

# FERMI SURFACE IN THE NEW ORGANIC QUASI-TWO-DIMENSIONAL METAL $\alpha$ -(BETS)<sub>2</sub>TlHg(SeCN)<sub>4</sub>

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Quantum oscillations of de Haas—van Alphen and Shubnikov—de Haas and semiclassical angular oscillations of the magnetoresistance have been observed in the quasi-two-dimensional organic metal  $\alpha$ -(BETS)<sub>2</sub>TlHg(SeCN)<sub>4</sub>. The quantum oscillations are connected with the cylindrical part of the Fermi surface. The angular oscillations are associated with the carrier motion on both cylindrical part and quasi-planar sheets of the Fermi surface. The values of the Dingle temperature,  $T_D \approx 2$ –3 K, and the effective mass,  $m^* \approx 1.03m_0$ , have been defined. A possibility of the weakening of the many-body interactions has been shown in this compound.

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## 1. INTRODUCTION

Charge transfer salts with alpha-type crystal structure  $\alpha$ -(ET)<sub>2</sub>MHg(XCN)<sub>4</sub>, where (ET) = (BEDT-TTF) (bis(ethylenedithio)-tetrathiofulvalene) and M = K, Tl, Rb, NH<sub>4</sub>, X = S, Se are among the most popular objects in the physics of organic conductors. Their studies provided important results in fermiology of low-dimensional metals. There are some reasons for this. A specific shape of the Fermi surface (FS) in these compounds was shown to include both a cylindrical part characteristic of quasi-two-dimensional electron systems and corrugated planar sheets charac-

teristic of quasi-one-dimensional electron systems [1]. Alpha-metals with M = K, Tl, Rb and X = S undergo the Peierls-type phase transition at  $T_p \leq 10$  K associated with the nesting of the one-dimensional part of the FS [2–4]. Such a transition leads to considerable reconstruction of FS [5]. The other known metals of this family retain their high-temperature structure down to the lowest temperatures [6,7]. Only one of them, (ET)<sub>2</sub>NH<sub>4</sub>Hg(SCN)<sub>4</sub>, undergoes a superconducting (SC) transition [8]. The reasons for the presence or absence of phase transformations in these isostructural alpha-type metals are not yet clear. All these compounds can be investigated by different techniques of fermiology like Shubnikov—de Haas (SdH) quantum oscillations of the magnetoresistance,

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de Haas—van Alphen (dHvA) quantum oscillations of the magnetisation, and semiclassical angle-dependent magnetoresistance oscillations (AMRO) in high magnetic fields [1]. These effects are easily observed both in the alpha-salts which undergo phase transitions and those keeping their electron structures down to low temperatures. Therefore one can study in detail the effect of slight changes in chemical compositions of organic conductors on radical changes in their electron structure. Such investigations are necessary condition for the directed chemical syntheses.

It was shown earlier [6,7] that the substitution of S atoms by Se ones in the anions of  $(\text{ET})_2\text{TlHg}(\text{SCN})_4$  and  $(\text{ET})_2\text{KHg}(\text{SCN})_4$  giving  $(\text{ET})_2\text{TlHg}(\text{SeCN})_4$  (hereinafter, ET-Tl-Se) and  $(\text{ET})_2\text{KHg}(\text{SeCN})_4$  (hereinafter, ET-K-Se) results in the suppression of the phase transitions. The complex with Tl shows such effect even at substituting half of sulphur atoms in the anion by selenium ones [9]. One observes the increase of the effective mass in selenium complexes as compared to sulphur analogs and a significant role of many-body interactions [7, 10].

Recently the family of the metallic alpha-salts has been essentially widened by substituting the ET molecule by BETS which includes four central selenium atoms instead of four sulphur ones in ET [11]. In ET-metals the overlapping of sulphur orbitals provides metallic conductivity in ET layers. Therefore one could expect that the substitution of a part of sulphur atoms would result in significant changes in conducting properties of metals synthesised on the base of BETS as compared with ET analogs. Indeed, on cooling the new organic metals,  $\alpha$ - $(\text{BETS})_2\text{KHg}(\text{SCN})_4$  (hereinafter, BETS-K-S) and  $\alpha$ - $(\text{BETS})_2\text{NH}_4\text{Hg}(\text{SCN})_4$  (hereinafter, BETS-NH-S) do not demonstrate the phase transitions characteristic of the ET analogs [12]. Besides, the parameters of electronic structures of new metals change significantly as compared to the ET analogs, namely, the effective mass decreases, the width of the conductivity band increases, and the Coulomb repulsion becomes weaker [12].

The present paper reports the study of magnetic field properties of the new metallic alpha-phase compound,  $(\text{BETS})_2\text{TlHg}(\text{SeCN})_4$  (hereinafter, BETS-Tl-Se), isostructural to  $\alpha$ - $(\text{ET})_2\text{MHg}(\text{XCN})_4$  [13]. This compound was found to show quantum oscillations (dHvA and SdH) and semiclassical angle-dependent magnetoresistance oscillations. The studies enabled to determine the shape and size of the FS, evaluate the parameters of the electronic structure, and analyse the low-temperature state in comparison with ET-Tl-Se and other alpha-salts.

