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Low-temperature magnetoresistance of GaSb whiskers

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Transverse and longitudinal magnetoresistancies in *n*-type GaSb whiskers with different doping concentration (Te) in the vicinity to the metal-insulator transition (MIT) from metal side of the transition were studied in the temperature range 1.5–60 K and magnetic field 0–14 T. Shubnikov-de Haas oscillations in GaSb whiskers at low temperatures were revealed in magnetic field range 2–12 T. The oscillation period $0.025T^{-1}$ was found at various doping concentration in GaSb whiskers. The effective mass of electrons $m_c = 0.041m_0$ and Dingle temperature of about 7.5 K were found in GaSb whiskers with impurity concentration in the vicinity to MIT. The presence of negative magnetoresistance in GaSb whiskers with the impurity concentration in the nearest approximation to MIT with resistivity $\rho_{300\text{K}} = 0.0053\ \Omega\cdot\text{cm}$ was observed and associated with weak localization. Besides for the whiskers a resistance minimum was observed at temperature about 16 K that is connected with Kondo effect. Magnetoresistance studies of *n*-type conductivity for GaSb whiskers revealed the crossover from weak localization to antilocalization in the temperature range of 1.4–4.2 K and magnetic fields below 1 T.

PACS: 73.43.Qt Magnetoresistance;
72.15.Rn Localization effects (Anderson or weak localization);
71.30.+h Metal-insulator transitions and other electronic transitions;
72.20.My Galvanomagnetic and other magnetotransport effects.

Keywords: GaSb whiskers; transverse and longitudinal magnetoresistance oscillations; effect Kondo; weak localization and antilocalization.

1. Introduction

GaSb is an important material for sensors, solid-state lasers and microelectronic circuits caused by crystal perfection [1,2]. Epitaxial layers and quantum dots of GaSb grown on the semi-insulator substrates were used in high speed devices due to low dislocation density [3,4]. But influence of substrates substantially limits their advantages. Using of nano- and microwhiskers and also ingots on the base of GaSb allow avoiding described imperfection [5,6]. GaSb nanowires were widely used in subwavelength-wire lasers of photonic integrated circuits [7] due to their high mobility and dimensional dependences [8,9].

GaSb whiskers have attracted attention due to their unique electrical and optical properties and potential applications in nano- and optoelectronics. For a success in the development and optimization of new devices and systems made on the basis of GaSb whiskers it is necessary to have a deep understanding of their electronic structure [10]. The effective mass of structure based on InAs/GaSb nanowires was also calculated studying their electronic and optical properties [11]. These structures were investigated for different sizes of InAs and GaSb structures. Besides a weak localization (WAL) of two-dimensional conduction holes was observed in GaSb-InAs-GaSb quantum-well structure, which revealed by observation of negative magnetoresistance [12]. Interesting physical effects (negative or anomalous positive magnetoresistance, magnetoresistance oscillation beating, etc.) occurred in materials with impurity concentration in the vicinity to metal-insulator transition due to large overlapping of wave function of charge carriers leading to increase of spin-orbital interaction in such samples. For example, two-dimensional processes of weak electron localization and spin-orbit scattering were also observed in the carbon fibers on the metallic side of the MIT at low temperatures [13]. Positive magnetoresistance effect in these fibers is due to the presence of spin-orbit scattering in a weak magnetic field, and negative magnetoresistance effect in strong magnetic fields due to the suppression of weak localization processes by the magnetic field [13]. However, weak localization and antilocalization processes slightly studied in GaSb whiskers.

The aim of this paper are studies of Shubnikov-de Haas oscillatory effects as well as charge carrier localization/antilocalization process in *n*-type GaSb whiskers with different doping concentration (Te) in the vicinity to MIT from metal side of the transition at low temperatures 1.5–60 K in the high magnetic fields with induction up to 14 T.

2. Experimental procedure

The object of the studies was *n*-type GaSb whiskers obtained by the method of chemical transport reactions. Investigated whiskers were doped with tellurium during their growth. The results of the whiskers investigation by ion mass spectroscopy have shown that GaSb microcrystals have Te concentration correspondent to metallic side of MIT and equal about to $2 \cdot 10^{18}$ cm^{-3}. GaSb microcrystals were selected with lateral dimensions about 30–40 μm and length 2–3 mm. Au wires with diameter of 10 μm were used to create electrical contacts to the whiskers that form an eutectic with the crystal under pulsed welding. This technique was tested and described in previous studies for SiGe whiskers [14,15], and it allows us to measure the resistance of the crystal using the scheme with four contacts along the crystal. Additional contacts were created by the same method for the study of galvanomagnetic properties of the whiskers.

