HEAT TREATMENT EFFECT ON RADIATION STABILITY OF THE SCHOTTKY BARRIER ON THE BASE OF n-Ge

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ABSTRACT

The analyses of the method for increase of radiation stability of semiconductor devices are given in the present state. For this purpose in n-Ge the thermal defects have preliminarily been created and their interaction with radiation defects in the irradiation process has been investigated by photocapacity and photoconductivity methods.

It has been found that when interacting with radiation defects in the irradiation process, preliminarily created thermal defects in n-Ge form more stable defects which lead to increase of radiation stability of diodes.

The set of the obtained experimental data indicates that at heat treatment of Germanium at temperatures of T $\geq$ 500 °C the defects with intrinsic structural disturbances of the crystal lattice itself are formed. These defects interacting with radiation defects during irradiation form more stable defects leading to increase in radiation stability of the material. The fact that the insertion velocity of radiation defects in thermally treated samples is less than in thermally untreated samples indicates that thermal defects are responsible for mobile radiation defects. The results obtained from this study are agree with the handled data.

Key Words: Stability, Semiconductor, Effect, Schottky.

1.INTRODUCTION

Recently, much attention is given to the investigation of the ionising radiation effect on the self diffusion in solids. This is attributed to the fact that the radiation-stimulated processes in solids determine the character of the change of the properties of solids at their interaction with radiation. The investigation of these regularities in solids allows to obtain information on mechanisms of the formation and annealing of radiation defects and is also of great practical importance due to the problem of increase in radiation stability of semiconductor devices. (Jafarov, 1990)

The purpose of the present paper is the study of the interaction mechanism of radiation defects with thermal defects preliminarily inserted into the Germanium treated at temperature of 500°C . For this purpose the Ge has been irradiated by electrons with the energy of 4.5 MeV, and photocapacity and photoconductivity methods have been used for investigation of the processes of radiation defect formation in Ge under irradiation. (Berman, Lebedev, 1981) In the experiments the n-type Germanium samples with the basic electron concentration of $\sim 10^{14}$ cm^{-3} have been used. The Schottky diodes on the base of n-Ge have been prepared by vacuum evaporation method. (Strikha, Buzanova, Radzievski, 1974)

2.METHODS AND MATERIALS

The ohmic contacts have been obtained by deposition of 50% In - 50% Sn alloy layer. During investigations the two types of samples have been used, i.e. preliminarily thermally treated at 500°C (the I type) and thermally untreated (the II type-controlled) samples. These samples have been irradiated by accelerated electrons of 4.5 MeV at the dosage of 10^{13} cm^{-2}. The measurements were carried out by the photocapacity method at temperature of 77 K in the linear part of the $C^{-2}\sim f(u)$ dependence. The concentration values of the photoactive centers in the space charge(N_{eff}) layer were determined from the linear part of the $C^{-2}\sim f(u)$ characteristic. The exponent of the current-voltage characteristic before irradiation for all the Schottky barriers was equal to 2~3. After the electron irradiation at the dosage of 10^{13} cm^{-2} the exponent for thermally treated samples changes slightly, while for thermally untreated samples it increases and becomes equal to ~3.2 indicating a considerable change of the character of carrier distribution in the space charge layer due to the sample irradiation.

3.RESULTS AND DISCUSSION

As seen in Fig.1 the illumination of diodes by impurity light with the energy of $h\gamma \leq 0.3$ eV in the I-type samples the capacity is practically unchanged. The increase of photocapacity is observed at the energy 0.32 eV due to level ionisation, Ev~0.32 eV (Curve 1). The illumination of diodes by light with the energy of $h\gamma \geq 0.40$ eV the photocapacity remains unchanged.

To determine the energy level position more accurately, the induced photocapacity spectra were investigated, i.e. the sample was initially illuminated by light with the energy of $h\gamma > E_g$ (leading to intensive generation of majority carries through the space charge layer) , and then the $N_{eff} = f(h\gamma)$ dependence was taken (Fig.1, curve 1') . As seen in Fig.1, the decay of photocapacity is observed in the range of 0.20 - 0.30 eV due to electron occupancy of level with the ionisation energy of E_v – (0.20 – 0.30) eV. The charged center concentration in the space charge layer determined from the $e^{-2} \sim f(u)$ dependence was 4.10^{15} cm^{-3} (Fig.2).

The investigation of the II-type (controlled) sample photocapacity spectra has shown that the increase of capacity is observed in the range of $h\gamma = 0.20 - 0.25$ eV. At $h\gamma > 0.25$ eV the character of the change of capacity completely corresponds to that of the I-type samples. The correlation of the photocapacity spectra of the both types of samples entirely corresponds to the character of the change of the I-type sample capacity. The above correlation revealed the occurrence of additional level $E_v \sim$ (0.20-0.25) eV wih concentration of 7.10^{14} cm^{-3} in thermally untreated samples under electron irradiation of 4.5 MeV. The estimation shows that the total concentration of the charged carriers in the II-type samples decreases indicating the acceptor character of the radiation level formed. It has also been clarified that the induced photocapacity spectra of the both types of samples are identical (Fig.1, curves 1',2'), i.e. under irradiation the donor photoactive centers with the energy of $E_1 = E_v + (0.20 - 0.30)$ eV are formed.

Isochronous annealing of diodes irradiated with the dosage of 10^{13} cm^{-2} at 400°C (t = 30 min.) leads to a considerable change of photocapacity and induced photocapacity spectra in the range of $h\gamma = 0.20$-0.25 eV due to radiation defect annealing in samples of the II-type (curve 3').

These facts indicate that all the levels completely decay at annealing the II-type sample passes into the basic state, while in thermally treated samples (I type) the complicated complexes stable at high temperature are probably formed during annealing.