## 2. EXPERIMENTAL

The BETS-Tl-Se samples grow as parallelepipeds with an average size of  $1 \times 0.5 \times 0.05 \text{ mm}^3$ . The procedure of chemical synthesis of the samples together with their crystal structure are described in detail in [13]. Conducting layers of BETS parallel to the *ac*-plane alternate along the **b** direction with the anion layers. The longest size of samples corresponds to the **a** direction and the shortest one corresponds to the **b\*** direction. The averaged conductivity of the samples in the conducting plane amounts to  $\approx 50 \Omega^{-1} \text{ cm}^{-1}$  at room temperature.

DHvA oscillations were observed by a cantilever torquemeter in magnetic fields up to 14.4 T [14]. The temperature could be lowered down to 0.45 K. The magnetic field orientation was varied by the rotating of the sample with respect to the field direction in the *ab\**-plane.

The magnetoresistance was measured by a standard four-probe technique using 330 Hz a.c. current applied mainly perpendicularly to the plane of the highest conductivity *ac*. This direction provides the best conditions for the observation of AMRO [1]. The maximal magnetic field value was 14 T in AMRO experiments and the minimal temperature was 1.45 K. The sample orientations were changed by using a two-axes-rotation insert with which the sample could be rotated with respect to the field direction in different planes perpendicular to the *ac*-plane. The part of SdH experiments was carried out using the magnetic fields up to 20 T, the temperature down to 1.3 K and at the current direction along **a**.

## 3. RESULTS

All the BETS-Tl-Se samples showed a metal-like dependence of resistance on temperature with no peculiarities. The residual resistance ratio at the 1.4 K is about 200. In the magnetic field perpendicular to the conducting plane and at the current direction along **b\***, the resistance grows almost without saturation and increases approximately five times at 14 T [13]. At the current direction along **a** (Fig. 1) the magnetoresistance is more than two times less and the saturation exists.

In magnetic fields higher than 10 T SdH and dHvA quantum oscillations are observed (Figs. 1 and 2). At the field direction perpendicular to the conducting plane quantum oscillations contain the only fundamental frequency  $F \approx 640 \text{ T}$ . The angular dependence of