Low-temperature conductivity of GaSb whiskers was investigated in the temperature range 1.5–300 K. For these studies crystals were placed in the helium cryostat where they were cooled to temperature 4.2 K. The temperatures below 4.2 K were reached by pumping the cryostat. The effect of magnetic field on the properties of the whiskers was studied using the Bitter magnet with the induction 14 T and time scanning the field 1.75 T/min in the temperature range 1.5–77 K. Stabilized electric current through the crystal was created by the current source Keithley 224. It was in the range of 1–10 mA depending on the crystal resistance. The temperature was measured using Cu-CuFe thermocouple.

Electrical voltage crystal contacts, output signals from the thermocouple and the sensor's magnetic field were measured by the digital voltmeters type Keithley 199 and Keithley 2000 with precision up to $1 \cdot 10^{-6}$ V and simultaneous automatic registration hits.

The electron concentration in the samples was determined based on Hall investigations. The parameters of investigated sample are presented in Table 1.

3. Experimental results and their discussions

3.1. *Temperature dependences of* GaSb *whisker resistance*

Three groups of *n*-type GaSb whiskers with different doping concentration (Te) in the vicinity to MIT from metal side of the transition were selected to study their magnetoresistance:

Table 1. GaSb whisker parameters at *T* = 300 K

Resistivity, Ω·cm	Mobility, cm^2/(V s)	Electron concentration, cm^{-3}
0.0036	1000	$1{,}75 \cdot 10^{18}$
0.004	1050	$1{,}66 \cdot 10^{18}$
0.0053	1200	$1{,}5 \cdot 10^{18}$

1. GaSb whiskers with the impurity concentration in the nearest approximation to MIT with resistivity ρ_{300K} = = 0.0053 Ω·cm.

2. GaSb whiskers with the greater impurity concentration with resistivity ρ_{300K} = 0.004 Ω·cm.

3. Heavily doped microcrystals with the largest impurity concentration with resistivity ρ_{300K} = 0.0036 Ω·cm.

Temperature dependences of the resistance for *n*-type GaSb whiskers with different doping concentration in the temperature range 1.5–300 K are presented in Fig. 1. As one can observe, the behavior of these characteristics is almost similar in wide temperature range 30–300 K, while significantly differs in low-temperature range below 4.2 K (inset of Fig. 1).

The peculiarities obtained on the temperature dependences of the resistance at temperature range 30–300 K differ for GaSb whiskers with various concentrations due to change of the carrier transport mechanism. The presented characteristics correspond to the straight metallic conductivity of GaSb whiskers with resistivity ρ_{300K} = 0.0036 Ω·cm (Fig. 1, curve *3*), clearly semiconductor conductivity for samples with ρ_{300K} = 0.0053 Ω·cm (Fig. 1, curve *1*) and intermediate slope of the temperature dependences of the resistance for crystals with ρ_{300K} = 0.004 Ω·cm (Fig. 1, curve *2*).

At low temperatures for GaSb whiskers with resistivity ρ_{300K} = 0.0036 Ω·cm and ρ_{300K} = 0.004 Ω·cm sharp drop

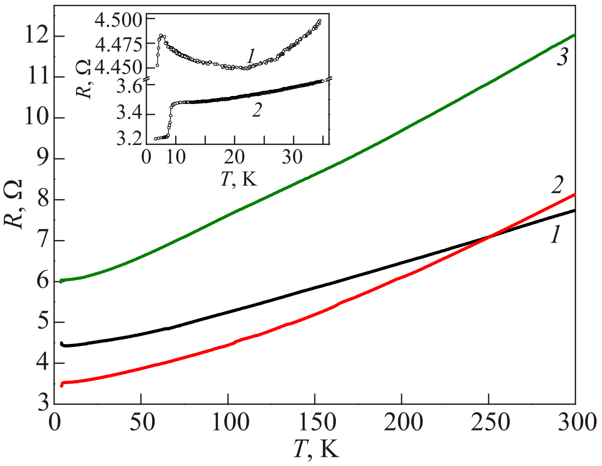

Fig. 1. Temperature dependences of the resistance for *n*-type GaSb whiskers with resistivity at different ρ_{300K}, Ω·cm: 0.0053 (*1*), 0.004 (*2*), 0.0036 (*3*). On the inset: curves *1* and *2* in the temperatures range 1.5–30 K.

of the whisker resistance at temperature below 4.2 K was observed (Fig. 1, curves *2*, *3*). For GaSb whiskers with resistivity $\rho_{300\mathrm{K}}$ = 0.0053 Ω·cm a resistance minimum was observed at temperature about to 16 K, while sharp drop of resistance shifts to temperature 1.7 K (inset of Fig. 1, curve *1*) as compared with previous samples (Fig. 1, curves *2*, *3*).

