Influence Of Impurity Ni Atoms on The Electrophysical Parameters of Si

N.A.Turgunov[1]	[1]Research Institute of Semiconductor Physics and Microelectronics at NUUz, Tashkent, Uzbekistan. elmurod_8883@umail.uz
E.Kh.Berkinov[1]	[1]Research Institute of Semiconductor Physics and Microelectronics at NUUz, Tashkent, Uzbekistan.
R.M.Turmanova[1]	[1]Research Institute of Semiconductor Physics and Microelectronics at NUUz, Tashkent, Uzbekistan.
N.B.Xaytimmetov[1]	[1]Research Institute of Semiconductor Physics and Microelectronics at NUUz, Tashkent, Uzbekistan.
L.E.Madaliyeva[2]	[2]School No.44, Namangan city, Uzbekistan.

ABSTRACT

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Currently, silicon single crystals doped with impurity atoms of 3d transition metals forming bulk impurity nozzles in silicon are considered widely studied materials in terms of obtaining semiconductor materials with predetermined parameters, as well as control of electrophysical parameters. For this reason, scientific research is being conducted on a global scale to obtain semiconductor materials with multicomponent impurity clusters with unique structural properties in volume, as well as to study their structural, electrophysical and photovoltaic properties [1-6].

In this regard, special attention is paid to the development of new technologies for the production of semiconductor materials with impurity micro- and nanoscopes by diffusion alloying with various impurities. Of particular interest is the study of the processes that occur in their volume when impurity atoms are introduced into the volume of semiconductor materials at high temperatures (T = 1000^0 C), their structural structure, the laws of change of physical parameters depending on temperature [7-12].

A modern device for measuring the Hall effect Ecopia HMS-7000 has the ability to determine the concentration of charge carriers, mobility, resistivity, conductivity and temperature dependence of the Hall coefficient in n- and p-type semiconductors. This device allows you to get results in the form of tabular data, as well as in the form of graphs. The system adapts to each temperature set by the user, stabilizes and performs measurement work. Then it exhibits various electrical properties of the material under study depending on the temperature.

In this regard, the concentration and mobility of impurity nickel atoms introduced into silicon by the diffusion method, as well as changes in the resistivity values of samples depending on temperature, are investigated in this article.

The experimental part

Initial samples and model samples of n-Si<Ni> were prepared for research. Single-crystal silicon of the KEF brand with a resistivity of 35 Ohm·cm, grown according to the Chokhralsky method, were used as initial samples. Samples prepared in the form of a rectangular parallelepiped with dimensions of 12x6x2 mm were purified by chemical methods. The diffusion of nickel into silicon was carried out at a temperature of T = 1273 K in a SUOL-4M furnace for t = 2 hours. The diffusion temperature was controlled using a platinum-platinum-rhodium thermocouple. After diffusion annealing, the samples were cooled by fast (υ_{cool} = 250 K/s) and slow (υ_{cool} = 1 K/s) cooling methods. In this paper, the results of the study of the concentration and mobility of nickel atoms in silicon and the temperature dependence of resistivity were presented by the Hall effect method using the Ecopia HMS-7000 device and compared with the original sample. To measure the electrical parameters of the samples by the Hall effect method, they were cut in the form of a parallelepiped measuring 6x6x1.8 mm. In the process of measuring the electrophysical values of the prepared samples, the temperature was increased in the range from 300 K to 500 K.

Results and discussions

Graphs of the dependences of the resistivity values of the initial samples and samples of n-Si<Ni> on temperature experimentally obtained in the temperature range T=300÷500 K are shown in figure 1. With an increase in the temperature of 320 K, the value of ρ in the initial sample decreases and amounts to 31.7 Ohm·cm. With a subsequent increase in the temperature value to 440 K, this value gradually increases (Fig.1, curve 1). In this case, the p value of the sample reaches its highest value, which is 61.9 Ohm·cm. After that, when the temperature rises from 440 K to 500 K, this value gradually decreases and at the end is 38.1 Ohm·cm. For n-Si<Ni> samples obtained by rapid cooling after diffusion annealing, a significant increase in the value of ρ is observed with an increase in temperature from 300 K to 440 K, and at a temperature of 440 K this value reaches its highest value, reaching 90.18 Ohm·cm (Figure 1, curve 2). After that, when the temperature rises from 440 K to 500 K, the value of ρ decreases sharply and at 500 K it is 43.2 Ohm·cm. In samples cooled with n-Si<Ni> obtained by slow cooling after diffusion annealing, at 300 K, the value of ρ was 30.46 Ohm·cm. As can be seen, when the temperature rises to 400 K, the value of the samples increases by more than 2 times and reaches its maximum value. With a further increase in temperature to T = 500K, the value of p gradually decreases and is ~ 40 Ohm·cm (Figure 1, curve 2).

