ELECTRIC CONDUCTIVITY AND MAGNETIC SUSCEPTIBILITY OF Tl(Cr, Mn, Co)S_2 LAYERED COMPOUNDS

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ABSRACT.

By method of solid- state reaction from chemical elements weighted in stoichiometrical relation $TlCrS_2$, $TlMnS_2$ and $TlCoS_2$ have been synthesized. There have been carried out X-ray, magnetic and electric investigations. $TlCrS_2$ is a semiconductive ferromagnetic, $TlMnS_2$ is a semiconductive antiferromagnetic, but $TlCoS_2$ is ferrimagnetic with semi-metallic course of conductivity (without gap of semiconductor).

Keywords: electric conductivity, semiconductor, thermal power, dependence, temperature, magnetic susceptibility

I. INTRODUCTION

The low simmetricallity of crystalil structure of $TlMeX_2$ (where Me =3d-metal, X=S, Se, Te) typed compounds is predetermined by the dependence of their magnetic and kinetic properties from crystallographic direction [1]. Besides in these compounds the magnetic and semiconducting properties are combined [2, 3]. The above mentioned circumstances are the perspective materials for their application in physics and technology of semiconductors the $TlMeX_2$ compounds.

II. THE PREPARATION OF THE SAMPLES AND THE EXPERIMENTAL TECHNIQUES

Tl(Cr, Mn, Co)S_2 samples are synthesized in vacuum quartz ampoules by method of solid-state reaction from chemical elements weighted in stoichiometrical relation. Synthesis is carried out in the following sequence. Ampoule with chemical elements is placed into the furnace where the temperature rises from room one up to 1050K with the rate 100 deg/hour. At this temperature the ampoule is held for 120 hours, then it is cooled down to the room temperature with the same rate. For prevention of interaction of chemical components with the internal wall of the quarts ampoule the last one is in the rotation during the synthesis process. Obtained samples are rubbed to the powder pressed under the high pressure and undergone to the homogenizing annealing for 480 hours at 600K.X-ray analysis of samples is carried out on the diffractometer DRON-3M (CuK_α -radiation, Ni-filter). Angle resolution of photographing was ~0,1°. Continuous scanning regime is used. Diffraction angles are determined by the method of measurement on the intensity maximum. At experiments the determination error of reflection angles does not excess ±0,2°.

Difractograms of synthesized samples written down in the angle interval $10°\leq 2\theta \leq 70°$ at the room temperature, are definitely induced un hexagonal ($TlCrS_2$, $TlCoS_2$) and tetragonal ($TlMnS_2$) syngonies with parameters of crystalline lattice: a=3,538Å; c=21,962Å; c/a~6,21; z=3; ρ_x=6,705g/sm^3; a=3,726Å; c=22,510Å; c/a~6,04; z=3; ρ_x=6,026g/sm^3; a=7,74Å; c=30,60Å; c/a~3,95; z=20; ρ_x=6,40g/sm^3 respectively.

Magnetic susceptibility (χ) of Tl(Cr, Mn, Co)S_2 compounds was measured by Faraday method on the magnetoelectric scales. Electrical conductivity (σ) and thermal power (S) of synthesized samples are measured by the compensated method. The Ohmic contacts are created by the way of the electrodeposition of cuprum on the edges of the samples.

III. THE EXPERIMENTAL RESULTS AND THEIR DISCUSSION

The investigations are carried out in the temperature interval 80÷400K in the quazistatic mode. In Fig.1 it is shown the temperature dependence of the reverse magnetic susceptibility of $TlCrS_2$ typical for ferromagneticals materials. The paramagnetic Curie temperature (T_p) defined by extrapolation of dependence $\chi^{-1}(T)$ to the range of temperatures, is 115K.

From dependence $\chi^{-1}(T)$ effective magnetic moment (μ_{eff}) of, which is equal to 3,26μ_B is calculated. The theoretical quantity of μ_{eff}, calculated by taking in account pure spin quantity of magnetic moment of three valent Cr-ions is 3,85μ_B. As it is seen there are satisfactory agreement of theoretical and experimental results.

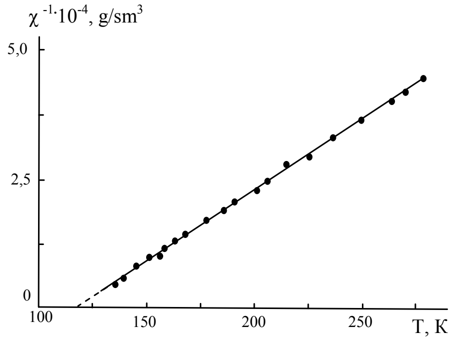

Fig. 1. The temperature dependence of the reverse magnetic susceptibility of $TlCrS_2$.

The temperature dependency of electrical conductivity and thermal power are presented in Fig.2. As it is seen from Fig.2 σ(T) has a semiconductive course. The S(T) behavior indicates of transfer p-type charge carrier. At T~340K on S(T) dependence of $TlCrS_2$ the anomaly is observed, which, apparently, stipulated by transfer of n-type carriere in the conductivity zone of $TlCrS_2$ semiconductor.

