Local analysis of porous silicon structure fabricated by non-traditional approach

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Abstract. A comparison of experimental electron backscattering diffraction patterns for porous Si formed by ion implantation and thermal annealing is presented. For this purposes Ag-ion implantation into monocrystalline c-Si substrates at energy of 30 keV with dose of $1.5x10^{17}$ ion/cm^2 was carried out. Surface nanoporous Si structures were studied by scanning electron microscope imaging and electron backscattering diffraction. Amorphization of Si after implantation and recrystallization of porous Si after annealing is observed. Ion implantation is suggested to be effective technique for a formation of nanoporous semiconductor layers, which could be easily combined with the crystalline substrate matrix for various applications.

1. Introduction

Main fields of application with porous silicon (PSi) are microelectronics, optical waveguide, photo sensor and solar cells[1]. The first time PSi was produced and characterized by A. Uhlir in 1956. At that time PSi was formed by electrochemical etching of Si [2].

At the present the electrochemical etching is most applicable technic for fabrication of PSi. Recently, in 2013 it was suggested to use a novel technological way for formation PSi based on low-energy high-dose implantation of noble metal ions [3,4]. Ion implantation widely used in modern industrial process of semiconductor microelectronics. Thus such physical method of creation PSi could easily integrated in industrial semiconductor process.

The precise control of crystalline structure is one of the important tasks in science especially in the field of new material fabrication. For this purpose various analysis methods such as electron microscopy [5-7], Raman scattering and X-ray diffraction are applied. Every of this methods have advantages, but also have some limitation.

Aim of present work is a creating of thin semiconductor layers PSi on surface of a monocrystalline c-Si used Ag^+-ion implantation combined with postimplantation thermal annealing and structural analyze of this materials by electron backscattering diffraction method.

2. Experimental details

A (100)-oriented single crystalline Si wafer as the substrate was used for Ag^+-ion implantation to create PSi structures. The substrates were cleaned in a wet chemical etching process. The semiconductor wafers were implanted with Ag^+ ions at energy of 30 keV and the ion current density

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of 8 μA/cm^2 with dose of 1.5x10^{17} ion/cm^2 using the ion implanter ILU-3 at residual vacuum of 10^{-5} Torr and room temperature of the irradiated samples. Thermal annealing was realized with VUP-5M during 30 minute at 600°C.

Fabrications of PSi samples were carried out in Kazan Physical-Technical institute. Analyze of local structure and observation of surface sample morphology were performed with scanning electron microscopy (SEM) Merlin (Carl Zeiss), which combined with a detector of electron backscattering diffraction (EBSD) Norlys HKL (Oxford Instruments). Microscopy measurements were carried out in Interdisciplinary Center for Analytical Microscopy of Kazan Federal University.

3. Results and discussion

EBDS used in practice for control various structural parameters of materials [6]. EBDS determines a thickness of sample, which participate in capture diffraction picture. Modeling of profile intensity distribution of backscattering electrons for Si was realized by the Casino 2.48 software for case of accelerating voltage 20 keV and tilt angle 70 to surface sample respective horizontally (Fig. 1). Thus, transmitted analyzing thickness of sample is about 300 nm

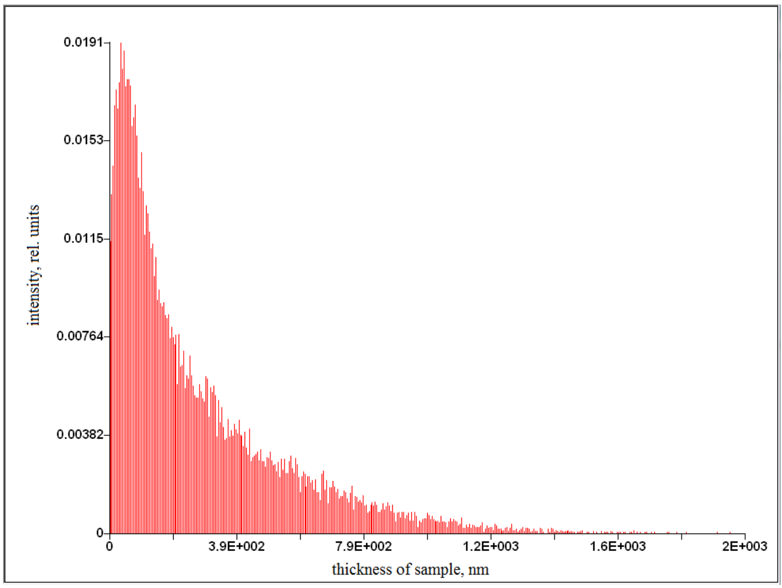
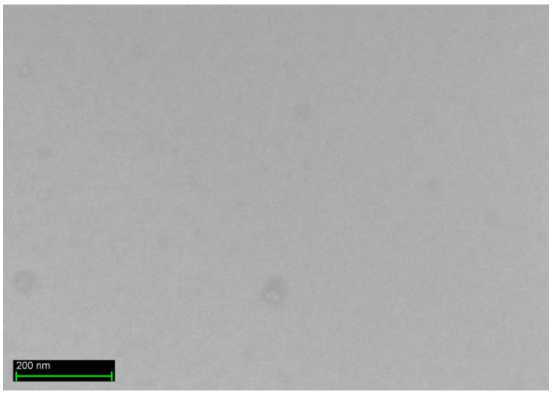


Figure 1. Intensity distribution backscattering electrons in Si

A plane-view SEM image of unimplanted Si wafer looks likes as very smooth without any surface structural inhomogeneity (Fig. 2a). Experimental EBDS pattern of c-Si shows typical monocrystalline Kikuchi structure (Fig. 2b). Identification of Kikuchi band was carried out in program Aztec 2.1 and demonstrated that surface crystal orientation is (100). A plane-view SEM image of PSi formed by Ag-ions with dose 1,5x10^{17} ion/cm^2 is presented in Fig. 3a. In contrast to unimplanted Si (Fig. 2a) the morphology of PSi surface characterized by a structure with the black holes on the implanted Si. On experimental electron backscattering pattern (Fig. 3b) In EBDS image seems asa superposition of low intensity Kikuchi band of monocrystalline substrate and diffusely ring from formed PSi layer.

