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INFLUENCE OF IMPURITY Ni AND Cu ATOMS ON THE ELECTROPHYSICAL PROPERTIES OF Si

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Abstract

The paper presents the results of studies of the electrophysical properties of Si, doped Ni and Cu samples. It is revealed that a decrease in the mobility of charge carriers in the temperature range of 120÷320 K is of particular importance in increasing the resistivity of samples.

Keywords: silicon, nickel, copper, impurity, Hall effect.

Introduction

Currently, scientific research is being conducted in many scientific centers of the world to obtain semiconductor materials with multicomponent clusters of impurity atoms that have unique structural properties, as well as to study their electrophysical, photoelectric, optical properties [1-5]. In this regard, special attention is paid to the development of new technologies for the production of semiconductor materials with impurity micro- and nano-inclusions.

In our previous studies on the study of the electrophysical properties of silicon doped with impurities of 3d transition metals by the diffusion method, it was revealed that they are mainly associated with changes in the states of impurity atoms in the silicon crystal lattice [6,7]. In this work, the temperature dependences of the concentration and mobility of charge carriers, as well as the resistivity of samples n-Si<Ni> and n-Si<Cu> were investigated using the Hall effect method on the Ecopia HMS-7000 device.

Experimental Setup

In the conducted studies, single-crystal silicon of the KEF brand with a resistivity of 0.3 Ohm·cm, grown according to the Chokhralsky method, was used as the initial sample. Diffusion of nickel and copper in silicon was carried out in a SUOL-4M furnace at a temperature of T=1473 K for t=2 hours. The diffusion temperature was controlled using a platinum-platinum-rhodium thermocouple. After diffusion annealing, the samples were cooled at a rate of $\upsilon_{cool}=200$ K/s. To measure the Hall effect, the samples were cut in the form of a parallelepiped in the corresponding dimensions of 5x5x2 mm. When measuring the electrophysical parameters of the prepared initial samples, as well as samples of n-Si<Ni> and n-Si<Cu>, the temperature increased from 100 K to 320 K.

Result discussions

The graph of the temperature dependence of the resistivity of the initial sample, as well as samples of n-Si<Ni> and n-Si<Cu> shown in Fig.1 shows that for the initial sample and samples of n-Si<Ni> these dependences have almost the same character. At a temperature of 100 K in the initial sample, the value of ρ is 0.135 Ohm·cm, and in the samples n-Si<Ni> ρ=0.139 Ohm·cm. Then, when the temperature value increases to 120 K, these indicators decrease slightly (Fig.1, curves 1 and 3). With a further increase in temperature, they begin to gradually increase and when T = 320 K is reached, the value of ρ in the initial samples increases almost 3 times and is 0.37 Ohm·cm. In samples of n-Si<Ni> at T=320 K, the value of ρ increases to 0.368 Ohms·cm.

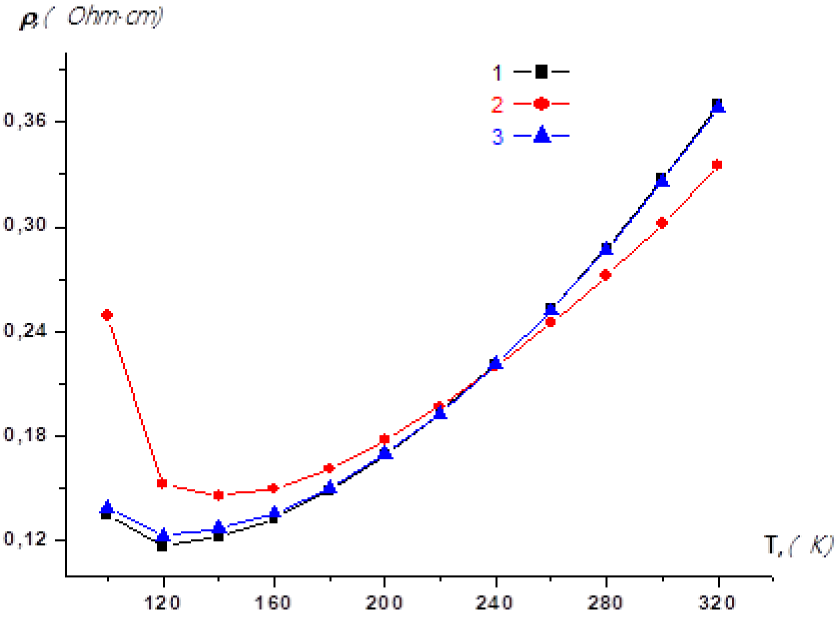

Fig. 1. Temperature dependence of resistivity: 1 - initial sample; 2 - samples of n-Si<Cu>; 3 - samples of n-Si<Ni>.

