THE INFLUENCE OF IMPURITIES ON KINETICS OF ANNEALING OF $Ge_{1-X}Si_X$ RADIOACTIVE DEFECTS

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In the present work there have been presented the results of our previously carried out investigations of electrophysical properties of solid solutions of *n*-$Ge_{1-x}Si_x$ [1, 2] and conductivity compensation of an electronic $Ge_{1-x}Si_x$ under irradiation has been studied. The irradiation was conducted at 77 K and at room temperature by electrons with energy of 4.5 MeV and by γ-quanta of ^{60}Co.

The results of study of Hall effect and conductivity and the influence on them of isochronous annealing of $Ge_{1-x}Si_x$ monocrystals grown by Chokhralsky method and alloyed Sb ($5\cdot10^{-14}$-$1\cdot10^{15}$cm^{-3}) have been presented. Atomic content of Si was 0.05-0.15%. The annealing was carried out at 300-420 K, exposure time at each temperature was 15 min.

The levels E_c-0.13eV, E_c-0.2eV in a lower part of the forbidden zone belong to the most electrically active acceptors in a spectrum of arising in *n*-$Ge_{1-x}Si_x$ radioactive defects. The annealing temperatures 350, 420 K correspond to the acceptor states. The structure of defects to which the acceptor states belong was discussed in [2].

In the present work we'll only emphasize that the acceptors energetic characteristics and their radioactive constants depend on Si content and in formation of a defect corresponding to the acceptor state *E*, an atom of *V* group element takes part. The similar process of defect formation occurs also in Ge.

The concentrations of donors and acceptors were calculated with the use of the temperature dependence of electrons concentration by a law of active masses. The results obtained by means of two calculation methods [3, 4] which in use to the irradiated Ge have been analyzed in [5], coincide. The calculation was made in approximation of equality of electron effective masses and long-orbit splitting of basis donor state in Ge and $Ge_{1-x}Si_x$, therefore the quantitative comparison with the data for Ge had been presented only for $Ge_{1-x}Si_x$ with Si 0.05% at.

In the case of *n*-$Ge_{1-x}Si_x$ due to the increase of acceptors during irradiation the compensation of conductivity increases up to the change a type of conductivity.

The kinetics of the electrons concentrations change in germanium and solid solutions with Si 5% at and Si 10% at with conductivity of *n*-type is presented in fig. 1. In Ge samples at relative integral flow corresponding to the sharp pass of Hall coefficient through the minimum the $n\rightarrow p$ conversion of conductivity type occurs.

At Φ/N_0 respective doses in samples of solid solution with Si 5% at and Si 10% at the $n\rightarrow p$ conversion of conductivity type (defined by Lissajous figure) also takes place. However, these transitions are not accompanied by passing Hall coefficient through the minimum and in the indicated sections the samples are in a compensated state.

It has been established that as the silicon content in a solid solution increases, a dose necessary for the $n\rightarrow p$ conversion, decreases. It follows from this that the more silicon in the samples of solid solution of *n*-$Ge_{1-x}Si_x$ irradiated by the same respective doses of electrons, the greater the concentration of holes after conversion of conductivity type which for the samples with Si content 0; 5; 10% at amount to $6.5\cdot10^{11}$cm^{-3}, $2\cdot10^{12}$cm^{-3}, $1.4\cdot10^{13}$cm^{-3}, respectively. In fig. 2 the doses dependences of N_D (1) and N_A (2) for *n*-$Ge_{1-x}Si_x$ with Si 0.05% at are presented. As for donor states, it was observed experimentally both decrease and increase of donor concentration with Φ dose. In fig.3 the temperature dependences of Hall mobility of the electrons for the same sample are given.

