IMPURITY OF ATOMS OF MANGANESE DIFFUSION BY OUTSIDE ELECTRIC FIELD INTO SILICON

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Abstract. *In this work, manganese atoms were diffused into a silicon sample using an external constant electric field, and the electrophysical parameters of the samples were studied using the Van der Paw method. In addition, the surface morphology and element composition of the samples were analyzed using a scanning electron microscope. From the results, it was found that Mn atoms were significantly diffused in the samples placed on the side of the negative pole of the constant external electric field compared to the samples placed on the side of the positive pole.*

Keywords: *silicon, electrodiffusion, nickel, clusters, positive and negative polarity.*

INTRODUCTION

In the rapidly developing field of electronics, obtaining new materials whose fundamental parameters differ from traditional semiconductor materials is of scientific and practical importance. The development of the electronic industry in the Republic of Uzbekistan is impossible without the development of the electronics industry, the updating of production bases in existing enterprises and the introduction of modern technologies. Therefore, in order to rationally use the devices and equipment in the enterprises of the electronics industry, it is necessary to constantly update them to modern ones and improve them in accordance with the market requirements. Many technological steps are performed in the production of devices and devices based on semiconductor materials. Currently, obtaining new materials by the electrodiffusion method and studying their electrophysical parameters are promising directions in electronics, especially nanoelectronics [1-3].

It is of great scientific and practical importance to reveal the mechanism of inclusion and distribution of atoms of semiconducting materials under the influence of an electric field. It is known from the literature that in the process of high-temperature diffusion, incoming atoms move chaotically and are mainly in the form of positive ions. Diffusion parameters of known input atoms, for example; the diffusion coefficient depends on the solubility of the input atoms and their location in the crystal lattice, diffusion temperature and time [4-6]. Introduction of impurity atoms into ceramnium under the influence of an electric field and knowing their size distribution allows obtaining very important scientific information. In an electric field with a sufficiently high current density ($J=25\div40$ A/cm^2), the diffusion process accelerates significantly, and the diffusion temperature of the atoms decreases by $T=150\div200$˚C compared to the diffusion temperature in the gas phase.

Based on the enhancement of the migration of positively charged ions under the influence of an electric field, it was found that it is possible to increase the solubility of the input atoms by

1.5÷2 degrees even at low temperatures compared to the gas phase diffusion [7-12] temperature [13]. This state, which is almost impossible to realize under normal diffusion conditions, allows to significantly increase the solubility of the input atoms, which create a deep energy level under the influence of an external electric field, and the number of electrically active atoms in the initial sample. By controlling the current flowing through the sample, it will be possible to control the distribution of the concentration of atoms on the surface and volume of the sample. Under the influence of an external electric field, the input atoms enter the silicon volume and allow the input atoms to change their position in the crystal lattice. That is, the placement of the incoming atoms in the nodes or internodes of the silicon crystal lattice can be controlled using an electric field. The diffusion method under the influence of an electric field causes interaction of input atoms with atoms of the starting material silicon to different charge states. Large amounts of dopant atoms, in turn, lead to the formation of nanoclusters of dopant atoms in silicon.