Sharp drops of GaSb whiskers resistance at temperatures below 1.7 and 4.2 K are likely correspond to partial superconductivity of the whiskers and was described elsewhere [16].

Peculiarities observed on the temperature dependences of resistance in GaSb whiskers with clearly semiconductor conductivity and $\rho_{300\mathrm{K}}$ = 0.0053 Ω·cm at low temperatures (inset of Fig. 1, curve *1*) could be explain by Kondo effect.

Kondo effect is usually revealed in materials doped with magnetic impurities [17–20]. The dominant role plays exchange interaction between magnetic moments of intrinsic 3*d* electron localized on magnetic impurities and free charge carriers. One can assume that the similar anomalies of the temperature dependence of the resistance may occur in semiconductors doped with nonmagnetic impurities to the concentration correspondent to MIT [21]. Then exchange interaction takes place between magnetic moments of twice occupied by charge carrier impurities and free charge carriers. Such Kondo effect was observed in heavily doped with boron Si-Ge whiskers that have no any magnetic impurities [22]. Now we observed the similar effect in *n*-type conductivity GaSb whiskers with concentration near the MIT and resistivity $\rho_{300\mathrm{K}}$ = 0.006–0.005 Ω·cm.

The resistivity of the material described by the formula [16]:

$$\rho_e \approx \rho_0\left[1-\frac{4J}{N}\zeta(E_F)\ln\frac{E_F}{kT}\right], \qquad (1)$$

where ρ_e is resistivity value due to exchange interaction, ρ_0 is resistivity values calculated by Born approximation, $\zeta(E_F)$ is the density of states at the Fermi level, E_F is Fermi energy, N is impurity concentration, J is exchange interaction integral, k is Boltzmann constant, T is temperature. The density of states at the Fermi level increases in crystals by applying of magnetic field. These could lead to appearance of anomalous magnetoresistance, which is positive or negative depending on the sign of the exchange interaction integral J, according to the model proposed in work [17].

As Kondo effect occurs as a result of the exchange process between localized on impurity atoms holes and free carriers, then the effect can be seen only at identified impurity concentration when it is possible the formation of sufficient number of elementary processes in interaction between free carriers and those localized. Energy dependence of the density of states in the system qualitatively changes due to the interaction carriers, which is reflected in the temperature dependences as a minimum resistance.

Our results showed that the maximum Kondo effect was observed for GaSb whiskers with resistivity $\rho_{300\mathrm{K}}$ = 0.0053 Ω·cm. Deep minimum of the resistance is visible on the inset of Fig. 1, curve *1* at temperature about to 16 K.

Increasing the impurity concentration increases the probability of overlapping of wave functions, resulting in increased value of direct exchange interaction, which can lead to a change in the sign of exchange interaction integral *J*.

Attenuation of Kondo effect observed with little change in doping impurity concentration, in particular in GaSb whiskers with resistivity $\rho_{300\mathrm{K}}$ = 0.004 Ω·cm of the same diameter. So, minimum of the resistance is invisible in the temperature range 4.2–30 K (inset of Fig. 1, curve *2*).

3.2. Shubnikov-de Haas oscillations in GaSb *whiskers*

Longitudinal and transverse magnetoresistance of *n*-type GaSb whiskers in the temperature range 4.2–60 K were studied at magnetic fields 0–14 T. Results of these investigations for GaSb whiskers with different doping concentration are presented in Figs. 2–4.

Longitudinal and transverse magnetoresistance peaks of GaSb whiskers with different doping concentration (Te) in the vicinity to MIT from metal side of the transition were revealed at low temperatures in the magnetic field 0–14 T (Figs. 2–4). The maximum peak amplitude decreases with increasing temperature in whole range of fields. Magnetic field inductions at liquid helium temperature which correspond to longitudinal and transverse magnetoresistance peaks of GaSb whiskers are presented in Table 2.