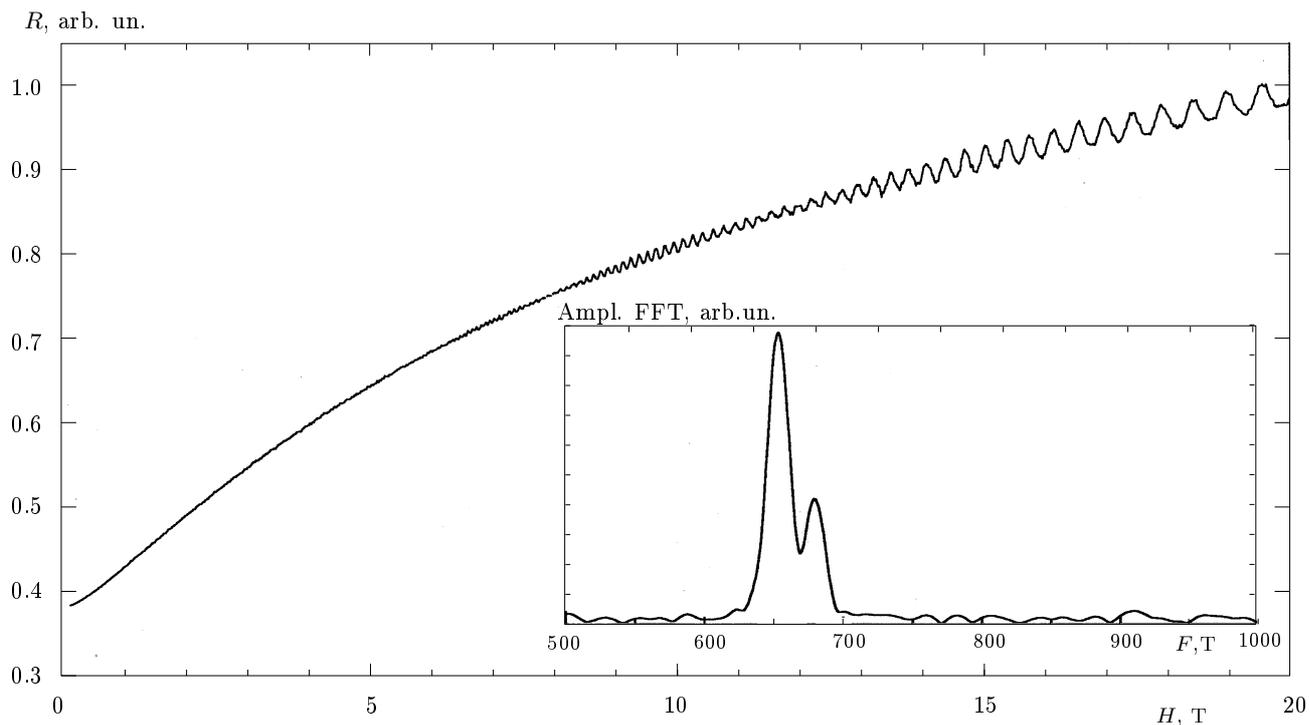


Fig. 1. Magnetoresistance showing Shubnikov—de Haas oscillations;  $T = 1.3$  K,  $\theta \approx 5^\circ$ ,  $\mathbf{I} \parallel \mathbf{a}$ . Insert: FFT of these oscillations

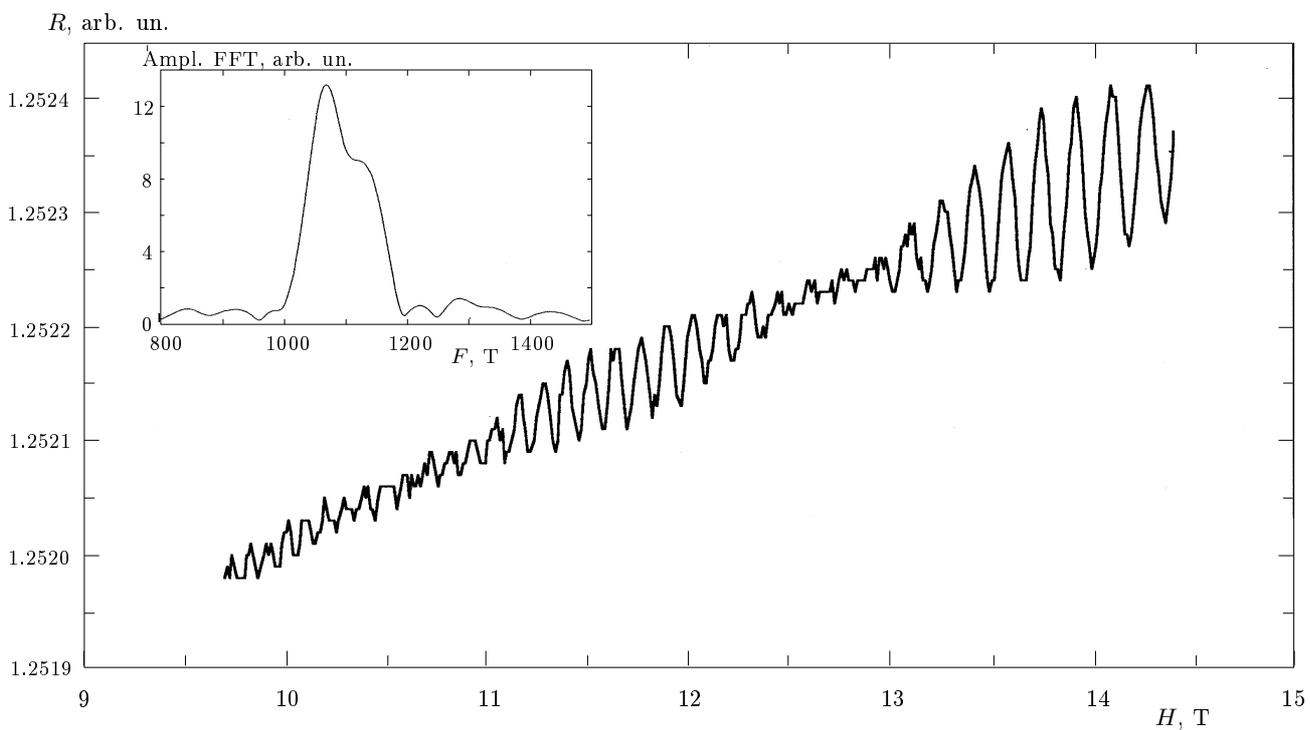
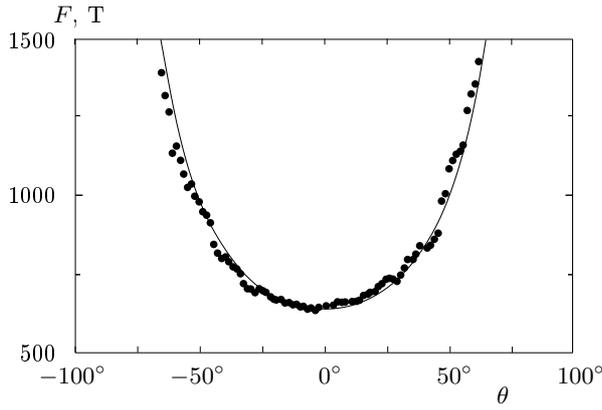
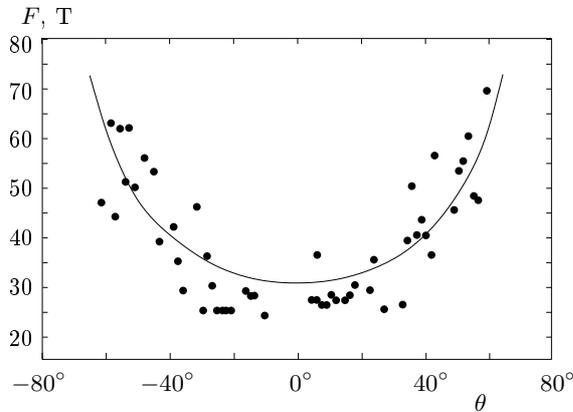


