MAGNETIC FIELD INFLUENCE ON THE Ag_2Te CRYSTALS MAGNETIC RESISTANCE

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Abstract

The influence of the unhomogeneities in the own point defects distribution on the Ag_2Te crystals magnetic resistance field and temperature dependencies is investigated. It is found that in strong magnetic field at 300 K the field crosswise and longitudinal dependence is close to linear. On the basis of the observed specific features in crosswise and longitudinal resistance it may be concluded that the bigger part of the own point defects in Ag_2Te are located in fluctuational accumulations, unhomogeneously distributed in the crystal volume.

1. INTRODUCTION

It was found in our previous work [1] that long time high temperature vacuum annealing of n-type Ag_2Te single crystals synthesized from high purity starting components leads to considerable decreasing of the impurity charge carriers concentration. As we suggest it is due to the diminishing of the overstoichiometrical silver atoms content in the interunits, which may be considered as donor impurities in Ag_2Te [2].

It was found also that the concentration of the impurity electrons as a function of the annealing time aims at $t \geq 100$ h to a top value $n_0 \cong 2.4\ 10^{17}$ cm^{-3} (T=77 K) at an annealing temperature highest than the structural phase transition $\alpha \leftrightarrow \beta$ temperature [1]. One can not observe trends for changing in the crystal properties including the type of the electroconducting after a long time annealing, which indicates the predominant content of the donor-type defects

On the basis of evaluation of the effective mass $m/m_0 = 0.021$ [3] and permittivity $\varepsilon = 15.6$ [4] values it is not difficult to see that the above mentioned n_0 value corresponds to the high doping condition $N.a_b^a \geq 1$ (N - impurity concentration, a^b - Borr radius). As it is known the probability for fluctuational accumulations of impurity atoms increases in high doping conditions, which causes local disturbances in the crystal potential relief. On the other hand the above mentioned silver atoms accumulations in the interunits are probably relatively stable at the used annealing temperature, as one can conclude from the top concentration n_0 existence.

As a rule, it is difficult to register an unhomogeneity in the defect distribution by the traditional methods, because of the deep disposing of the Fermi level in the conductivity zone, where the density of the states is very close to its value in the ideal crystal [5]. It is known also [6] that the studying of the field and temperature dependences of the magnetic resistance is an effective method for high doped semiconductors investigation. The existence of local potential relief disturbances gives an opportunity to use a model for the interpretation of the magnetic resistance behavior observed. In this model the existence of inclusions very different in electroconductivity is supported. In such kind of model the longintudinal magnetic resistance should be different from zero even for the crystal in low magnetic field and in the same time the crosswise one should increase in value. The existing equation in the case of low magnetic field s may be written as follows [7]:

$$\Delta\rho_{\perp} / \rho_0 = (b_r + 0.025f).(\mu H/c_o)^2 \quad (1)$$

$$\Delta\rho_{||} / \rho_0 = 0.3f(\mu H/c_o)^2, \quad (2)$$

where: b_r - coefficient, determining the crosswise magnetic resistance in homogeneous samples, depending on scattering coefficient “r” [8].

f - relative value of the fluctuational accumulations;

μ - electron mobility;

H - magnetic field strength;

c_0 - light velocity.

It is important to note that longitudinal magnetic resistance in low magnetic fields for degenerative semiconductors (used in the present investigation) does not depend on the temperature [2].

In strong magnetic field ($\mu H/c_o >> 1$) the part of the crosswise magnetic resistance connected to the unhomogeneities in the impurity distribution may be presented as

$$\Delta\rho_{\perp} / \rho_0 = 0.49f(\mu H/c_o), \quad (3)$$

i.e. it depends linearly on the magnetic field strength.

2. EXPERIMENTAL

Ag_2Te was obtained by direct monotemperature synthesis using 5N purity starting components (Ag and Te). The synthesis was carried out in vacuumed and welded at residual pressure of 0.133 Pa quartz ampoules, preliminary filled with the components. At the maximum temperature of the synthesis (T=1000±10 °C) a two hours vibrational melt stirring

was applied. The melt was cooled in “switch of furnace” regime. Ag_2Te single crystals was obtained by Bridgeman method, “nonmobile furnace - mobile ampoules” variant at the following starting parameters: diameter of the ampoules ∅ = 10 mm, platean temperature T = 1000±2 °C; gradient at the crystallization front a=30 °C/Sm, speed of the ampoules motion V=3 cm/min. The single crystals was tempered at T_t=400±2 °C for 72 hours in vacuum. The change in the type of the single crystal electroconductivity was not observed. It was always N-type. The longitudinal and crosswise magnetic resistances were measured by exchange method in magnetic field (1T magnetic induction).