Thirteen peaks with maximum (Table 2) were revealed on longitudinal magnetoresistance dependence at liquid helium temperature for *n*-type GaSb whiskers with resistivity $\rho_{300\mathrm{K}}$ = 0.0053 Ω·cm (Fig. 2, curve *1*). While the number of longitudinal magnetoresistance peaks at temperature 4.2 K decreases due to change of whisker concentration and consists of 4 and 9 for GaSb whiskers with resistivity $\rho_{300\mathrm{K}}$ = 0.004 Ω·cm (Fig. 3(a), curve *1*) and $\rho_{300\mathrm{K}}$ = 0.0036 Ω·cm (Fig. 4(a), curve *1*), respectively.

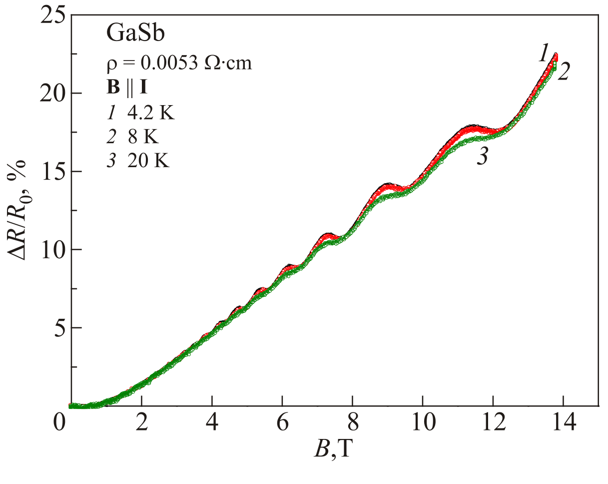

Fig. 2. (Color online) Longitudinal magnetoresistance of GaSb whiskers with resistivity $\rho_{300\mathrm{K}}$ = 0.0053 Ω·cm at different *T*, K: 4.2 (*1*), 8 (*2*), 20 (*3*).

Table 2. Magnetic field inductions of longitudinal and transverse magnetoresistance peaks in GaSb whiskers with resistivity ρ_{300K} = = 0.0053 Ω·cm at temperature 4.2 K

	Magnetoresistance Max *B*, T												
№	1	2	3	4	5	6	7	8	9	10	11	12	13
Longitudinal	11.3	9.0	7.3	6.2	5.4	4.75	4.25	3.85	3.5	3.25	3	2.8	2.65
Transverse	7.46	4.3	3.0	2.39	1.96								

The number of transverse magnetoresistance peaks decrease compared to results presented for GaSb whiskers in the longitudinal magnetic field at the same temperature. In particular, for samples with resistivity ρ_{300K} = 0.004 Ω·cm (Fig. 3(b), curve *1*) their number decreases to five at 4.2 K in magnetic fields up to 14 T (Table 2). Our studies have shown, that the Shubnikov-de Haas oscillations are observed in the low-temperature range. Magnetophonon and Shubnikov-de Haas oscillations of magnetoresistance were also revealed in *n*-type conductivity Ge and InSb whiskers, respectively [23,24].

Oscillatory effect was revealed up to 50 K for GaSb whiskers with ρ_{300K} = 0.004 Ω·cm (Fig. 3(a), curve *5*), but it already absent at temperatures above 30 K for heavily doped crystals with ρ_{300K} = 0.0036 Ω·cm (Fig. 4(a), curves *4*–*6*).

The values of magnetic field induction are unchanged for GaSb whiskers with different impurity concentration, which correspond to longitudinal and transverse magnetoresistance peaks. Amplitude of the magnetoresistance peaks is changes with doping concentration.

The magnetoresistance oscillations are periodic in 1/*H*. Magnetoresistance oscillation period *P* in the opposite field for quadratic dispersion law is described as follows [24]:

$$P = \Delta\left(\frac{1}{H}\right) = \frac{\hbar|e|}{E_F m_c c}\,, \qquad (2)$$

