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PHASE TRANSFORMATIONS IN SEMICONDUCTOR SILICON BY THE INFLUENCE OF MAGNETIC FIELD

Abstract. The magnetic processing influence on the semiconductor silicon phase composition grown by the Czochralski method was investigated at present work. The processing has registered splitting of diffraction lines, as well as the emergence of new peaks at the angles of scattering 90-92 degrees due to the curvature of the Si_{FCC} crystal lattice and the formation of Si_{ROMB} along with it. This indicates the occurrence of phase transformations in semiconductor silicon samples in the process of magnetic processing.

Key words: monocrystalline silicon, magnetic processing, phase composition, phase transformations.

Introduction. The study of the influence of the magnetic field on solids has recently attracted considerable interest. Scientists have identified the number of phenomena associated with the influence of a weak magnetic field on the various physical processes in paramagnetic crystals [1]. Theoretically, it is assumed that the magnetic field affects paramagnetic materials, mainly causing the formation and destruction of chemical bonds. The growing number of scientific publications on this topic caused the emergence of a new direction in physics - spin micromechanics, aimed at the study of micromechanical spin-dependent processes that affect the mechanical properties of solids [2].

At present, there are a lot publications which devoted the topic of magnetic field influence on the structure and properties of elementary semiconductors, in particular, crystalline silicon in the scientific literature. The generalization of the results of previous work has shown that magnetic processing adds additional energy to the system and causes the evolution and modification of structural defects in paramagnetic silicon. This, in turn, indicates the possibility of changing the structural-sensitive properties and the phase composition of silicon as a result of magnetic processing [3].

In this paper, the phase composition of monocrystalline silicon samples was investigated under the action of permanent magnetic fields of the different induction.

Materials and methods of research. The effect of permanent magnetic fields on the phase composition of semiconductor silicon was studied at present work. Samples of monocrystalline semiconductor silicon were grown by the Czochralski method (Cz-Si) were selected as raw materials. Sampling was carried out in constant magnetic fields with induction of 0.4 and 1.2 T. Exposure of samples was 240 and 720 days. To determine the phase composition of the samples X-ray diffraction analysis was performed on the Drone-3 installation and calculations using the Rietveld method [4].

Results and discussion. In the initial state of the Cz-Sian diffraction patterns, reflexes of the FCC lattice are observed, with the maximum intensity having a line (400) at the angles of scattering up to 65 degrees (Figure 1).

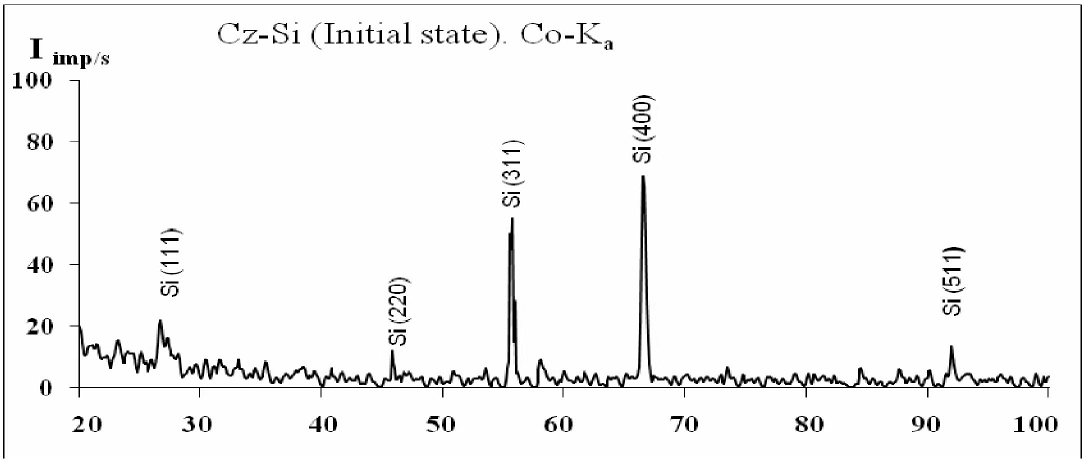

Figure 1 - The diffractogram of the sample Cz-Si (initial state)

After processing silicon samples in a constant magnetic field with induction of 0.4 T, there is an appearance of reflexes at the angles of dispersion of 30-40 degrees (Figure 2), identified as the rhombic phase of silicon [4].

