in porous silicon under irradiation and the way of its elimination

A.S. Lenshin*, P.V. Seredin, V.M. Kashkarov, D.A. Minakov

Voronezh State University, Russia

ARTICLE INFO

Keywords:
Porous silicon
Kinetics of degradation
Porous nanostructures
IR-spectroscopy

ABSTRACT

Using of infrared (IR) and photoluminescence (PL) spectroscopy a comparative study of distinctions in composition and photoluminescence properties of porous silicon with different morphology was performed. Basing on the obtained experimental data and conventional theoretical models the main factors were found that have a negative effect on the intensity of PL in porous silicon and its degradation under the impact of directed irradiation in the visible range. With porous silicon as an example having the pores of 50–100 nm in size there was demonstrated a possibility for improving of these characteristics by its chemical treatment in polyacrylic acid.

1. Introduction

In order to solve the applied problems in the fields of electronics, alternative power engineering and medicine extensive investigations of nanostructures on the basis of different semiconductor substances and compounds are currently performed. At the same time production technology on the basis of multicomponent semiconductor heterostructures is quite expensive and at the same time rather complicated. Therefore, active attempts are implemented in order to replace them with more available and manufacturable materials or circuit elements based on different kinds of nanosilicon that is present as a component in amorphous, polycrystalline, porous and other Si forms [1–4]. However, Si-based nanostructures due to their extended surface covered with different hydrogen and hydroxyl complexes encounter a lot of problems connected with the change of their composition and degradation of the properties. It is revealed as in standard technological processes, connected with heating, adsorption of the vapors of different substances, impacts of directed radiation, as in the process of ageing under natural conditions [5–7]. Therefore a search for the efficient and, if possible, inexpensive protecting coatings for Si-based nanostructures is an actual scientific problem. In a dependence on the area of application of these nanostructures different metal or polymer films are deposited on the surface. These materials can be reflecting or semi-transparent ones, otherwise, nanostructures can be packaged into evacuated case, etc. Chemical treatment of the surface with different organic and inorganic compounds, e.g., acids seems to be quite reasonable way [8,9]. Treatment of the surface in polyacrylic acid (PAA), according to a number of investigations [9–11], demonstrated good results for PAA as a reagent for modification and passivation of silicon-based nanostructures.

The aim of the work was to study the effect of porous silicon treatment in polyacrylic acid solutions on its luminescence properties in the natural conditions and under the impact of directed laser irradiation.

2. Experimental technique

Porous silicon samples with different pores sizes were obtained by electrochemical etching in fluoric acid solutions of single-crystalline silicon wafers with both n- and p-type conductivity. Technique for obtaining all of the samples, the features of their morphology according to the electron microscopy data, the changes in composition and photoluminescence (PL) with time are described in details in [7]. Morphology of the surface of porous silicon samples was studied by scanning electron microscopy (SEM) with the use of microscope JEOL – JSM 6380LV. The mean size values of pores in the samples, according to SEM data (Fig. 1) [7], were of: sample No. 3 − 50–100 nm, No. 7 − 50–100 nm, No. 18 −150–200 nm, No. 29 – less than 10 nm, No. 30 p ~1000–2000 nm, No. 30n layer – pores of different diameter, small were less than 30 nm, large were up to 2000 nm.

Porous silicon sample with pores sizes of ~50 − 100 nm (sample No. 3) obtained with the substrate of n-type conductivity with (100) orientation was chosen for the treatment in PAA solution. Porous silicon samples just after etching of crystalline silicon were rinsed in isopropyl alcohol. After that the samples were dipped into the aqueous solution of polyacrylic acid for 20 min. The ratio of water and the acid

* Corresponding author.
E-mail address: lenshinas@mail.ru (A.S. Lenshin).

http://dx.doi.org/10.1016/j.mssp.2017.03.020
Received 21 December 2016; Received in revised form 27 January 2017; Accepted 21 March 2017