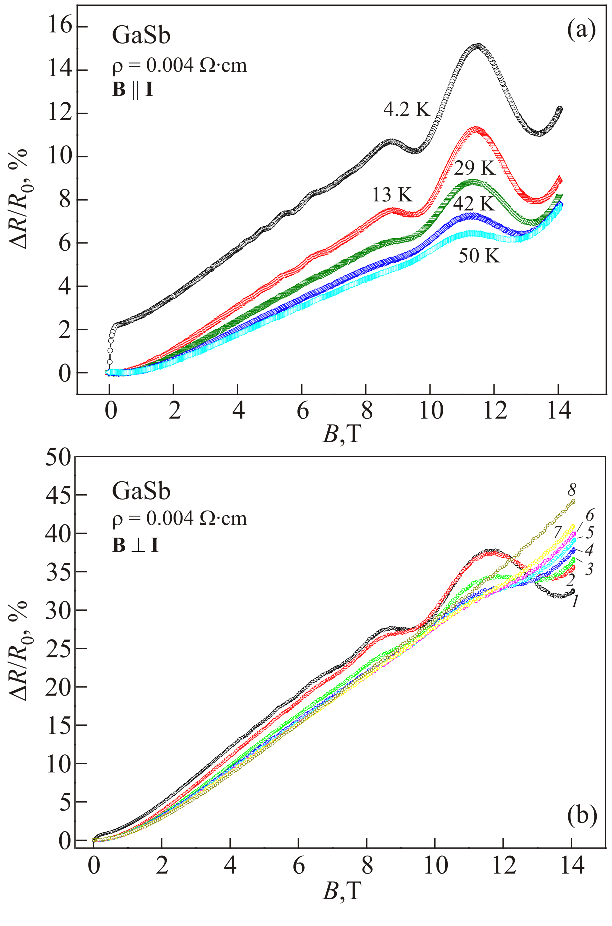

Fig. 3. (Color online) Longitudinal (a) and transverse (b) magnetoresistance of GaSb whiskers with resistivity ρ_{300K} = 0.004 Ω·cm at different *T*, K: 4.2 (*1*), 13 (*2*), 29 (*3*), 42 (*4*), 50 (*5*), 60 (*6*), 70 (*7*), 80 (*8*).

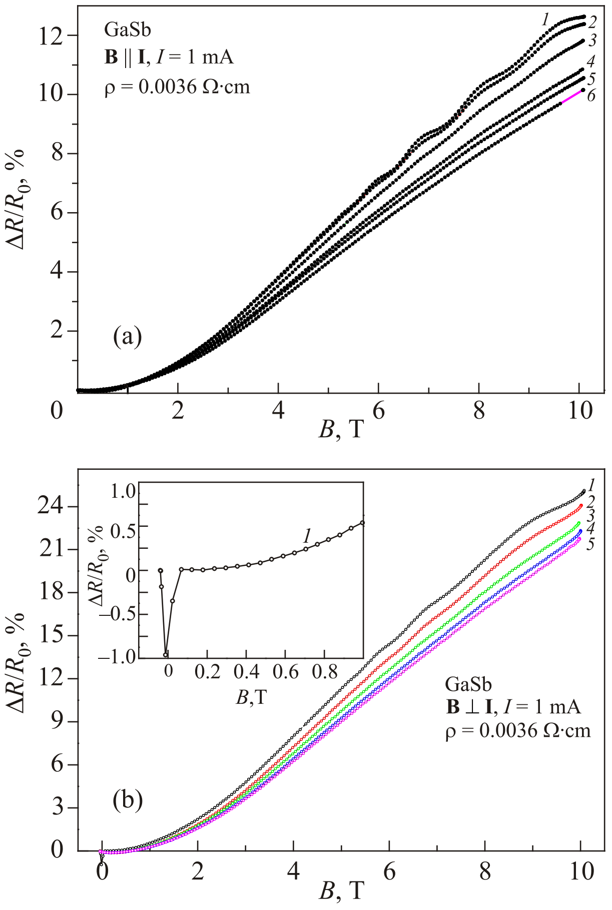

Fig. 4. (Color online) Longitudinal (a) and transverse (b) magnetoresistance of GaSb whiskers with resistivity ρ_{300K} = 0.0036 Ω·cm at different *T*, K: 4.2 (*1*), 13 (*2*), 29 (*3*), 40 (*4*), 50 (*5*), 60 (*6*). On the inset: curve *1* at 4.2 K.

where e is the elementary charge; $\hbar$ is the Planck constant; m_c is effective cyclotron mass in c is speed of light.

Oscillation period was found from the experimental data. The Shubnikov-de Haas oscillation period differs for GaSb whiskers with various doping concentration. The period reaches 0.025 T^{-1} in n-type GaSb whiskers doped to concentration removed from MIT to the metal side of the transition.

From magnetoresistance studies (Figs. 2–4) in the magnetic field 0 – 14 T the effective mass of electrons was determined according to the relative change in oscillation amplitude at various temperatures T_2 and T_1:

$$m_c = \frac{|e|\hbar H}{2\pi^2 k_B T_1 c}\,\mathrm{Ar\cosh}\frac{A(T_1,H)}{A(T_2,H)}, \qquad (3)$$

where k_B is the Boltzmann constant [24].