Thermal annealing was carry out at 600°C in vacuum in order to recrystallize PSi structure. Porous Si layers after annealing procedure is shown Fig. 4a and this image demonstrates some consistence with PSi created by implantation. Diffraction pattern in Fig. 4b shows reconstruction Kikuchi band of annealed PSi to cubic syngony. Identification Kikuchi band indicates about appearance of crystallographic orientation modified PSi to be different from (100).



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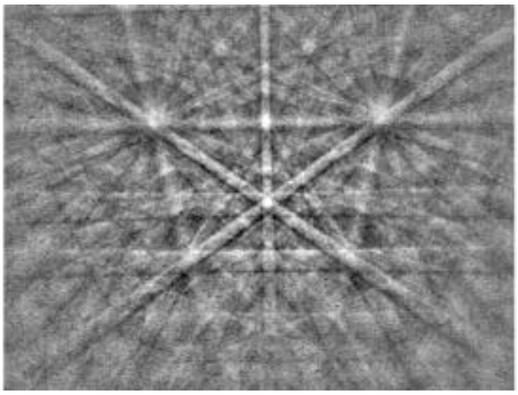
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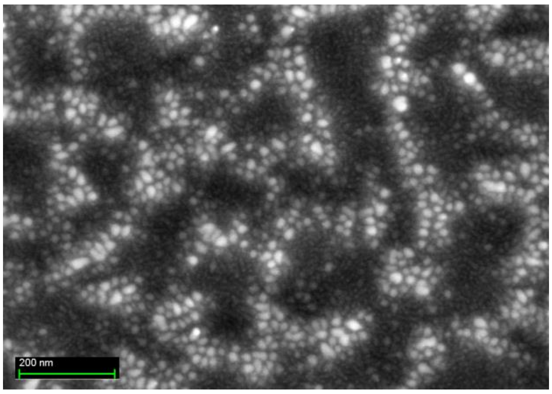
Figure 2. a) SEM image of unimplanted c-Si surface, b) Eelectron backscattering pattern of c-Si.



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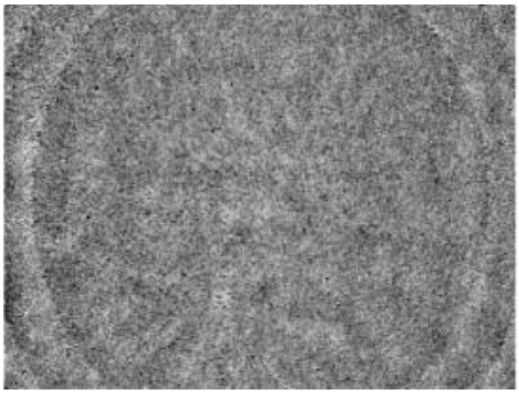
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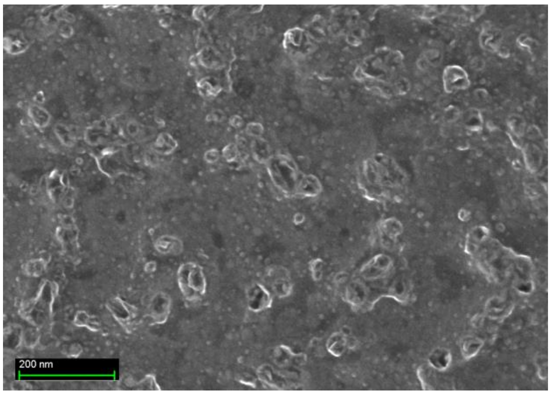
Figure 3. a) SEM image of surface PSi formed by Ag^{+}-ion implantation, (b) Eelectron backscattering pattern of PSi



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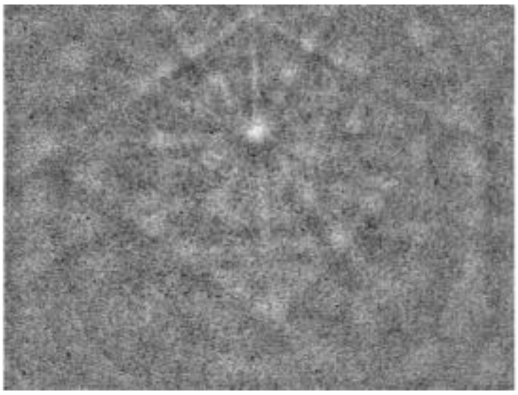
b)

Figure 4. (a) SEM image of annealed PSi (a), and (b) Electron backscattering pattern of annealed PSi

4. Conclusions

In this work PSi layer using high dose low energy Ag-ion implantation of c-Si was fabricated and epyт modified by thermal annealing. For the first time a structure analysis of surface layers PSi by EBDS was carry out. It was concluded that after Ag-ion implantation the surface layer PSi is amorphous which could be partly recrystallized by annealing. Crystallographic structure of annealed PSi is different from unimplanted c-Si (100).

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