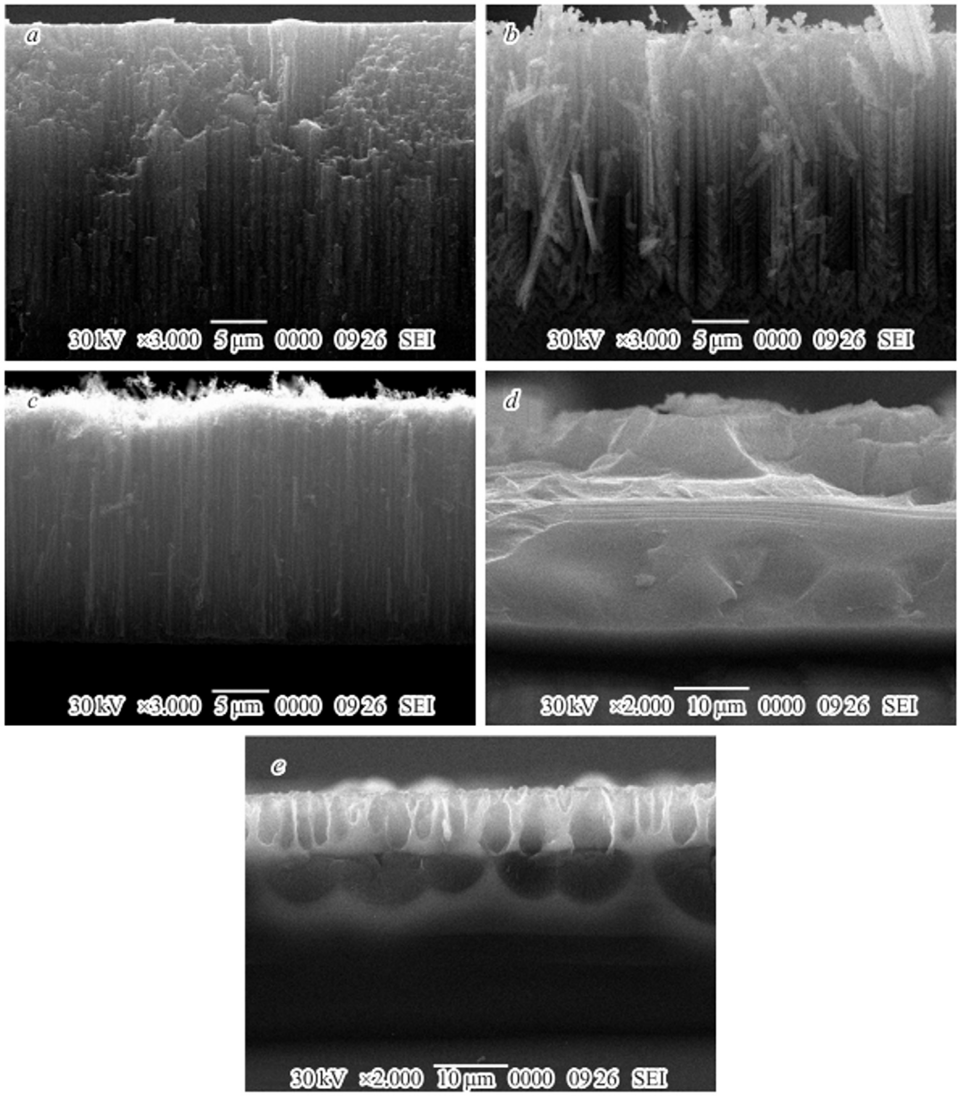

Fig. 1. SEM-images of the cleavages for porous silicon samples [7]. a) sample No. 3, b) No. 7, c) No. 18, d) No. 29, e) No. 30.

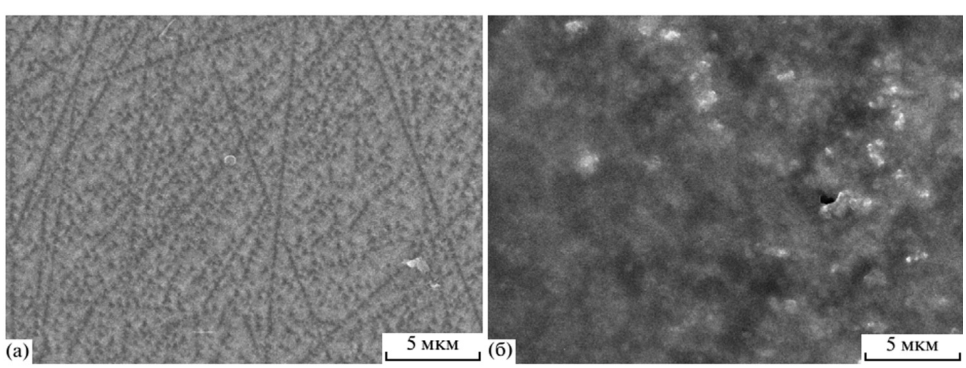

Fig. 2. SEM-images of the porous silicon surface (sample No. 3) a) before and b) after treatment in PAA solution.

in a solution was of 4: 1. The effect of PAA treatment on morphology of porous silicon is shown in Fig. 2. Treatment of the sample in PAA (Fig. 2) resulted in a considerable change of the surface relief; some of the pores became less expressed. Similar studies of por-Si morphology using SEM, was presented in [12–15], where correlation between morphology of Si samples with their PL properties was investigated.

IR-transmission spectra of porous silicon samples were obtained with IR-Fourier spectrometer Vertex70 (Bruker) applying an attachment for the attenuated total reflection (ATR) spectroscopy. Depth of analysis for porous silicon samples with the use of this technique does not exceed 1.5 µm for the range of wavenumbers up to 2000 cm^{-1}, while in the range of 2000–4000 cm^{-1} this value is less than 10 µm. Thus, one can obtain data on the chemical bonds of the investigated samples just within the limits of the porous layer depth [16].

One more method applied for the study of porous silicon samples was luminescent spectroscopy technique. Laser radiation stimulating luminescence is successfully used in such kinds of spectrometers. This radiation is directed to the object through the optical waveguide.