Besides from magnetoresistance studies (Figs. 2–4) the Dingle temperature was determined as the ratio of the amplitudes of Shubnikov-de Haas oscillations for two successive maxima magnetoresistance due to equations from work [24]. The effective mass of electrons $m_c = 0.041 m_0$ and Dingle temperature T_D up to 7.5 K were found for n-type conductivity GaSb whiskers with impurity concentration in the vicinity to MIT from metal side of the transition. Obtained high values of T_D correspond to the heavily doped by tellurium impurity GaSb whiskers. Taking into account the obtained value for oscillation period $0.025T^{-1}$ as well as the effective mass of electron E_F = 1,1 eV was calculated according to equation (2).

3.3. Crossover from weak localization to antilocalization in GaSb *whiskers*

The peculiarities of magnetoresistance of n-type conductivity GaSb whiskers with different impurity concentration were investigated in weak magnetic field 0–1 T and low temperature range 1.4–4.2 K. The experimental dependences of magnetoresistance at fixed temperatures are shown in Figs. 5(a)–(c) in these ranges of magnetic field and temperature.

Studies have shown that n-type conductivity GaSb whiskers detected anomalies values of magnetoresistance: the appearance of negative magnetoresistance in weak magnetic fields at low temperatures. The negative magnetoresistance is due to the fact that the magnetic field allows to ordering spins carriers and thus avoids impurity scattering on localized state. Weak localization occurs in the temperature range 1.4–1.7 K in GaSb whiskers with clearly semiconductor conductivity for samples with resistivity ρ_{300K} = = 0.0053 Ω·cm (Fig. 5(a)).

The presence of negative magnetoresistance in GaSb whiskers with the impurity concentration that correspond to the straight metallic conductivity with resistivity ρ_{300K} = = 0.0036 Ω·cm was observed in magnetic field up to 0.5 T at the temperature 4.2 K (Fig. 5(c)) and associated with weak localization as for n-type InSb whiskers in work [24]. Perhaps a significant reduction of magnetoresistance effect associated with the manifestation of Kondo effect in these crystals.