The temperature dependence of the resistivity of n-Si<Cu> samples, in contrast to n-Si<Ni> samples, in the temperature range T=100÷320 K has a different form. At a temperature of T =100 K, the ρ value of these samples is 0.249 Ohm·cm. In the subsequent increase in temperature to T=120 K, it decreases sharply and amounts to 0.157 Ohm·cm. With a further increase in temperature, the ρ value of the samples of n-Si<Cu> begins to gradually increase and at T=320 K it reaches 0.335 Ohm·cm (Fig.1, curve 2).

Fig.2 shows graphs of the temperature dependence of the charge carrier concentration for the initial samples, as well as samples of n-Si<Cu> and n-Si<Ni> in the temperature range T=100÷320 K. According to the results obtained, the concentration of charge carriers in the initial samples at a temperature of 100 K is $n=6.27\times10^{15}$ cm^{-3}. When the temperature rises to 120 K, this value increases to 7.76×10^{15} cm^{-3}. A further increase in temperature to 140 K leads to an increase in the value of n by almost 2.5 times. In subsequent temperature values up to 320 K, this value practically does not change (Fig. 2, curve 1). A typical pattern is also observed in n-Si<Ni> samples. The n value of these samples at a temperature of 100 K is 6.24×10^{15} cm^{-3}. When the temperature rises to 120 K, this value decreases slightly and equals to $n=6.12\times10^{15}$ cm^{-3}. Then, with a further increase in temperature to 140 K, the n value of these samples increases sharply and at a temperature of 320 K reaches 1.7×10^{16} cm^{-3} (Fig.2, curve 3). In the samples of n-Si<Cu>, the value of n at a temperature of 100 K is 1.18×10^{16} cm^{-3}. When the temperature rises to 120 K, this value decreases by ~ 20%. The subsequent increase in temperature to 320 K leads to an increase in the value of n by almost 8 times (Fig.2, curve 2).

The graph of the temperature dependence of the mobility of charge carriers in the initial sample, in samples n-Si<Cu> and n-Si<Ni> in the temperature range T=100÷320 K is shown in Fig.3. The value of the mobility of charge carriers μ of the initial sample at a temperature of 100 K is 6228 cm^2/V·s. At that The same temperature for n-Si<Ni> samples is equal to 6890 cm^2/V·s, and for n-Si<Cu> samples it is 2130 cm^2/V·s.

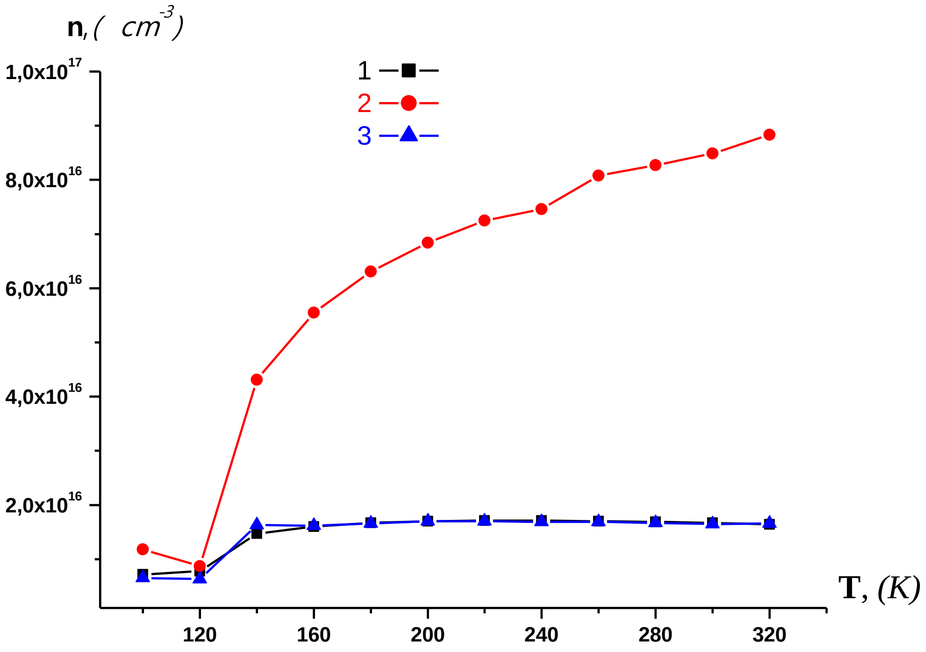

Fig. 2. Temperature dependence of charge carrier concentrations: 1 - initial sample; 2 - samples of Si<Cu> and 3 - samples of n-Si<Ni>.