Figure 2 shows a graph of the dependence of the concentration of charge carriers on temperature for the initial samples and samples of n – Si<Ni> in the temperature range T=300÷500 K. According to him, at a temperature of 300 K, the value of n in the initial samples is 1.17×10^{14} cm^{-3} (Fig.2, curve 1). When the temperature rises to 320 K, the n value for these samples increases slightly and is 1.5×10^{14} cm^{-3}. Then, with a further increase in the temperature value to 420 K, this value practically does not change. When the temperature rises to 440 K, the value of n of the initial samples increases sharply and at 500 K it reaches its maximum and is 3.5×10^{14} cm^{-3}. For n-Si<Ni> samples obtained by rapid cooling after diffusion annealing, the value of n at room temperature was 1.05×10^{14} cm^{-3}. Then, when the temperature value increases to 440 K, this value practically does not change. However, with the next increase in the temperature value to 500 K, this value increases sharply, where it reaches its maximum and is 4.15×10^{14} cm^{-3} (Fig.2, curve 2). In the samples of n-Si<Ni> obtained by slow cooling, the value of n at a temperature of 300 K is 1.33×10^{14} cm^{-3}.

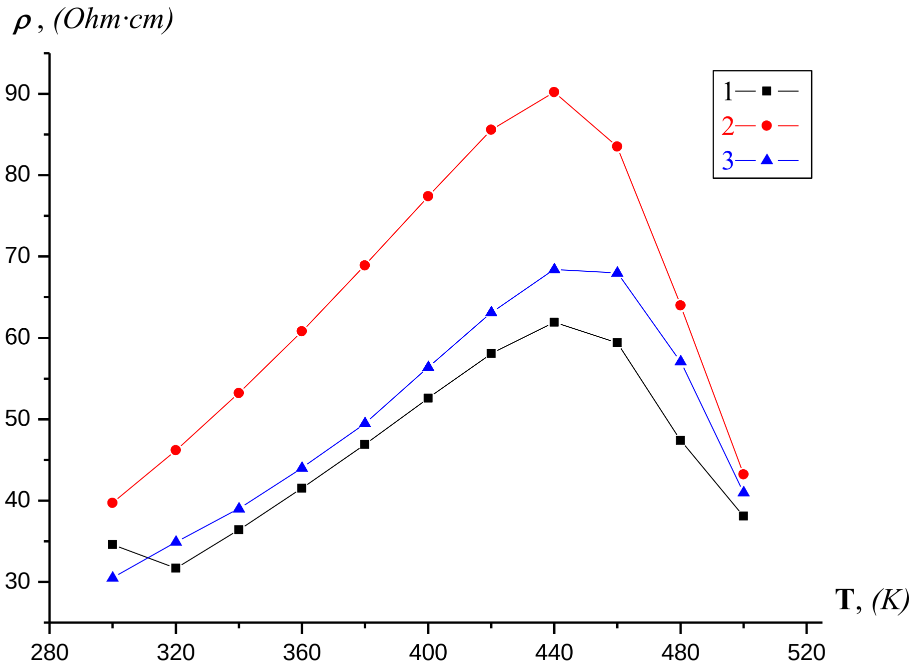

Figure 1. Temperature dependence of resistivity: 1 - initial sample; 2 - samples of n - Si<Ni>, with υ_{cool} = 250 K/s; 3 - samples of n-Si<Ni>, with υ_{cool} = 1 K/s