Fig. 2. Magnetization with de Haas—van Alphen oscillations;  $T = 0.45$  K,  $\theta = -50^\circ$ . Insert: FFT of these oscillations



**Fig. 3.** Angular dependence of the fundamental frequency of dHvA oscillations. The solid line corresponds to the Eq. (1)



**Fig. 4.** Angular dependence of the beat frequency of dHvA and SdH oscillations. The solid line corresponds to the Eq. (2)

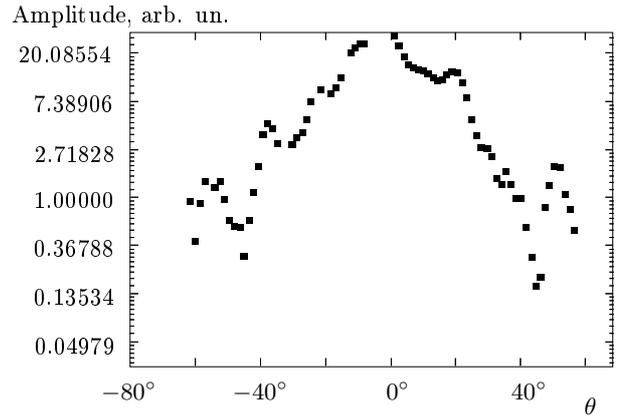
this frequency from the dHvA experiment is depicted in Fig. 3 and is described by the relationship:

$$F(\theta) \approx 640[\text{T}] / \cos \theta, \quad (1)$$

where  $\theta$  is the angle between  $\mathbf{b}^*$  and the field direction. In magnetic fields tilted from the  $\mathbf{b}^*$  direction one observes the beat of the fundamental frequency (Figs. 1 and 2). The beat is absent only at the angles close to  $\theta = 0$  and  $\theta = \pm 20^\circ$ . The angular dependence of the beat frequency in the rotation plane  $ab^*$  from the dHvA and SdH experiments is presented in Fig. 4. It can be described by the expression:

$$F_{beat} = \Delta F \approx 30[\text{T}] / \cos \theta \quad (2)$$

( $F_{beat}$  is the difference between frequencies on FFT spectrum: see inserts in Figs. 1 and 2).



**Fig. 5.** Angular dependence of dHvA oscillation amplitude

The angular dependence of the dHvA oscillation amplitude is presented in Fig. 5. At field directions corresponding to  $\theta = \pm 45^\circ$  the oscillation amplitude vanishes. Most probably this vanishing is due to so-called «spin zeros» associated with the spin reduction factor  $R_S$  from Lifshitz—Kosevich (LK) formula [15]:

$$R_S = \cos(\pi r \mu g / 2), \quad (3)$$

where  $r = 1, 2, 3, \dots$  is the harmonic index,  $\mu = m^*/m_0$  is the relative effective mass ( $m_0$  is the mass of free electron), and  $g$  is the  $g$ -factor. Factor  $R_S$  vanishes under condition:  $\mu g = 2n + 1$ , where  $n = 0, 1, 2, \dots$

The effective mass of the samples under study (which not always coincides with  $m^*$  from (3)) was estimated from the changes in the amplitudes of dHvA oscillations with temperature. Such changes are described by the temperature reduction factor  $R_T$  in LK formula for the oscillation amplitude [15]:

$$R_T = \frac{\alpha r \mu T}{H} \frac{1}{\text{sh}(\alpha r \mu T / H)}, \quad (4)$$

where  $\alpha = 2\pi^2 k_B m_0 / eh \approx 14.7 \text{ T/K}$ . The dHvA results for the effective mass at different field directions are shown in Fig. 6. The angular dependence of the mass is quite well fitted by the expression:

$$m^* \approx 1.03 m_0 / \cos \theta, \quad (5)$$

i.e., the value of the effective mass in the conducting plane constitutes  $m^*(0) = 1.03 m_0$ .