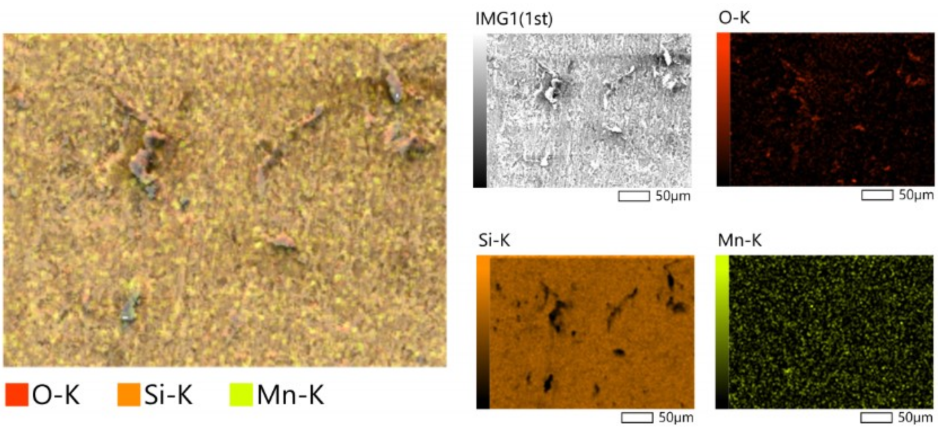
MATERIALS AND METHODS

For the experiment, a silicon sample with specific electrical resistance ρ~5 Ω·cm, concentration of charge carriers (cavities) $n_p \sim 5 \cdot 10^{15}$ cm^{-3}, grown by the Chokhral method, was selected. The surface of the samples was chemically treated [14], and a thin layer was formed by spraying Mn atoms on the surface of the samples. After that, 2 samples were taken, and by touching the surfaces on which a thin layer of Mn was formed, an electric current was passed through the samples with a current density equal to 40 A/cm^2 using a constant current source. In this case, the sample placed on the positive pole of the source was designated as sample ***A***, and the sample placed on the negative pole of the source was conditionally designated as sample ***B***. The diffusion process was carried out for 30 minutes in a vacuum chamber with air suction.

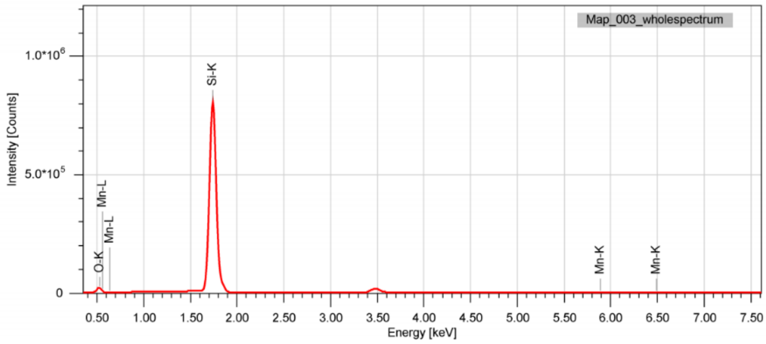
After diffusion, the sample surface topology and X-ray energy dispersive microanalysis results were obtained using a JSM-IT 200 (SEM) scanning electron microscope, and the electrophysical parameters of the samples were determined using an Ecopia HMS 3000 device.

RESULTS AND DISCUSSION

Figure 1 shows the surface topology of sample ***A*** (1a) and the results of X-ray energy dispersive microanalysis (1b) using a JSM-IT 200 scanning electron microscope. Figure 2 shows the topology of the ***B*** sample surface (2a) and the results of X-ray energy dispersive microanalysis (2b) obtained using a JSM-IT 200 scanning electron microscope. From the results of the experiment, manganese atoms diffused by the electric field were detected in significantly larger quantities on the surface of the sample placed on the negative pole of the source than on the surface of the sample placed on the positive pole of the source.

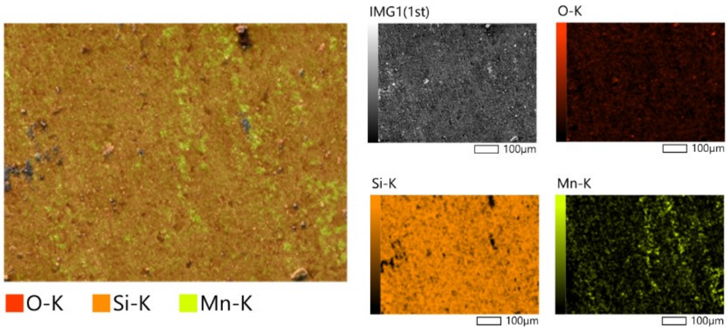


a)



b)

Figure 1. Analysis of the sample (***A*** sample) placed on the positive pole of the source;
a — surface topology of silicon with manganese atoms;
b - X-ray energy dispersive microanalysis results.