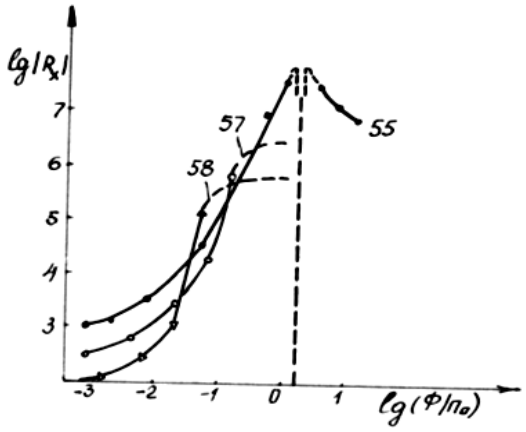

Fig. 1. Dependence of Hall coefficient on relative integral dose for different samples of *n*-type $Ge_{1-x}Si_x$.
55 – Ge samples alloyed Sb, 57 and 58 - the samples of $Ge_{1-x}Si_x$ solid solution with 5% and 100% of Si respectively.

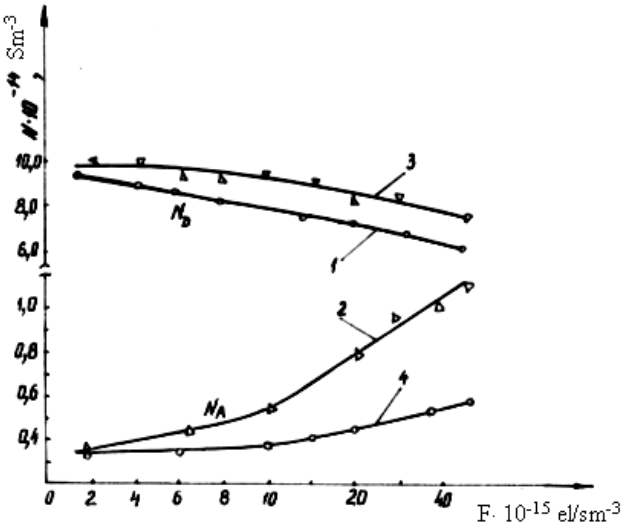

Fig. 2. Dose dependence of N_D (1) and N_A (2) for *n*-$Ge_{1-x}Si_x$ with 0.05% Si at.

The Hall mobilities of current carriers have been estimated on experimental temperature dependences of Hall

coefficient and electrical conductivity. In order to discuss experimental results, the temperature dependences of Hall mobility are presented prior irradiation and after the proper annealing. It has been established that mobility of *p*-type samples with Si 0; 5; 10; 15% at within the temperature range 80-300K is significally higher than prior irradiation.

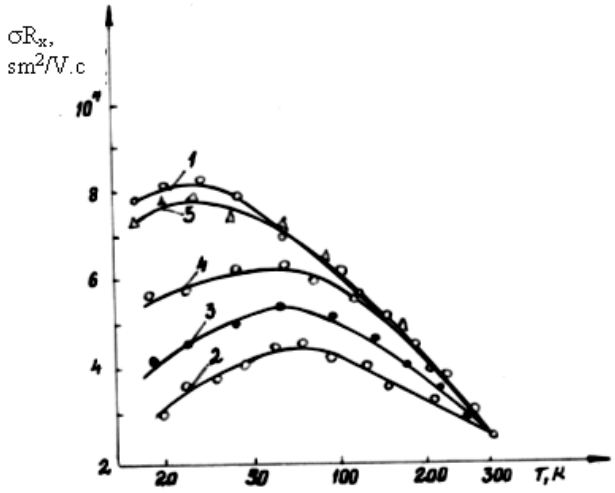

Fig. 3. Temperature dependences of Hall mobility of electrons $Ge_{1-x}Si_x$ with x=0.05.

The annealing of the irradiated samples at 300 K slightly decreases the value of Hall mobility except the germanium sample of *p*-type in which the mobility increases a little.