The Dingle temperature was evaluated from the field dependencies of the dHvA oscillation amplitude using the expression for the Dingle reduction factor  $R_D$  [15]:

$$R_D = \exp(-\alpha r \mu T_D / H).$$

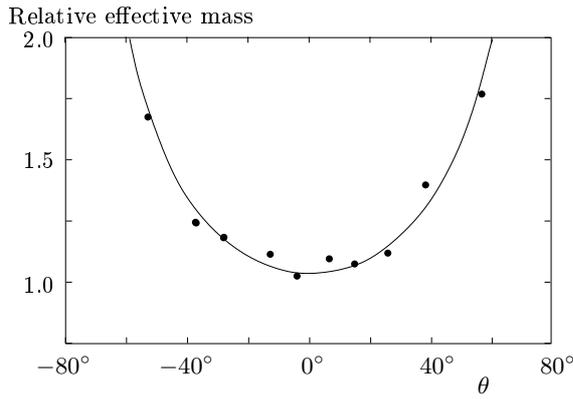


Fig. 6. Angular dependence of the effective mass. The solid line corresponds to the Eq. (5)

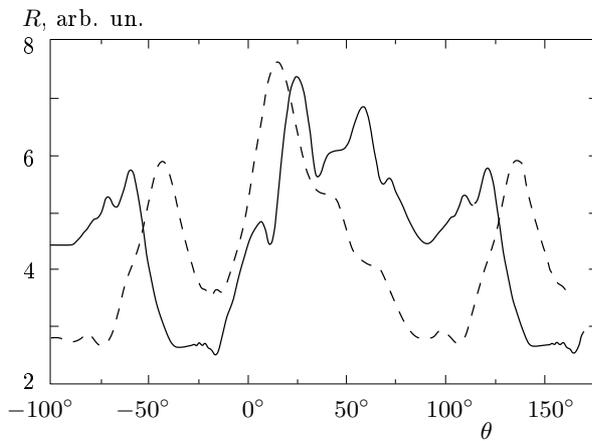


Fig. 7. Angular dependencies of the magnetoresistance;  $H = 14$  T,  $T = 1.45$  K,  $\mathbf{I} \parallel \mathbf{b}^*$ . The solid line corresponds to the rotation plane  $b^*c$ , the dashed line corresponds to the rotation plane close to  $b^*a$

To minimize the undesirable effect of the beat on the field dependence of the amplitude, the Dingle plots were made for  $\theta = 0^\circ$  at which no beating was observed. Such an evaluation yields  $T \approx 2-3$  K.

The angular dependencies of the magnetoresistance were measured using the two-axes-rotation insert in the following way. At first at the initial position of the sample rotator  $\mathbf{b}^* \perp \mathbf{H}$  a screw for manual  $\varphi$ -rotation ( $\varphi$  is an azimuthal angle lying in  $ac$ -plane) around the  $\mathbf{b}^*$  axis was connected with the rotator and a definite plane of  $\theta$ -rotation was set. An angular coordinate  $\varphi$  of this rotation was measured from the  $\mathbf{c}$  axis. After that the screw was disconnected and the sample was rotated with stepper motor around the axis perpendicular to the field direction. Angular coordinate of the recorded magnetoresistance corresponded to the angle  $\theta$  between

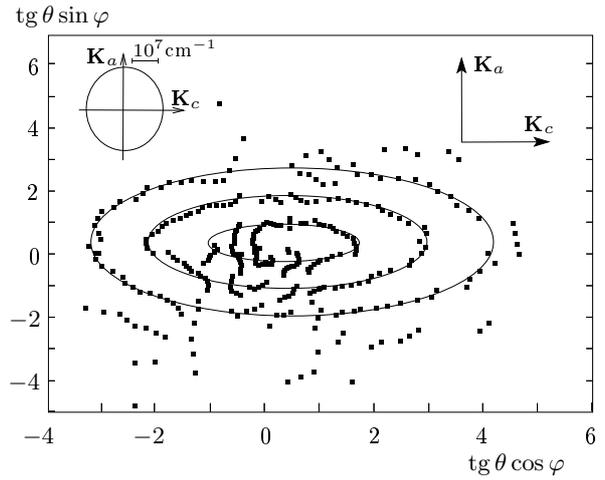


Fig. 8. AMRO maxima positions in the  $\text{tg } \theta$  scale plotted in polar coordinates. The polar angle corresponds to the azimuthal angle in the  $ac$ -plane. Arrows show the directions of the reciprocal lattice. Insert: the FS cross-section reconstructed from these data

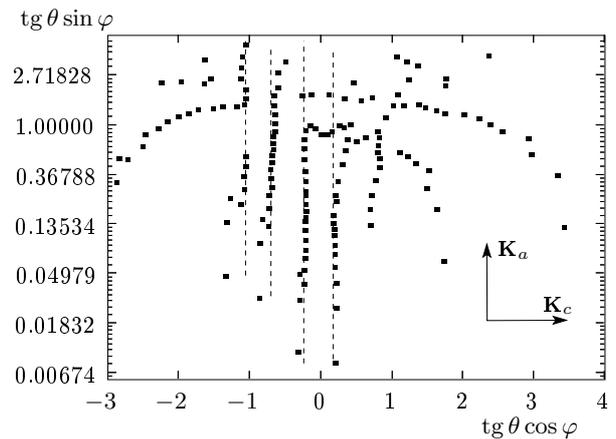


Fig. 9. AMRO minima positions in the  $\text{tg } \theta$  scale plotted in polar coordinates. The polar angle corresponds to the azimuthal one in the  $ac$ -plane. Arrows show directions of the reciprocal lattice