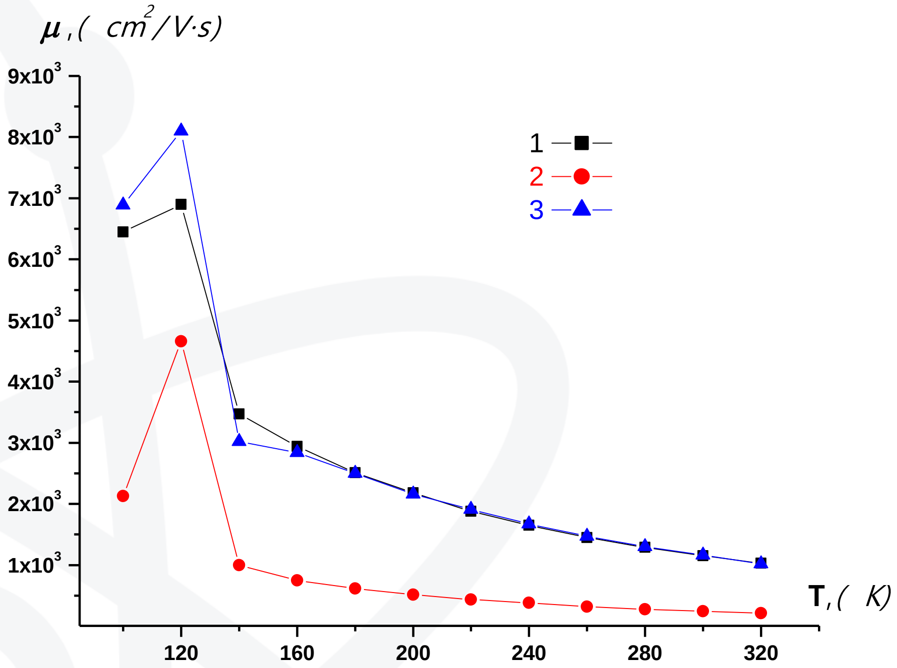

Fig. 3. Temperature dependence of charge carrier mobility in samples: 1 - initial sample; 2 - n-Si<Cu> samples; 3 - n-Si<Ni> samples.

As can be seen from the graph, the temperature dependence of the mobility of charge carriers in the initial sample and in n-Si<Ni> samples varies almost equally.

When the temperature rises to 120 K, the value of μ in the initial sample increases and amounts to 6900 cm²/V·s, and in n-Si<Ni> samples it reaches 8100 cm²/V·s. And with a subsequent increase in temperature to 140 K, the value of μ in these samples decreases sharply, and at a temperature of 320 K is 1030 cm²/V·s and 1020 cm²/V·s, respectively (Fig.3, curves 1 and 3). In samples of n-Si<Cu> at a temperature of T =100 K, the value of μ is 2200 cm²/V·s. And when the temperature rises to 120 K, the value of μ increases sharply and amounts to 4660 cm²/V·s. A further increase in the temperature value leads to a sharp decrease in the value of μ and at T = 140 K it is 996 cm²/V·s. With a subsequent increase in temperature to 320 K, this value gradually decreases to 211 cm²/V·s (Fig. 3, curve 2).

Conclusions

Thus, the results obtained showed that the electrophysical properties of n-Si<Ni> samples in the temperature range under consideration, compared with n-Si<Cu> samples, have distinctive characters. The resistivity of n-Si<Cu> samples increases by ~2 times in the temperature range 120÷320 K, while this indicator increases by more than 3 times in n-Si<Ni> samples. In this temperature range, the concentration of charge carriers in n-Si<Cu> samples increases by almost 8 times, and in n-Si<Ni> samples this value increases by almost 2.5 times. At the same time, the mobility of charge carriers in n-Si<Ni> samples decreases by 7÷8 times, and in n-Si<Cu> samples it decreases by more than an order of magnitude. Consequently, it turns out that the increase in the resistivity of samples n-Si<Cu> and n-Si<Ni> in the temperature range 120÷320 K mainly depends on the decrease in the mobility of charge carriers.

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