The annealing at T=420K leads to the increase of Hall mobility as compared with the mobility values prior irradiation. In a sample with Si 15% at the mobility is almost reduced to the initial value. For comparison of the experimental results in different samples, in fig. 4 there have been given the dependences of relative Hall mobilities (M/M_0) on Si% at measured at temperature 80 K, where M_0 is a value of mobility the prior irradiation. The mobility in all samples measured at once after irradiation, increased on an average by a factor of 2 (curve 1). The annealing at 300K almost reduces the initial mobility except germanium (curve 2) in which the mobility still increased by 3.7 times, the further annealing at 420K increased inversely the value of Hall mobility (curve 3) except a sample of solid solution of $Ge_{1-x}Si_x$ with Si 15 % at.

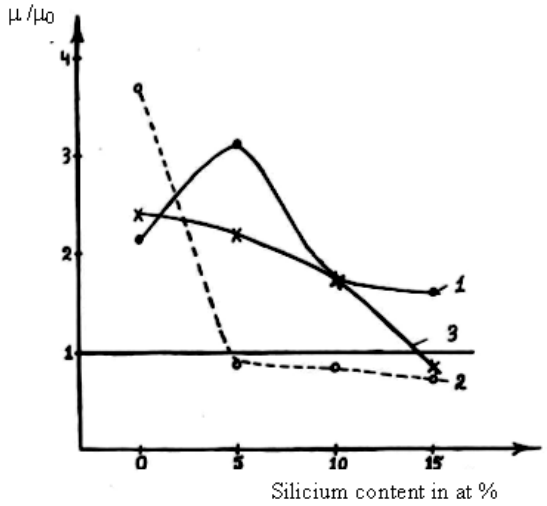

Fig.4. Dependence of relative Hall mobilities (M/M_0) on Si in % for *p*-$Ge_{1-x}Si_x$.

The analysis of temperature dependences of Hall coefficient and mobility of charge carriers in irradiated and annealed samples of Ge and $Ge_{1-x}S_x$ permits to draw the following conclusions:

1. Decrease of N_D during irradiation observed experimentally along with the other dose dependences of N_D is not connected to electrically inactive defects in a model [6]. The stability of such defects as the acceptor states E_c=0.2eV is limited within the temperature range 350-420K.

2. The number of the radioactive levels and their ionization energies depend on Si content in solid solutions.

3. One can change markedly the values of Hall mobility depending on the temperature of irradiation, annealing and Si content in solid solution. Indeed, as it is seen from fig. 3 (curve 3), the mobility in samples of solid solution with Si 0-10 % at, irradiated at 100K and annealed at 420K, increases on an average by a factor of two, as compared with the initial mobility. This seems to be connected to a change of charge state of the non-homogeneities regions.

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$Ge_{1-x}Si_x$ BƏRK MƏHLULUNDA YARANAN RADİASİYA DEFEKTLƏRİNİN KİNETİK TABLAMASINDA AŞQARLARIN ROLU

Bu işdə bizim tərəfdən əvvəllər öyrənilmiş n - $Ge_{1-x}Si_x$ bərk məhlulunun elektrofiziki xassələrinə elektron şüalarının təsirinin davamı olaraq, n - $Ge_{1-x}Si_x$ bərk məhluluna γ və elektron şüalarının təsiri ilə kompensasiya olunma və yaranan radiasiya

defektlərinin kinetik tablamasında aşqarların rolu öyrənilmişdir. Bunun üçün şüalanma mənbəyi kimi ^{60}So - γ qurğusundan və enerjisi 4,5 MeV olan elektron sürətləndiricisindən istifadə olunmuşdur. Şüalanma temperaturu 77K÷300K-dir.

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ВЛИЯНИЕ ПРИМЕСЕЙ НА КИНЕТИКУ ОТЖИГА РАДИАЦИОННЫХ ДЕФЕКТОВ Ge_{1-x} Si_x

В настоящей работе приведены результаты начатых нами ранее исследований электрофизических свойств твердых растворов *n*-Ge_{1-x} Si_x [1,2] и изучена компенсация проводимости электронного Ge_{1-x} Si_x при облучении. Облучение осуществлялось при 77К и при комнатной температуре электронами с энергией 4,5 МэВ и γ - квантами ^{60}Co.

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