The annealing temperature dependence of the defect concentration for diodes based on n-Ge after electron irradiation with the dose of 10^{13} cm^{-2} for E_v + 0.02 and E_v +0.30 eV levels is shown in Fig.3. In the temperature range of 200~600°C a complete decay of defects takes place in the I-type samples, while in samples of the II-type a partial decay of defects is observed due to the formation of more stable defects. In this case in thermally treated samples the defect concentration is higher than in thermally untreated samples. It has also been found that the $N_T \sim f(T)$ dependence is described by the expression $N_T = 3.87 \cdot 10^{20} \cdot \exp(\theta/KT)$ cm^{-3} where $\theta = 1.7 \pm 0.2$ eV is the energy of thermal defect formation. The correlation of the charged center effective concentration in the space charge layer before and after heat treatment shows that the created thermal defects are more stable and are the donors. The comparison of the center concentration with the ionisation energy of E_V +0.30 eV in thermally treated and untreated samples with equal irradiation doses shows that in thermally treated samples it is higher as compared to controlled samples (the II-type). This result points to the fact that a preliminary thermal treatment of n-Ge leads to stimulation of radiation processes, particularly, to increase of insertion velocity of radiation defects with the energy level of E_V +0.30 eV. It follows from this fact that thermal defects are the additional sources of vacancies under irradiation of samples.

The set of the obtained experimental data indicates that the heat treatment of Germanium at temperatures of $T \geq 500$ °C the defects with intrinsic structural disturbances of the crystal lattice itself are formed. These defects interacting with radiation defects during irradiation form more stable defects leading to increase in radiation stability of the material. The fact that the insertion velocity of radiation defects in thermally treated samples is less than in thermally untreated samples indicates that thermal defects are responsible for mobile radiation defects.

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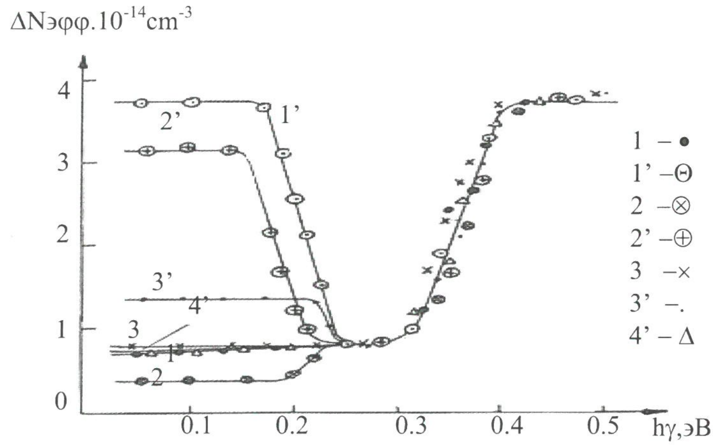

Figure 1. The photocapacity (1,2,3) and the induced photocapacity (1',2',3') spectra of the Schottky diodes on the base of n-Ge after irradiation by electrons at the dosage of 10^{13} cm^{-2}.

1-1' -for thermally treated samples (the I type)

2-2' -for thermally untreated samples (the II type)

3-3' -after annealing for thermally untreated samples

4' - after annealing for thermally treated samples

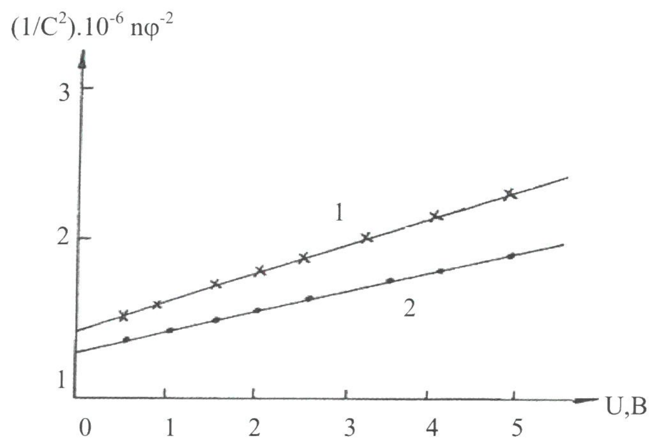

Figure 2. The capacitance-voltage characteristic of the Schottky diodes on the base of n-Ge after the electron irradiation at the dosage of 10^{13} cm^{-2}.

1 -for thermally treated samples 2 -for thermally untreated samples

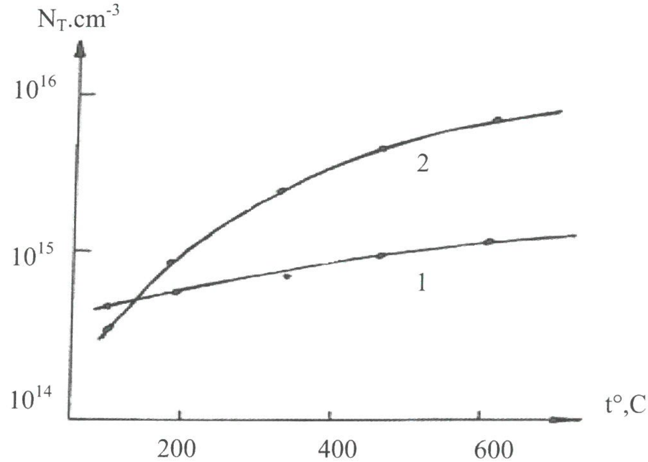

Figure 3. The annealing temperature dependence of defect concentration after electron irradiation at the dosage of 10^{13} cm^{-2} (t=30 min.).

1 -for thermally treated samples 2 -for thermally untreated samples