A negative sensitivity effect in dual-collector lateral npn-type bipolar magnetotransistors, formed in the well, found experimentally, is investigated using instrument-technological modeling. It is established that the sign of the sensitivity is determined by the separation of the electron and hole fluxes in the well–substrate pn-junction in the magnetic field. The modulation of the conductivity in the space-charge region of the pn-junction by the magnetic field is analyzed.

Key words: bipolar magnetotransistor, instrument-technological modeling, magnetoconcentration effect.

It has been established experimentally [1] that an external transverse magnetic field with an induction of up to 2 T has no effect on the injection level of the emitter in a dual-collector silicon pnp lateral magnetotransistor. No modulation of the injection by the magnetic field is observed. The magnetosensitivity of a silicon lateral magnetotransistor is determined by the change in the emitter–collector transfer constant. An external transverse magnetic field causes rotation of the emitter current lines in the base region in a semiconductor with a uniform impurity distribution.

Magnetoconcentration effects occur in silicon lateral magnetotransistors, which lead to an additional increase or decrease in the power of the collector current, depending on the sign of the magnetic induction ($B^+$, $B^-$). The parameters of the base material, the ratio of the base length to the diffusion length of the minority charge carriers and the rate of surface recombination influence the magnetoconcentration effect. For short base lengths and slow rates of surface recombination, the magnetoconcentration phenomena are negligibly small, and the dependence of the collector current strength on the induction is linear. An increase in the density in the substrate reduces the sensitivity. The absolute current sensitivity increases exponentially as the distance between the emitter and the collectors decreases.

In this paper, magnetoconcentration phenomena are taken to mean the change in the concentration of injected carriers due to surface recombination along the base length in a magnetic field, which press the carriers towards the surface from one side of the emitter and displace them from the surface from the other side. This effect gives rise to nonlinearity of the change in the current strength of each collector depending on the magnetic induction for large distances between the emitter and the collectors. The difference between the current strengths of the collectors depends linearly on the induction.

The distributions of the current density and the electron current lines in a dual collector bipolar nnp-magnetotransistor with uniform doping of the substrate, obtained by calculation using ISE TCAD instrument-technological modeling programs [2], show that the current lines are shortened on one side of the emitter and the current strength of the first collector, situated on the other side, is increased. On the other side of the emitter, the current lines are lengthened, and the current strength of the second collector is reduced. The sensitivity is defined as being positive.

In a dual-collector lateral nnp-magnetotransistor, situated in a diffusion well, with a surface density $N_S = 2 \cdot 10^{16}$ cm$^{-3}$ and a diffusion depth $X_J = 6.6 \mu$m a change in the sign of the current difference of the collectors is observed [3] in the mag-
netic field compared with a bipolar magnetotransistor in the substrate with uniform doping $N_a = 10^{15}$ cm$^{-3}$ ($N_a$ is the acceptor density). Dual-collector lateral magnetotransistors were manufactured using the same technology and having the same topology as bipolar magnetotransistors. Only the type of conductivity of the substrate was changed and a diffusion well with $p$-type conductivity was produced in it.

The change in the voltage on the collectors of the dual-collector lateral magnetotransistor has the opposite sign compared with the bipolar magnetotransistor. For a positive deflection of the electrons injected from the emitter due to the action of the Lorentz force into the second collector, the current strength in the first collector increases and in the second it decreases. The sensitivity turns out to be negative.

Hence, the introduction of a well with a nonuniform impurity distribution into the base region of a dual-collector lateral magnetotransistor changes its characteristics and the sign of the sensitivity from positive to negative. The maximum value of the sensitivity increases. The connection of contacts to the substrate and well produces an operating threshold of the lateral transistor: when a certain emitter current strength is reached, an appreciable collector current occurs.

Fig. 1. Distributions of the differences in the rates of recombination of electrons and holes by the Shockley–Read–Hall mechanism ($a$) and of the electron and hole densities in a dual-collector lateral magnetotransistor ($b$, $c$) when acted upon by a magnetic field and without it.