$\mathbf{H}$  and the  $\mathbf{b}^*$  axis. The measurements were done for a set of  $\varphi$  in the range  $0-180^\circ$  with  $4^\circ$  step. Examples of recorded dependencies for  $\varphi = 0$  and  $\varphi = 88^\circ$  are presented in Fig. 7. Angular magnetoresistance oscillations (AMRO) are well pronounced. The results of the AMRO observations at all rotations are summarised in Fig. 8 and Fig. 9 by plotting the minima and maxima of the magnetoresistance, respectively, in polar coordinates where the angle  $\varphi$  performs as a polar one and the length of a radius-vector of every point corresponds to the tangent of the angle  $\theta$  at which the extremum of

AMRO was observed. Arrows indicate the directions corresponding to vectors of the reciprocal lattice. In Fig. 9 only positive values of  $\text{tg } \theta \sin \varphi$  are taken in to account.

#### 4. DISCUSSION

On decreasing of the temperature from 295 K down to 1.45 K the resistance of the samples falls down monotonically without any anomaly [13]. No sign of a SC transition, as observed in  $(\text{ET})_2\text{NH}_4\text{Hg}(\text{SCN})_4$  [8] or of a Peierls-type transition realised in a series of other alpha-salts [2–4] could be detected. The field dependence of the resistance in BETS-Tl-Se appears as a regular curve with almost no saturation [13]. Thus both new the alpha-phase metal and its ET analog [10] have no phase transitions within the 1.45–295 K temperature range. The residual resistance ratio in BETS-Tl-Se,  $\text{RRR} \approx 200$ , the value of the classical magnetoresistance at  $\mathbf{H} \parallel \mathbf{b}^*$  and  $H = 14$  T is almost an order of magnitude higher than the same averaged values of the ET analog [6,10]. Such a difference is unlikely attributed to the increase of the relaxation time in the new metal, since the Dingle temperature is 2–3 times higher than in the ET salt. The amplitude of the SdH oscillations is significantly lower in the new metal than that in the ET salt is in accordance with the higher values of the Dingle temperatures [10]. The large value of classical magnetoresistance seems to be most probably caused by an essentially higher contribution of carriers associated with the quasi-one-dimensional FS sheets in the BETS salt as compared with the ET one. The current direction along open Fermi sheets,  $\mathbf{I} \parallel \mathbf{b}^*$ , provides best conditions for the maximal value of this contribution. The weak saturation of the magnetoresistance, which is characteristic of open orbits, supports this supposition. Indeed, the changing of the current direction on to  $\mathbf{I} \parallel \mathbf{a}$ , decreases the value of the magnetoresistance almost 2.5 times and the noticeable saturation can be observed too (Fig. 1).

Quantum oscillations, SdH and dHvA, in the samples under study demonstrate the only fundamental frequency  $F \approx 640$  T at the  $\mathbf{H} \parallel \mathbf{b}^*$ . This value is close to that found in the quantum oscillations of the ET analog [10]. As it is expected for quasi-two-dimensional metals the behaviour of the angular dependence of the fundamental frequency is described by the relationship (1) and corresponds to the cylindrical shape of FS with the axis along the  $\mathbf{b}^*$  direction.

AMRO presented in Fig.7 are characteristic features of many low-dimensional organic metals [1]. They may

be associated with carriers motion on the cylindrical part of FS if this cylinder is slightly corrugated along  $\mathbf{b}^*$  axis [16]. In this case the maxima of AMRO are periodic in  $\text{tg } \theta$  and their positions are described by the relationship [17]:

$$\text{tg } \theta_n(\varphi) = \frac{\pi(n - 1/4) \pm (\mathbf{k}_{\parallel}^{max}(\varphi) \cdot \mathbf{u})}{k_H^{max}(\varphi)d}, \quad (6)$$