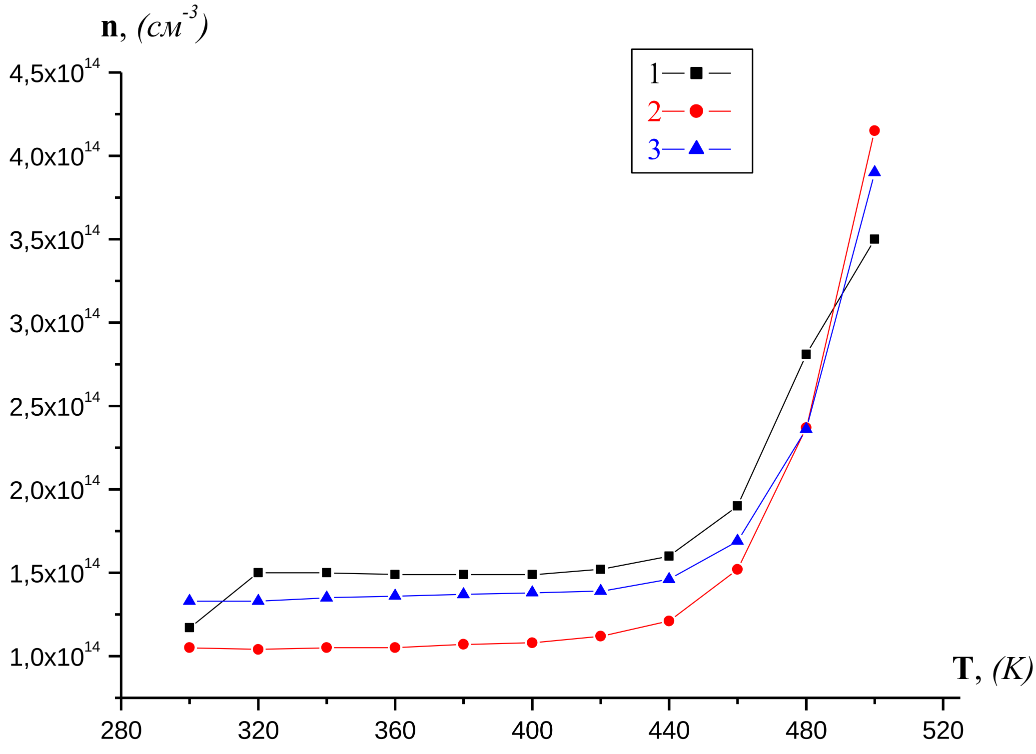

Figure 2. Temperature dependence of the concentration of charge carriers: 1 - initial sample; 2 - samples of n-Si<Ni>, with υ_{cool} = 250 K/s; 3 - samples of n-Si<Ni>, with υ_{cool} = 1 K/s.

Then, when the temperature value increases to 440 K, this value practically does not change. After that, with a further increase in temperature, the value of n samples increases sharply and at 500 K reaches its maximum and is 3.9×10^{14} cm^{-3} (Fig.2, curve 3).

Figure 3 shows a graph of the temperature dependence of the mobility of charge carriers in the initial samples and samples of n-Si<Ni> in the temperature range T=300÷500 K. As can be seen, at a temperature of 300 K, the value of the initial samples is 1546

$cm^2/V\cdot s$. For samples of n-Si<Ni> obtained by rapid cooling at the same temperature, the value of μ is 1499 *$cm^2/V\cdot s$*, and for samples obtained by slow cooling, it is equal to 1539 *$cm^2/V\cdot s$*.

With a further increase in the temperature value to 500 K, the value of μ for all samples decreases by almost 4 times (1,2,3-curves).

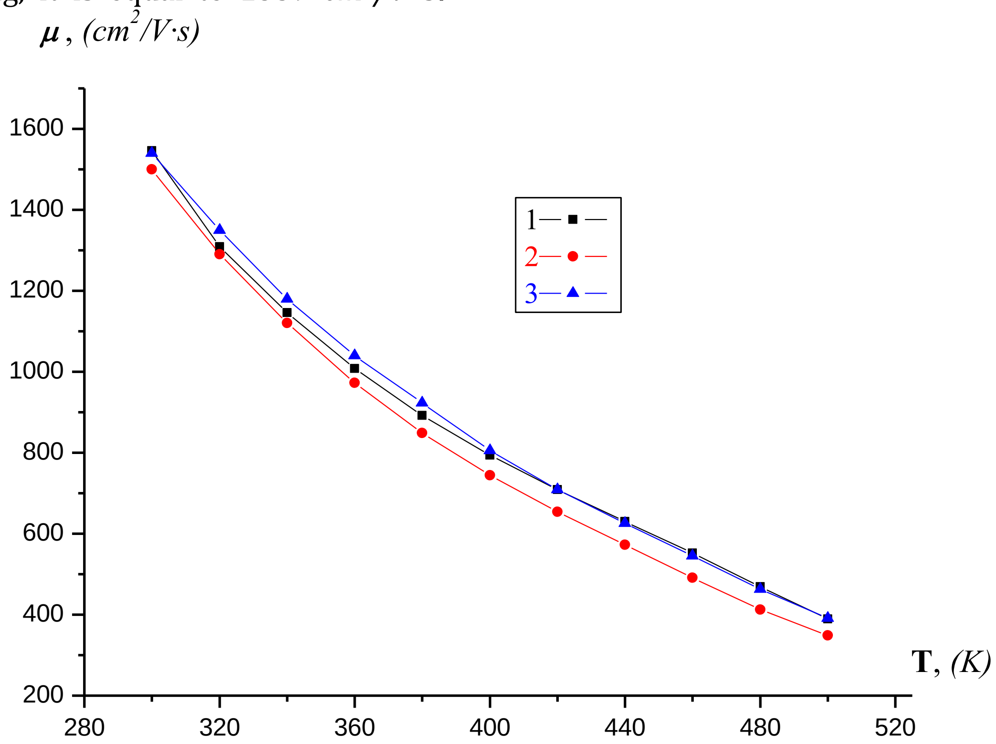

Figure 3. Temperature dependence of charge carrier mobility in samples: 1 - initial sample; 2 - samples of n - Si<Ni>, with υ_{cool} =250 K/s; 3 - samples of n-Si<Ni>, with υ_{cool} = 1 K/s.

Conclusion

From the results obtained above, it can be seen that the concentration of charge carriers in the initial samples and in n-Si<Ni> samples cooled by fast and slow cooling methods after diffusion annealing practically does not change with an increase in temperature from 300 K to 440 K. However, in this range, the resistivity of the initial samples increases by ~ 2 times, for n-Si<Ni> samples cooled by rapid cooling, this value increases by almost 2.3 times, and in samples cooled by slow cooling, it increases by almost 2.2 times. Such an increase in the value of ρ samples mainly depends on a decrease in the value of the mobility of charge carriers in a given temperature range.

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