3. RESULTS AND DISCUSSION

Figure 1 shows the results of Ag_2Te single crystals magnetic resistance measurement.

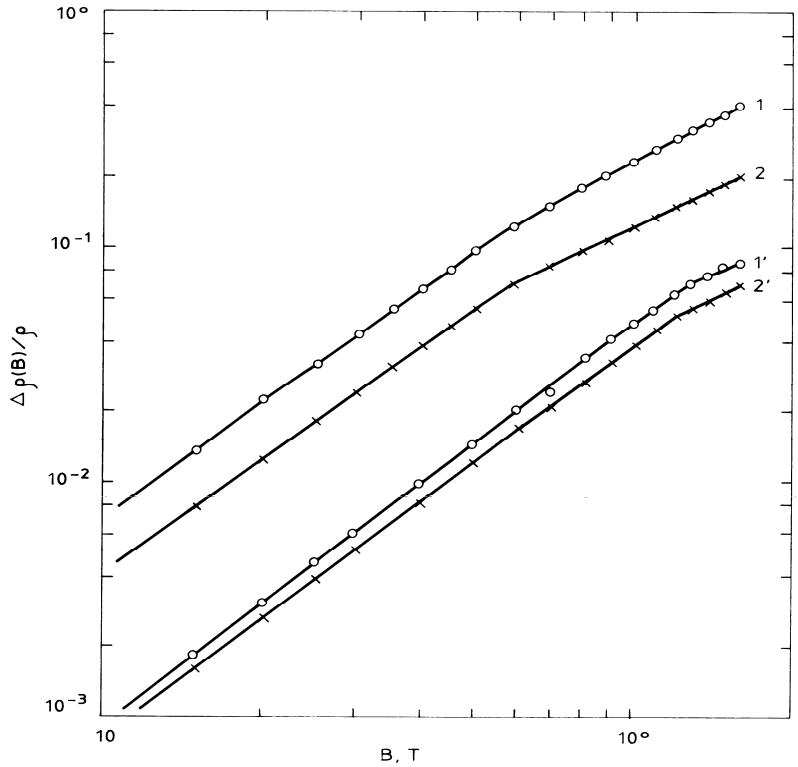

Figure 1 Ag_2Te magnetic resistance: 1 and 1’ - crosswise magnetic resistance at 77 and 300 K, respectively; 2 and 2’ - longitudinal at 77 and 300 K, respectively.

The experimental dependencies may be described by the equation:

$$\Delta\rho(H) / \rho_0 \cong H^{\alpha} \quad (4)$$

The values for the crosswire magnetic resistance in low magnetic fields are $\alpha_{\perp}$= 1.68 (at 77 K) è $\alpha_{\perp}$=1.74 at 300 K). These values show that the experimental dependence $\Delta\rho_{\perp} / \rho_0$ = f(H) is close to quadratic one, predicted by equation (1). The longitudinal magnetic resistance in low

magnetic fields may be described by equation (4), but a little bit lower exponent α values should be used: $\alpha_{||}$ = 1.58 (at 77 K) and $\alpha_{||}$ = 1.68 (at 300 K).

In strong magnetic field exponent α decreases (values of $\alpha_{\perp}$ = 1.16 and $\alpha_{||}$ = 1.05 at 77 K). Magnetic field induction B_0, is 0.65 T and 0.58 T, respectively for crosswise and longintudinal magnetic resistance. On this basis by the equation $\mu H/c_o \cong 1$ the electron mobility may be calculated. The result is $\mu \cong 1.54.10^4$ $sm^2/(V.s)$. This value is close to the Hall mobility value $\mu_H \cong 1.16.10^4$ $sm^2/(V.s)$ at 77 K. In this way the kink observed on the curves 1 and 2 may be explained by the strong field condition realization for the electrons. When the temperature T elevates, the magnetic field value B_0 (where the magnetic resistance exponent dependence changes) moves to the stronger magnetic fields regions and at T=300 K this value is 1.1÷1.2 T. It is due to the electron mobility decreasing at 300 K, which is $\mu_H \cong 4.9.10^3$ $sm^2/(V.s)$. It is not difficult to notice that the relative changing of the Hall mobility with the temperature is close to the B_0 relative changing. In strong magnetic field at 300 K the field dependence of the longintudinal and crosswise magnetic resistance is close to linear: $\alpha_{\perp} = \alpha_{||} + 1$ [10], while in the case observed $\alpha_{\perp} \cong \alpha_{||}$. An after specific feature of the Ag_2Te magnetic resistance is its temperature dependence. If we present this dependence as a exponent function