where  $\mathbf{k}_{\parallel}^{max}(\varphi)$  is the in-plane  $ac$  Fermi wave vector component whose projection,  $k_H^{max}$ , to the field rotation plane defined by an angle  $\varphi$  is maximal,  $\mathbf{u}$  is the in-plane  $ac$  component of the electron hopping vector,  $d$  is an interlayer distance and  $n = \pm 1, \pm 2, \dots$  is an integer. The sign « $\pm$ » corresponds to positive or negative values of the angle  $\theta_n$ . Knowing the value of the period of AMRO  $\Delta(\text{tg } \theta_n)$ , one could determine the value  $k_H^{max}$  at a fixed azimuthal angle  $\varphi$  and knowing a set of  $k_H^{max}$  at different angles  $\varphi$  one could determine in detail the shape of the FS cross-section in the conducting plane [17]. If all the values of  $\text{tg } \theta_n$  are drawn in the polar coordinate system with the azimuthal angle  $\varphi$  as a polar one, they form a set of concentric closed curves. At fixed angles  $\varphi$  the distances between the curves are equidistant and equal to the period of AMRO in this rotation plane. Figure 8 shows the maxima of AMRO in polar coordinates. They form a set of the closed curves. The period of AMRO varies from  $\Delta \approx 0.9$  at the sample rotating in the  $ab^*$ -plane to  $\Delta \approx 1.2$  at the sample rotating in the  $cb^*$ -plane. According to [17] the reconstruction of the FS yields the cross-section of the cylindrical FS in the conducting plane as the figure close to an ellipse with half-axes  $k_{Fc} \approx 1.2 \cdot 10^7 \text{ cm}^{-1}$  and  $k_{Fa} \approx 1.6 \cdot 10^7 \text{ cm}^{-1}$  (see insert in Fig. 8). The area of such an ellipse,  $S \sim \pi k_{Fa} k_{Fc}$  is in a good agreement with the frequency of quantum oscillations.

The second possible mechanism for the appearance of AMRO in low-dimensional metals is the motion of carriers along the planar FS sheets characteristic of quasi-one-dimensional electron systems. In this case the FS sheets must be corrugated in two directions [18]. Now the minima of magnetoresistance oscillations are periodic in  $\text{tg } \theta$  and follow the relationship [19]:

$$\text{tg } \theta_n(\varphi) \cos \varphi = \text{ctg } \beta + nK_1/K_2 \sin \beta, \quad (7)$$

where  $\varphi$  is the azimuthal angle counted from the direction parallel to the FS plane,  $K_1$  and  $K_2$  are the lengths of the translation vectors of the reciprocal lattice which lie in the FS plane,  $\beta$  is the angle between them, and  $n = 0, \pm 1, \pm 2, \dots$  is an integer. In polar coordinates (where the angle  $\varphi$  performs as a polar angle) all values of  $\text{tg } \theta_n$  form a set of straight lines parallel

to the one-dimensional axis of the crystal under study. The distance between these straight lines constitutes  $K_1/K_2 \sin \beta$ . Figure 9 depicts the minima of AMRO in polar coordinates. A set of straight lines parallel to  $\mathbf{K}_a$  is well pronounced. In this case the vectors  $\mathbf{K}_b$  and  $\mathbf{K}_c$  of the reciprocal lattice perform as the vectors  $\mathbf{K}_1$  and  $\mathbf{K}_2$ , respectively. The distance between the straight lines constitutes  $0.45 \approx K_b/K_c \sin \beta$ , which is in a good agreement with the parameters of the crystal lattice [13]. Therefore the results presented in Fig. 9 indicate the open FS sheets perpendicular to the  $\mathbf{K}_a$  direction.

It should be noted that these results appear as the first simultaneous observation of «quasi-one-dimensional» and «quasi-two-dimensional» AMRO in the alpha-type crystals. For example, only AMRO associated with the cylindrical FS sheet were observed in ET-Tl-Se [10]. The observation of «quasi-one-dimensional» AMRO in BETS-Tl-Se is most probably associated with a larger degree of the corrugation of the open FS sheets along the  $\mathbf{c}$  direction. In the isostructural BETS-K-S and BETS-NH-S salts the increase of corrugation in this direction was predicted theoretically [20], therefore this assumption seems to be right. Such an enhancement of corrugation may be one of the reasons for the suppression of the Peierls-type transition in the alpha-BETS salts. (The simultaneous presence of AMRO associated with closed and open FS parts results in the appearance of «wrong» points in Figs. 8 and 9. For example, a minimum with no physical origin always exists between two maxima of magnetoresistance associated with the cylindrical FS.) Thus it is shown experimentally that FS in BETS-Tl-Se consists of a quasi-one-dimensional part (two corrugated planes parallel to the  $K_c K_b$ -plane) and a quasi-two-dimensional part (corrugated cylinder with the axis along the  $\mathbf{b}^*$ ).

The corrugation of the cylindrical part of the FS may be reflected in beating behaviour of the quantum oscillations since the corrugated cylinder contains at least two close extremal cross-sections. In this case at the magnetic field direction approaching to the directions described by Eq. (6) the frequency of the beat tends to zero [1] and the amplitude of oscillations with the fundamental frequency sharply increases [16, 17]. The BETS-Tl-Se samples show the beat of the fundamental frequency (Figs. 1 and 2), however its behaviour differs from that described above. The observed beat disappears at field directions corresponding to  $\theta = 0^\circ$  and  $\theta = \pm 20^\circ$  but 1) the angular dependence of magnetoresistance shows no AMRO with the maxima at these angles (see Fig. 7); 2) at angles approaching to

$\theta = 0^\circ$  and  $\theta = \pm 20^\circ$  the frequency of the beat remains almost unchanged (Fig. 4) and the oscillation amplitude in the nodes increases in such way that the nodes fully disappear at these angles. Therefore the observed beat can not be explained by the corrugation of the FS cylinder. Another explanation could be crystal imperfections (twinning, bi-crystal), but the X-ray analysis of the crystal structure does not support this possibility. The magnetic interaction seems to be hardly the reason for the beat [15] since the amplitude and the dHvA oscillation frequency are rather small. Thus the reason for the beat observed is not clarified up to now and requires further investigations.