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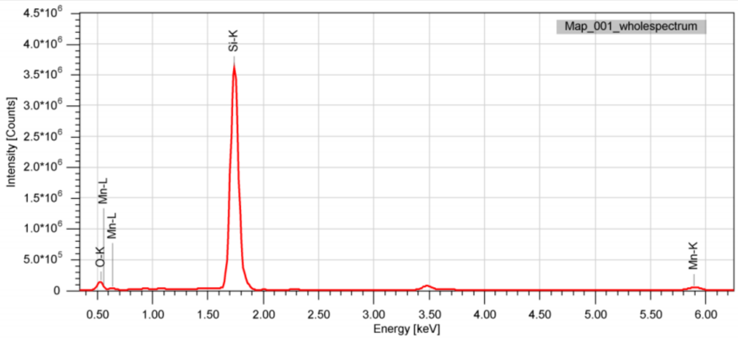

b)

Figure 2. Analysis of the sample placed at the negative pole of the source (***B*** sample);
a — surface topology of silicon with manganese atoms;
b - X-ray energy dispersive microanalysis results.

Figure 3 shows the relative electrical resistance of samples A (line 2) and B (line 1) as a function of depth. As can be seen from the graphs in Fig. 3, it was found that manganese atoms diffused in a small amount to the sample located on the positive pole of the source, but on the contrary, it was found that there was a large amount of diffusion to the sample located on the side of the negative pole. It can be explained that from the analysis of the literature (Diss. Bakhadrkhanov), when manganese (Mn) atoms diffuse into silicon (Si) at low temperature, the nodes can be in 3 different states, the 1st state is uncharged (neutral) Mn, the 2nd state is free of one electron. A doubly positively charged atom (positive ion) is Mn+, due to the loss of its 3-two electrons, a doubly positively charged atom (double positive ion) is in Mn++ states. We know that positive ions move towards the negative pole of the source, so the manganese (Mn+, Mn++) atoms with positive ions moved towards the negative pole of the source, and a large amount of manganese atoms diffused into the sample located on the negative pole side of the source. These manganese atoms compensate for the Boron atoms in the sample and reduce the concentration of charge carriers in the sample, thus increasing the resistivity of the sample (Figure 3).

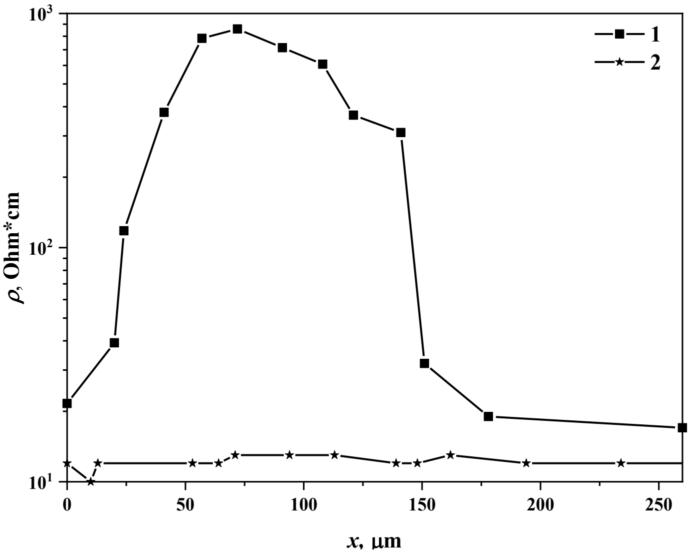

Figure 3. Depth dependence of specific electrical resistance of samples ***A*** and ***B***:
1-the sample with the constant current source placed on the side of the negative pole (sample ***B***);
2nd sample with the DC source on the positive side (sample ***A***).

SUMMARY

The results of the study showed that manganese allows the maximum penetration of silicon atoms under the influence of the electric field. It also proves that electrodiffusion is a new way to control the distribution of input atoms on the size of silicon, their solubility, and the concentration of charge carriers. Using the electrodiffusion method, it is possible to significantly increase the concentration of electroactive atoms in the silicon crystal lattice. Such a situation indicates that transition elements in the table of chemical elements have greater possibilities compared to other methods of diffusion into semiconductor material.

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