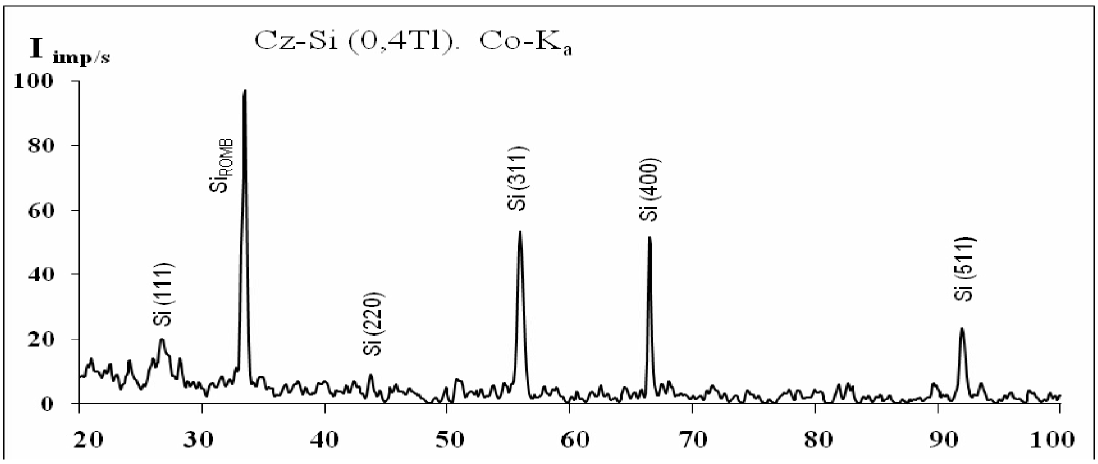

Figure 2 - The diffractogram of the sample Cz-Si (B = 0.4 T)

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The intensity of reflexes of FCC silicon at the corners of 65-70 degrees, after processing in a magnetic field, decreases. This can be explained by the initiation of the phase transformation of SiFCC↔SiROMB in silicon [5] under the action of a constant magnetic field with an induction of 0.4 T.

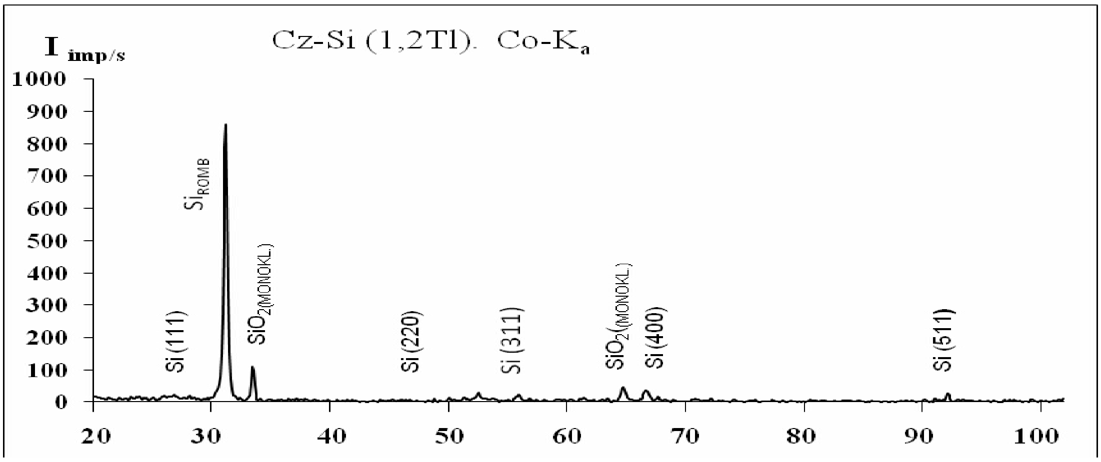
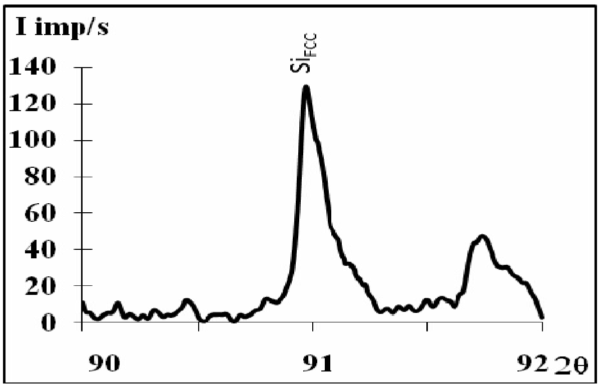