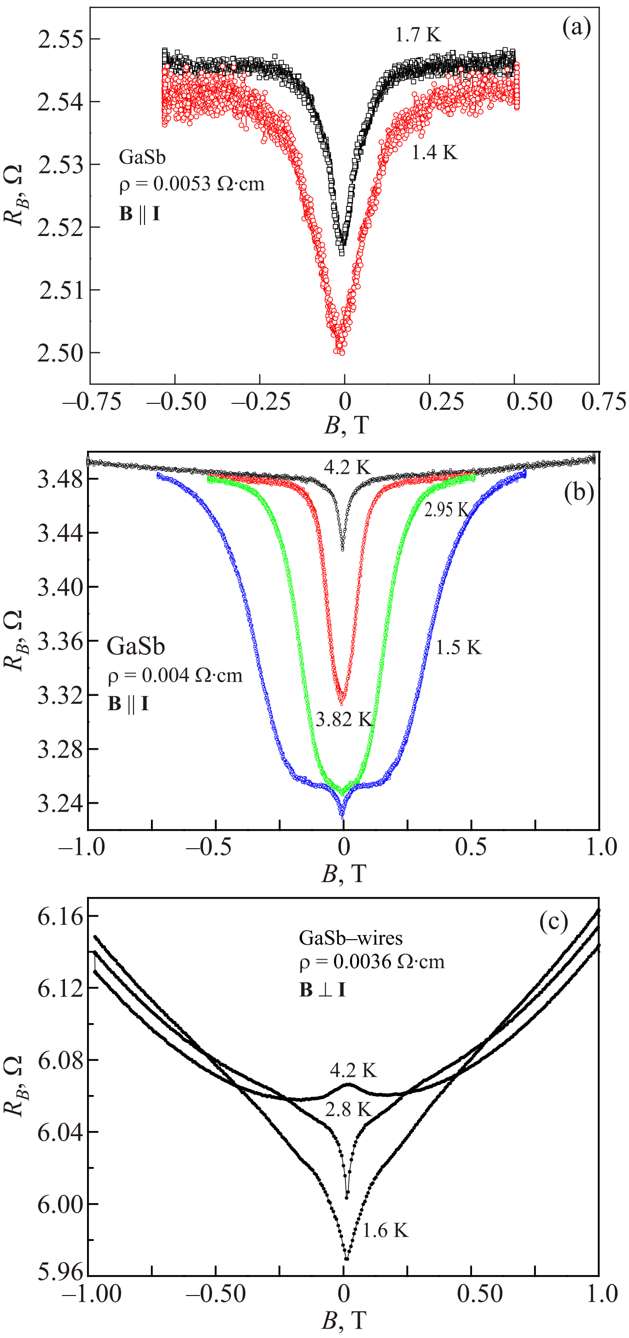

Fig. 5. (Color online) Longitudinal (a), (b) and transverse (c) magnetoresistance at different temperatures in the range 1.5–4.2 K for GaSb whiskers with different resistivity ρ_{300K}.

According to the WAL model [25] the electron-electron and electron-phonon scattering are supposed to emerge in the whiskers. The theoretical dependence of magnetoconductance in the magnetic field for two-dimensional electron gas [25] has the following form:

$$\frac{\Delta\sigma(B)}{G_0}=\frac{\sigma(B)-\sigma(0)}{G_0}=f\left(\frac{B}{H_{so}+H_{\varphi}}\right)+$$

$$+\frac{1}{2}f\left(\frac{B}{2H_{so}+H_{\varphi}}\right)-\frac{1}{2}(1+\beta)f\left(\frac{B}{H_{\varphi}}\right), \qquad (4)$$

where B is magnetic field induction, β is factor determining the value of Maxi-Thompson correction. Later, let us consider $\beta \to 0$.

$$G_0 = e^2/2\pi h. \qquad (5)$$

Function $f(x)$ is determined by the digamma function $\Psi(z)$:

$$f(z)=\Psi\left(\frac{1}{2}+\frac{1}{x}\right)+\ln(x). \qquad (6)$$

Parameter H_{φ} related with dephasing time τ_{φ} of the wave function of electron caused by electron-electron or electron-phonon interaction:

$$H_{\varphi}=\frac{\hbar c}{4eD\tau_{\varphi}}, \qquad (7)$$

parameter H_{so} is with dephasing time τ_{so}, caused by spin-orbit interaction of electrons:

$$H_{so}=\frac{\hbar c}{4eD\tau_{so}}, \qquad (8)$$

where D is the diffusion coefficient.

The conductivity change $\Delta\sigma(B)$ in a magnetic field, normalized by the amount G_0, was determined from experimental dependences of GaSb whiskers magnetoresistance in magnetic field in the following way:

$$\frac{\Delta\sigma(B)}{G_0}=\frac{\sigma(0)}{G_0}\left(\frac{\Delta R(B)}{R(0)}+(\mu H)^2\right), \qquad (9)$$

where μ is the Hall mobility, H is magnetic field intensity. The temperature dependences of mobility for GaSb microcrystals was taken from our previous studies [26].

From the weak localization theory is known the sign of conductivity correction depends on the relation between phase relaxation time of the electron wave τ_{φ} and spin relaxation time owing to spin-orbit interaction τ_{so} [27]. Temperature dependence of the resistance was determined by localization carriers and the spin relaxation was slight at condition $\tau_{so} >> \tau_{\varphi}$. But the quantum correction to conductivity was positive on condition of electrons are not interacting at limit $\tau_{so} << \tau_{\varphi}$. Described effect was called by antilocalization.

Dephasing time τ_{φ} of electron wave function is due to electron-electron or electron-phonon interaction, but τ_{so} is caused by spin-orbit electron interaction. Spin-orbit relaxation time is independent of the temperature, but phase relaxation time increases with decreasing the temperature [28]. Temperature dependences of spin-orbit relaxation time and phase relaxation time are presented in Fig. 6.

Spin-orbit electron relaxation time was determined from dependences of the magnetoresistance at different temperature in weak magnetic field as the point of crossover from weak localization to weak antilocalization. Crossover between weak localization and weak antilocalization was revealed in Fig. 5(c) for GaSb whiskers with doping concentration from metal side of MIT with $\rho_{300\text{K}} = 0.0036$ Ω·cm similar to results in the work [29].