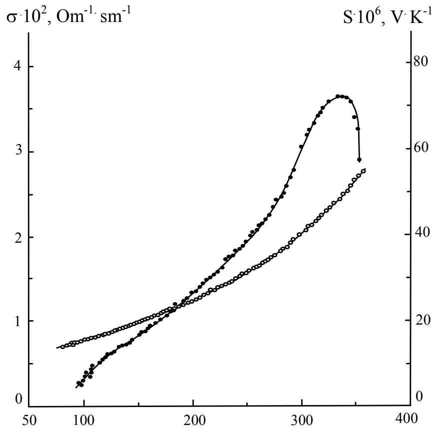

Fig. 2. The temperature dependences of electric conductivity (○) and thermal power (●) of $TlCrS_2$ ferromagnetic

The temperature dependence of $TlMnS_2$ the reverse magnetic susceptibility (fig. 3) follows to Curie-Weice law with the extrapolation to the range of negative temperatures which testifies existence of the antiferromagnetic exchange interaction.

According to Fig. 3, the temperature of $TlMnS_2$ compound magnetic transformation is below 80K.

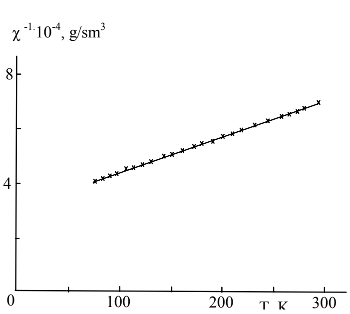

Fig. 3. The temperature dependence of $TlMnS_2$ reverse magnetic susceptibility

The temperature dependence of $TlMnS_2$ electrical conductivity is shown in fig. 4. As it is seen σ(T) dependence has the semiconductive course.

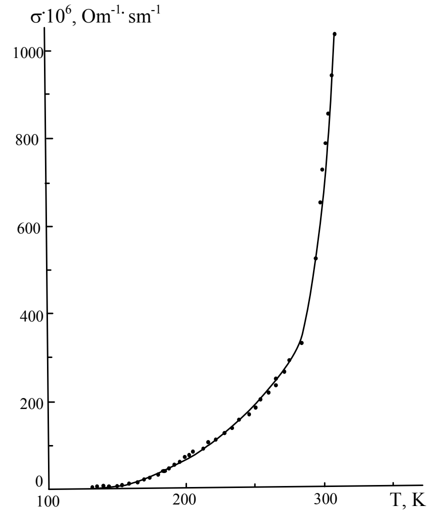

Fig. 4. The temperature dependence of antiferromagnetic $TlMnS_2$ electric conductivity.

The temperature dependence of $TlCoS_2$ compound reverse magnetic susceptibility has a hyperbolic character (fig. 5), which indicates to the ferrimagnetizm.

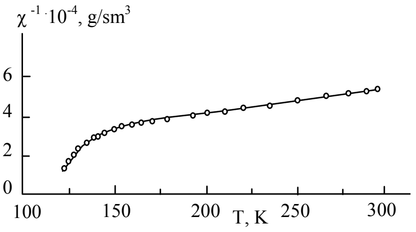

Fig. 5. The temperature dependence of $TlCoS_2$ reveres magnetic susceptibility.

The temperature dependence σ and S of $TlCoS_2$ ferrimagnetic is given in Fig.6. As it is seen from figure, σ decreases with the temperature increase from 80K. In the neighbourhood of 113K on the curve σ(T) of $TlCoS_2$ the bending is observed, caused as it is known from the literature of the ref [4], by the carrier charge scattering on the spins nonhomogenius, forming at the transition of the spin system of magnetic from the magnetoordered state to the paramagnetic one. The decrease of $TlCoS_2$ electroconduction is observed to ~250K then σ increases insignificantly in the interval 250÷325K. The further decrease of $TlCoS_2$ conduction at 325÷400K, apparently, due to the achieving temperature of $TlCoS_2$ semi-metal of the own conduction.

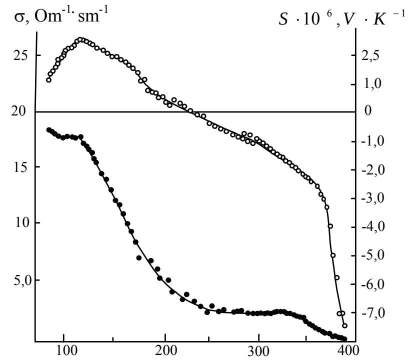

Fig. 6. The temperature dependence of electric conductivity (●) and thermal power (○) of TlCoS$_2$ ferrimagnetic.

From Fig.6 it is seen that S(T) of TlCoS$_2$ increases insignificantly at 80÷113K, achieving its maximum value at ~113K. Then with the increase of the temperature the change of the conduction from type p- to n- type is observed. Let's note that temperature (~113K), at which on the dependence σ(T) and S(T) of TlCoS$_2$, the anomaly, close to the temperature T_c=112K of phase transition of spin system of TlCoS$_2$ ferrimagnetic from the magnitoordered state to the paramagnetic, one is defined in the work [5].

IV. CONCLUSION

We will plan to research magnetic and electrical properties of TlCrS$_2$ and TlCoS$_2$ single crystal samples depending from crystalical directs (|| or ⊥ layer) in the temperature range 5÷300K, as the preliminary researches have shown that from three of electrical semiconductive magnetic layered materials Tl(Cr, Mn, Co)S$_2$ two of them (TlCrS$_2$, TlCoS$_2$) in perspective can be use in electron calculation systems, working under the low temperatures (quantum computers).

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