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Electrophysical properties of n-Si<Ni,Fe> samples

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ABSTRACT : *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 parameter. The paper presents the results of studies of the electrophysical properties of Si, doped Ni and Fe samples. It is revealed that a decrease in the mobility of charge carriers in the temperature range of 100÷320 K is of particular importance in increasing the resistivity of samples.*

KEYWORDS: *single crystalline silicon, 3d*-transition metal elements, *nickel, ferrum,* defects, diffusion, Hall effect.

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I.INTRODUCTION

The assembly of impurity atoms formed in times of high-temperature diffusion doping of single crystalline silicon samples with *3d*-transition metal elements significantly affect their electrophysical properties [1-4]. Solid semiconductor crystalline materials used in modern micro- and nanoelectronics are characterized by the presence of various defects. Depending on the application conditions and various external factors, these defects can have significant impact on the properties of crystalline materials [5-8].

II. EXPERIMENTAL PART

The starting material to obtain *n-Si<Ni,Fe>* samples was a single crystalline silicon sample (n-type conductivity phosphor-doped *n-Si:P*, resistivity 0.3 Ω·cm, grown by CZ technique). All samples were 10x5x2 mm in dimension in the shape of parallelepiped. Using a *VUP-4* -type vacuum deposition equipment, in which the vacuum was 10^{-4} Torr, the authors have been able to depose 0.4 µm-thick nickel atoms layer on tentatively prepared silicon samples surface. The deposition was performed on a single side. On the other side, 0.2 µm-thick iron atoms were deposited on the same samples. Simultaneous diffusion of nickel and iron atoms into silicon was carried out inside *SUOL-4*-type horizontal furnace at a temperature T=1423 K for 8 hours. The temperature in the furnace chamber was regulated using a platinum-platinum-rhodium thermocouple. After diffusion annealing, the samples were cooled rapidly (at rate υ_{cool}=200 deg/s). The electrophysical parameters of the above samples were measured using Ecopia-7000-type Hall equipment.

III. MEASUREMENT AND DISCUSSION

The Fig.1 shows the dependence curve of resistivity (ρ) of both initial sample and *n-Si<Ni,Fe>* on temperature within the interval between 100 and 320 K. In the initial and rapidly cooled *n-Si<Ni,Fe>* samples, the resistivity ρ varies almost equally depending on low temperatures, i.e., at 100 K the value of ρ tends to be 0.135 Ω·cm in the initial sample, in the rapidly cooled n-Si<Ni,Fe> samples and it is 0.154 Ω·cm respectively.

As the temperature increased to 120 K, these values have gradually tended to decrease, unless set at 0.11 Ohm-cm in the initial sample and 0.133 Ω·cm in the rapidly cooled *n-Si<Ni,Fe>* samples. On the other side as the temperature increased from 120 K to 320 K, these values increase and reach 0.37 Ω·cm in the initial sample and 0.404 Ω·cm in the rapidly cooled samples of *n-Si<Ni,Fe>* (Fig.1. 1- and 2- curves).

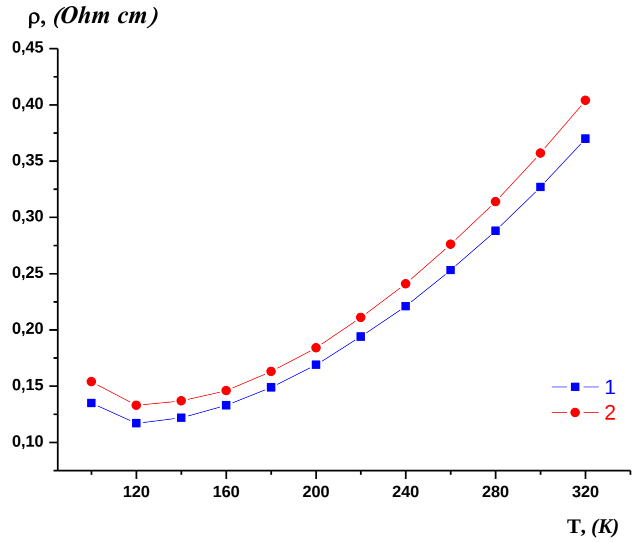

Fig.1. Temperature dependence of resistivity: 1-initial sample; 2 – rapidly cooled *n-Si<Ni,Fe>* samples.

Figure 2 shows the dependence curve of concentration of charge carriers - *n* on temperature for the initial sample and *n-Si<Ni,Fe>* samples in the temperature range of 100÷320 K.

According to the experimental results, the value of charge carrier concentration *n* in the initial sample at 100 K is $6{,}27\cdot10^{15}$ cm^{-3}. This value of *n* increases somewhat to $7{,}76\cdot10^{15}$ cm^{-3} when the temperature is increased to 120 K. A further increase in temperature to 160 K, the value of *n* tends to increase almost 2,5 times, amounting to $1{,}6\cdot10^{16}$ cm^{-3}. When the temperature is increased to 320 K, this value practically does not change (Fig. 2, curve 1).

In the rapidly cooled *n-Si<Ni,Fe>* samples at 100 K, the value of n is $6{,}5\cdot10^{15}$ cm^{-3}. When the temperature increases to 120 K, this value of *n* gradually increases and becomes equal to $9{,}5\cdot10^{15}$ cm^{-3}.

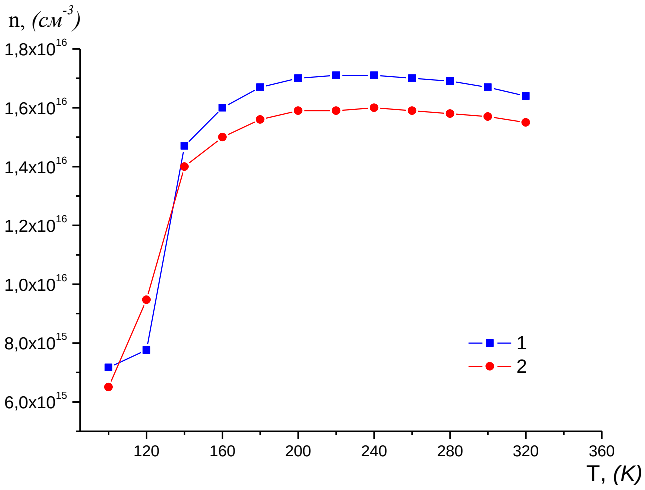

Fig.2. Dependence of concentration of charge carriers on temperature: 1 - initial sample; 2 - rapidly cooled n-Si<Ni,Fe> samples.

Then, when the temperature is increased to 140 K, the value of *n* in these samples increases sharply to $1{,}4\cdot10^{16}$ cm^{-3} (Fig. 2, curve 2). Thus, in the temperature range between 100 and 140 K, a slight decrease in resistivity values of the initial sample and n-Si<Ni,Fe> samples by almost ~2% is observed. In this temperature range, the concentration of non-equilibrium charge carriers in these samples increases almost 2÷2,5 times.

III. CONCLUSION

It was found that in the temperature range of 160÷320 K, the resistivity of the samples increases almost 2,5÷3 times, while the concentration of nonequilibrium charge carriers remains almost unchanged. At a temperature of 320 K, the value of ρ in the *n-Si<Ni,Fe>* samples is 11% higher than the initial sample, and the value of n at this temperature in the n-Si<Ni,Fe> samples is 9% lower than the initial sample.

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