The expressed cusps was revealed on longitudinal magnetoconductance dependences of *n*-type GaSb whiskers with resistivity $\rho_{300\text{K}} = 0.004$ Ω·cm at weak magnetic fields up to 1 T in the temperature range 1.5–4.2 K (Fig. 5(b)), that are shown in the normalized magnetoresistance profiles. The behavior of the magnetoresistance dependences is similar to that shown in Bi-Te crystals [30] and can be explained by the weak antilocalization effect. Weak antilocalization effect is due to spin-orbit interaction in the three-dimensional bulk structures, but for GaSb whisker the two-dimensional nature of the electron transport is likely to originate from the surface conductance. According to this weak antilocalization model [31–33] carrier transport is caused by the electron-electron and electron-phonon scattering [25]. Superconductive state associated with weak antilocalization at temperatures up to 4.2 K was studied in the whiskers with concentration in the vicinity to the MIT and resistivity $\rho_{300\text{K}} = 0.004$ Ω·cm (Fig. 5(b)).

So, both weak localization and weak antilocalization models compete for explanation carrier transport in *n*-type conductivity GaSb whiskers with different impurity concentration in the vicinity to MIT from metal side of the transition at low temperatures.

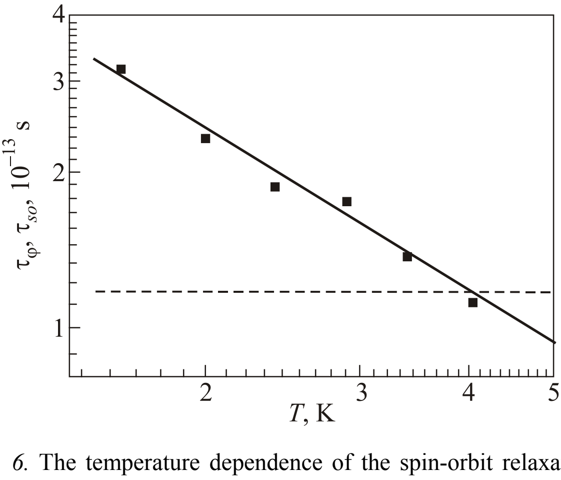

Fig. 6. The temperature dependence of the spin-orbit relaxation and dephasing times.

4. Conclusions

Temperature dependences of the resistance in *n*-type GaSb whiskers with different impurity concentration in the vicinity to the MIT from metal side of the transition were studied in the temperature range 1.5–300 K. At temperatures below 4.2 K the behavior of characteristics is significantly differs due to change of the carrier transport mechanism. The peculiarities of whisker resistance such as sharp drop at low-temperature range 1.7–4.2 K were observed for GaSb whiskers with various doping concentration, that could be explained by partial superconductivity of the whiskers and need further investigation. For GaSb whiskers with resistivity $\rho_{300\mathrm{K}} = 0.0053$ Ω·cm a resistance minimum was observed at temperature about to 16 K, that may indicate Kondo effect presence in the crystals. The effect is connected with exchange interaction between magnetic moments of twice occupied by charge carrier impurities and free charge carriers and occurs only at certain impurity concentration at the vicinity to MIT.

Longitudinal and transverse magnetoresistance of GaSb whiskers in the temperature range 4.2–60 K were studied at magnetic fields 0–14 T. Shubnikov-de Haas oscillations in GaSb whiskers with doping concentration in the vicinity to the MIT were revealed in all the range of magnetic fields at low temperatures. The period of magnetoresistance oscillation $0.025T^{-1}$ was found at various impurity concentrations of *n*-type conductivity GaSb whiskers. Some parameters such as the effective mass of electrons $m_c = 0.041m_0$ and Dingle temperature 7.5 K were also calculated.

The peculiarities of magnetoresistance of GaSb whiskers were investigated in weak magnetic fields 0–1 T and low-temperature range 1.4–4.2 K. The presence of negative magnetoresistance in GaSb whiskers with the impurity concentration in the nearest approximation to MIT with resistivity $\rho_{300\mathrm{K}} = 0.0053$ Ω·cm was observed and associated with weak localization. Weak antilocalization at temperatures up to 4.2 K was studied in the whiskers with concentration in the vicinity to the MIT and $\rho_{300\mathrm{K}} = 0.004$ Ω·cm. Crossover between weak antilocalization and weak localization was revealed in GaSb whiskers with doping concentration from metal side of MIT with $\rho_{300\mathrm{K}} = 0.0036$ Ω·cm. This crossover explained by change of the relation between the dephasing and spin-orbit electron relaxation times.

On the base of temperature dependences of the magnetoresistance studies the spin-orbit electron relaxation time and the temperature dependences of the phase relaxation time of the electrons wave were obtained due to the weak localization theory. Our work shows the crossover of quantum interference effect in GaSb whiskers from weak antilocalization to weak localization.

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