The angular dependence of the effective mass follows Eq. (5) as expected for a cylindrical FS. The value of the effective mass in the conducting plane  $m^* = 1.03m_0$  is two times lower than that in the ET salt and is close to the value of the effective mass observed in BETS-K-S and BETS-NH-S [12]. The decrease of the effective mass seems to be characteristic of all alpha-phase metal with the BETS cation. The angular dependence of the dHvA oscillation amplitude exhibits «spin zeros» at  $\theta \approx \pm 45^\circ$ . Using the condition for the «spin zeros»,  $\mu g = 2n + 1$ , and the angular dependence of the effective mass as  $\mu(\theta) = \mu(0)/\cos \theta$  and assuming  $n = 1$ , one could estimate the value of the spin-splitting factor [15]:

$$S = \frac{\mu g}{2} = \frac{g_S m_c (1 + \alpha)}{2m_0 (1 + \alpha')} \approx 1.05, \quad (8)$$

where  $g_S$  is the g-factor taken from the ESR measurements and approximately equal to 2 for most organic metals [1],  $m_c$  is a band mass,  $\alpha$  is a correction constant to the band mass which includes electron-electron coupling, and  $\alpha'$  is a correction constant to the g-factor which includes the electron-electron coupling. If the electron-electron coupling is neglected, Eq. (8) yields:  $m_c \approx 1.05m_0$ . (Taking in to account that the only «spin-zero» at  $\theta \approx \pm 45^\circ$  is observed, the choice of the value,  $n = 1$ , needs in explanations. If to assume  $n = 2$  than the value of the band mass,  $m_c \approx 0.36m_0$ , is too small in comparison, for example, with the theoretically calculated band mass for BETS-K-S and BETS-NH<sub>4</sub>-S,  $m_c \sim 0.6m_0$  [12]. If to assume  $n = 2$  than the value of the band mass,  $m_c \approx 1.8m_0$ , is too large in comparison with the effective mass,  $m^* \approx 1.03m_0$ , mentioned above.) Thus the band mass coincides with the effective mass determined from the temperature dependencies of the quantum oscillations amplitude. The band mass  $m_c$  is generally renormalized not only by the electron-electron but the electron-phonon coupling

$$m^* = m_c (1 + \alpha)(1 + \lambda), \quad (9)$$

where  $\lambda$  is the electron-photon coupling correction constant. This would be in agreement with the experimental data if to suppose the full absence of many-body interactions ( $\alpha = \alpha' = \lambda = 0$ ) in BETS-Tl-Se. This could explain the absence of any phase transitions in this compound. Considering that such transitions were observed neither in BETS-K-S nor in BETS-NH-S and the value of the effective mass in these compounds is also close to  $m_0$  [12], one could suggest the weakening of many-body interactions in these salts too and therefore the absence of the SC transition in BETS-NH-S is easily explained. In this case one should suggest that all alpha-BETS metals are not promising for the realization to the SC state.

However the above conclusions have a few objections: 1) The band mass evaluated from theoretical calculations differs almost two times from the effective mass determined experimentally in BETS-K-S and BETS-NH-S [12] in contrast with the experimental results for BETS-Tl-Se; 2) The contribution of the electron-electron coupling may be large enough in organic low-dimensional metals due to low carrier concentration [21]. Therefore the problem of many-body interactions in  $\alpha$ -BETS metals needs in the new detail experiments.

## 5. SUMMARY

The SdH and dHvA quantum oscillations and AMRO have been studied in the new organic metal (BETS)<sub>2</sub>TlHg(SeCN)<sub>4</sub>. The AMRO associated with the carriers motion both on cylindrical and quasi-planar parts of the FS were for the first time simultaneously observed in alpha-type metals. The detailed study of AMRO enabled to determine the shape and size of the FS. The quantum oscillations show the only fundamental frequency,  $F(0) \approx 640$  T, connected with the carrier motion on the cylindrical part of the FS. The beat of the fundamental frequency are observed. The beat behaviour are not explained by effects which are known at present. The evaluation of the parameters of carriers associated with the cylindrical FS, namely, the Dingle temperature,  $T_D \approx 2-3$  K and the effective mass in the conducting plane  $m^* \sim 1.03m_0$  was carried out. The angular dependence of the dHvA oscillation amplitude showed «spin zeros». The analysis of the positions of «spin zeros» with considering the values of the effective mass allowed one to suggest the weakening of many-body interactions in the  $\alpha$ -(BETS)<sub>2</sub>TlHg(SeCN)<sub>4</sub>.

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