$$\Delta\rho(H) / \rho_0 \cong H^{\beta}, \tag{5}$$

it may be started that exponent β depends on magnetic filed. The above mentioned dependence is shown in Figure 2. As one can see the Ag_2Te crosswise magnetic resistance temperature dependence in low magnetic fields is close to $T^{-3/2}$, while in strong ones it is close to T^{-1}. For longintudinal magnetic resistance these values are $\beta_{||} \cong -5/4$ and $\beta_{||} \cong -3/4$ for low and strong magnetic fields, respectively. By this way, in strong magnetic fields $\beta_{||} - \beta_{\perp} \cong 1/4$ while for the traditional scattering mechanisms $\beta_{||} - \beta_{\perp} = 1$ [10].

On the other hand, in correspondence to the equation (2) and (3) the longintudinal and crosswise magnetic resistance in strong magnetic field should not depend on the temperature.

The reasons for these features are not completely clear now. It may be supposed that the magnetic resistance temperature dependence in unhomogeneous Ag_2Te crystals is connected to the existence of p-component. This conclusion may be confirmed by the experimental fact, that the beginning of the own conductivity is observed at T≥120 K [1].

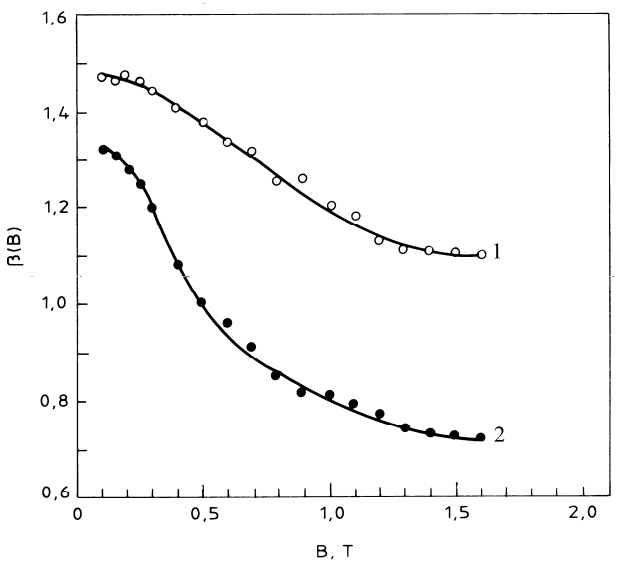

Figure 2 Changing of the exponent β in magnetic resistance temperature dependence on field magnetic induction: 1-for crosswise magnetic resistance;
2-for longintudinal magnetic resistance

To eliminate the magnetic resistance part, connected to Ag_2Te unhomogeneities we will use the data concerning 77 K. In this case on the base of longintudinal magnetic resistance in low fields by equation (2) it may be calculated f ≅ 0.34, while on the base of dependence $\Delta\rho_\perp/\rho_0$ = f(H) – Figure 1 and equation (1) - b_r ≅ 0.14. Values, close to the above mentioned may be calculated also by the crosswise magnetic field behavior in strong magnetic field using equation (3).

When the temperature increases both the crosswise and longintudinal magnetic resistances decrease both in low and strong magnetic fields (the exponent in equation (5) is always negative).It means, that the absolute value of the own point defects in Ag_2Te increases (Ag atoms in the interunits which may be considered as donor type impurities [2]) and as a result the fluctuational accumulations based on these defects and situated logically inhomogeneously in the crystal volume also increase both in number and volume, which may be categorically confirmed by the differences in $\Delta\rho_\perp$ and $\Delta\rho_{||}$ values. By this reason one can not observe a trend for changing in the Ag_2Te crystals of the conductivity after long time thermo treating at relatively high temperature (200÷800 °C) in vacuum. It is due to the fact that the increased number of the donor type own defects causes the appearance of an additional electron quantity Δn. In the same time the concentration of acceptor type defects at these temperatures is

considerably lower to give enough p-charge carriers quantity Δp capable to change the starting type of Ag_2Te crystal conductivity.

4. CONCLUSIONS

The influence of the own point defects on the Ag_2Te magnetic resistance field and temperature dependencies is investigated. A linear dependence of the magnetic resistance is found in strong magnetic field. This dependence may be described by the theory of unhomogeneous doped semiconductors, keeping the mind the possibility for impurity atoms fluctuational accumulation. As a result it may be concluded that the bigger part of the point defects in Ag_2Te are in the state of fluctuational accumulations unhomogeneous distributed in the crystal volume. It explains the absence of a tendency to change the type of the electroconductivity after long time Ag_2Te crystals vacuum thermotreating.

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