Nanoscale physics

MODELING OF ELECTRONIC PROCESSES IN SENSORY MAGNETIC SENSITIVE STRUCTURES

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Introduction

Magnetosensitive semiconductor transistor structures (MTS) are a basic sensitive element of sensors for various purposes [1,2]. It is known that the parameters of any semiconductor materials and structures are significantly affected by various types of ionizing radiation through, in particular, the defect formation mechanism [4].

The radiation defect influence study plays a significant role in the new semiconductor device development and creation and the study of their physical mechanism work can lead to important conclusions about the influence of intrinsic structural defects on material parameters. We studied the effect of irradiation with fast electrons and ^{60}Co γ-quanta on the two-collector MTS (TMTS) magnetic sensitivity.

Methods

At the highest rate in the silicon irradiated with different types of radiation, the levels of E_c-0.16 eV, E_c - 0.4 eV E_v + 0.45 eV, E_v + 0.30 eV and E_v + 0.01 eV are introduced. TMTS samples made by standard planar technology based on *n*-SI with ρ initial values equal to 150÷180 Ohm·cm and 100 Ohm·cm and were irradiated with electrons (energy of 2.5 MeV at 293 K) with a variable integrated radiation dose 10^{13} - 10^{16} el/cm^2 on a linear accelerator "Electronics".

Results and discussion

The effect of irradiation with fast electrons

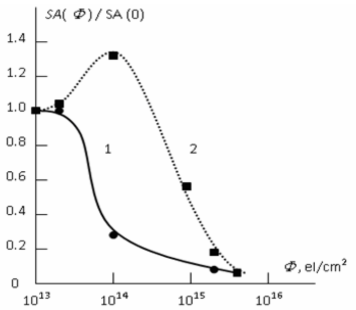

Fig. 1 The TMTS absolute sensitivity dose dependence when irradiated with electrons for samples with ρ=150 ÷ 180 Ohm·cm.
1 - immediately after irradiation with integral doses up to $3\cdot10^{13}$ el/cm^2 SA $\propto$ exp (-*K*/*Φ*), *K* = $2\cdot10^{16}$ el/cm^2;
2 - after annealing in the range of 50 ÷ 400 °C with a step of 50 °C with exposure for 30 min. The SA for TMTS samples annealed at 300 °C

At doses above $3\cdot10^{13}$ el/cm^2 there is a decrease in the diffusion length *L* at the transistor base due to the radiation defects concentration increase and the formation of areas of disorder.

According to the results it was possible to judge the effect of radiation defects introduced into the TMTS structure on its magnetic sensitivity.

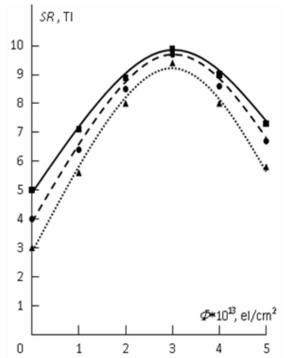

Fig. 2 Conversion efficiency dose dependence for three samples (ρ = 100 Ohm·cm) from the TMTS experimental party. ▲ - 10^{13} el/cm^2. ● - $3\cdot10^{13}$ el/cm^2, ■ - $5\cdot10^{13}$ el/cm^2

When the samples are irradiated with an electron dose of $3\cdot10^{13}$ el/cm^2, the Hall mobility increases approximately 3,3 times from $3\cdot10^3$ to 10^4 cm^2/(B·c), which is explained by the impurity scattering centers concentration decrease under the action of the electron irradiation small doses. It turns out that in inhomogeneities dispersal of great importance is the small concentration radiation defects formation and the presence of ionization.

The diffuse mechanism plays the main role in the inhomogeneities dispersal. At doses above 3×10^{13} el/cm^2 for TMTS (initial ρ = 100 Ohm·cm), the mobility begins to decrease due to an increased concentration of radiation defects and disorder areas. The sample annealing provides stability due to a decrease in the radiation defects concentration and the presence of ionization effects. Since SA $\propto$ SR $\propto$ μ^*_{mn}, μ^*_{mj}, a corresponding dependence of the magnetic sensitivity on the radiation dose is observed. The maximum magnetic sensitivity is associated with an increase in the lifetime of the injected minority charge carriers after annealing, matching the elimination of nonequilibrium, and a decrease in structural disorder.

For magnetically sensitive transistors, there is a minimum energy of 4.5 MeV, below which electrons have less influence on the parameters of the transistor sensitive to the magnetic field. With annealing time less than 2 hours, the increase in magnetic sensitivity decreases. Increasing the annealing time over 3 hours increases the cycle time and energy costs.

The effect of irradiation with ^{60}Co γ-quanta on the TMTS initial characteristics By the defect formation type, γ-quanta act similarly to fast electrons. For the most TMTS the magnetic sensitivity dose dependence has two areas: region in which the magnetic sensitivity does not depend on the dose: $10^5<\Phi<10^6$ rad; and region of magnetic sensitivity monotonic drop: $\Phi>10^6$ rad. The region of the magnetic sensitivity monotonic reduction $10^6 < \Phi < 5\cdot10^7$ rad can be described by the expression SA = SA0(1-*KTΦ*), *KT*=(1÷3)$*10^{-8}$ rad^{-1}. Here also the dose dependence is connected with a role of surface and volume defect formation at irradiation.

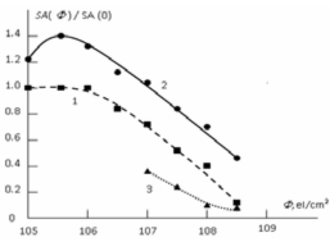

Fig. 3 TMTS samples on the n-Si basis (*ρ* = 150 ÷ 180 Ohm• cm) absolute sensitivity dose dependence when irradiated with γ-quanta ^{60}Co. 1 - immediately after irradiation; 2 - after annealing (120^{0}C for 30 min) ; 3 - for the KD-303 magnetodiode

Conclusions

Influence of the ionizing radiation on the semiconductor physical parameters leads to changes in the MTS basic parameters and leads, in particular, to a decrease in their magnetic sensitivity at absorbed doses greater than 10^{15} el/cm^2 (10^6 rad) due to surface and bulk defects. Increasing of the absolute magnetic sensitivity and increasing of the MTS parameter repeatability, can be achieved due to controlled irradiation with their subsequent annealing at the temperatures of 200–250^{0}C for 2-3 hours in the air.

References

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