Figure 3 - The diffraction pattern of the sample Cz-Si (B = 1.2 T)

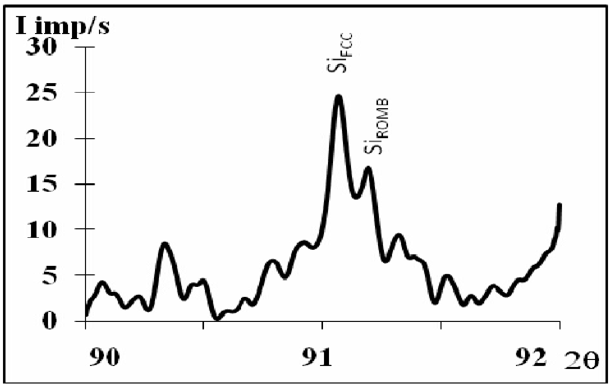
After processing samples in a strong constant magnetic field (B = 1.2 T (Figure 3)), there is decrease the intensity of the reflexes of all phases of silicon , and the appearance of a significant number of reflexes from silicon oxide, which confirms the assumption of activating the surface of silicon by a constant magnetic field and increasing its adsorption properties [6]. At the same time, the assumption is also confirmed for the stabilization of the phase structure of silicon under the action of a constant magnetic field [3]. Detailed study of the change in the profile of the lines [511] indicates the formation of additional phases in the volume of the crystal that have other types of lattices.

Fig. 4 shows the curves of the differential maximum (511) in the initial state and after processing in magnetic fields (B = 0.4 (b), 1.2 T (c)) obtained on the corners of the scattering of 90-92 degrees belonging to the FCC phase of silicon [5].

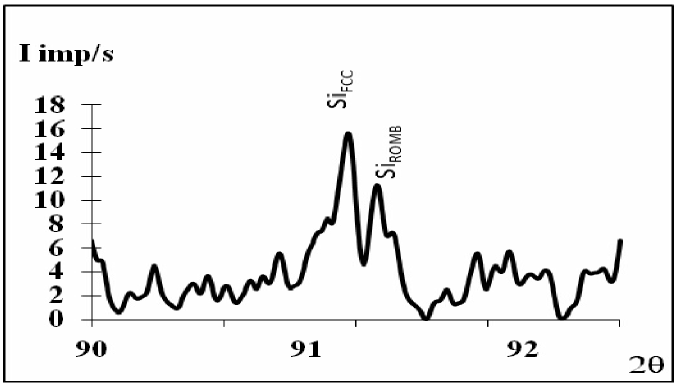
The splitting of the diffraction lines indicates the presence of distortions in the crystalline lattice of the original samples Cz-Si (Figure 4a), with the splitting of the maximum shown in Figure 4 (b, c) should be associated with the imposition of appropriate interferences of the rhombic phase of silicon [5, 7 , 8]. In this case, the splitting of the line [511] increases with the increase of the induction of the external magnetic field.



a



b



c

a – the initial state, b - 0.4T, c- 1.2T
Figure 4 – The line profile (511) before
and after magnetic processing

The splitting of the diffraction peaks at the angles of dispersion of 90-92 degrees with the increase of the induction of the external magnetic field, suggests the presence of two phases of silicon and is associated with the formation of SiROMB phase in the volume of material. The same splitting of the diffraction maximum [511] at the angles of 90-92 degrees was observed during the heat treatment of semiconductor silicon in the temperature range 280-450 C, which was due to the distortion of the crystalline lattice SiFCC by the formation of a certain amount SiROMB [8].

When thermal processing of samples of semiconductor silicon , there was a stronger splitting of the interference maximum [511] with annealing temperature increase from 280-320 C to 400-450 C [8]. In this paper, significant splitting was observed with an increase in the induction of an external magnetic field from 0.4 to 1.2 T. This indicates that the magnetic field, as well as thermal processing, initiates phase transformations in silicon .

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Conclusions: The effect of magnetic processing on the phase composition of semiconductor silicon grown by the Czochralski method was investigated. X-ray diffraction analysis of samples undergoing magnetic processing showed splitting of diffraction lines, as well as the appearance of new peaks at scattering angles of 90-92 degrees, which caused a distortion of the crystalline lattice SiFCC by forming along with Si-ROMB. This indicates the occurrence of semiconductor silicon samples of phase transformations in the process of magnetic processing.

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