Magnetoresistance, noise properties and the Koshino-Taylor effect in the quasi-1D oxide KRu$_4$O$_8$

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received 3 November 2011; accepted in final form 16 February 2012
published online 16 March 2012

PACS 72.15.Gd – Galvanomagnetic and other magnetotransport effects
PACS 72.70.+m – Noise processes and phenomena
PACS 75.47.-m – Magnetotransport phenomena; materials for magnetotransport

Abstract – The low-temperature electronic and galvanomagnetic transport properties of the low-dimensional oxide KRu$_4$O$_8$ are experimentally considered. A quadratic temperature variation of the resistivity is observed to be proportional to the residual resistivity. It shows the role of inelastic electron scattering against impurities, i.e. a large Koshino-Taylor effect, rather than a consequence of strong electronic correlations. In the same temperature range, the Kohler rule is not fulfilled. The resistance noise increases also sharply, possibly due to a strong coupling of carriers with lattice fluctuations in this low-dimensional compound.

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Introduction. – Hollandite crystals have been the subject of a number of investigations, due to their interesting physical properties intimately related to their low-dimensional character [1–6]. The hollandite structure is based on double chains of MO$_6$ octahedra (M = transition element such as Ru, Rh ...) conferring a quasi-one-dimensional (1D) structure. Recent calculations of the electronic structure of KRu$_4$O$_8$ indicate that the Fermi surface itself has a quasi-1D nature, with two sheet-like surfaces which are parallel and separated by a wave vector $\pi/c$ [7]. This result is in agreement with reports of anisotropic electronic conduction mechanisms and possible dimensional crossover in hollandites [3,5].

In a pure 1D electronic interacting system, only collective excitations can exist. A Fermi liquid description is not possible and is replaced by a Tomonaga-Luttinger liquid with spins and charges separation [8–10]. Recently, a strong violation of the Wiedeman-Franz law in the low-dimensional purple bronze Li$_{0.3}$Mo$_6$O$_{17}$ was found consistent with Tomonaga-Luttinger liquid theory [11]. In a low-dimensional system, it is well known that a charge density wave instability due the electron-lattice coupling can also be expected, resulting in a low-temperature resistivity upturn. This is not observed in KRu$_4$O$_8$ which shows a metallic behavior along the conducting chains with no anomaly down to low temperatures ($T = 1.8$ K). This is in agreement with the imperfect nesting of the Fermi surface reported in [7]. The strong warping of the two parallel pairs of Fermi surfaces of KRu$_4$O$_8$ [7] indicates also that the system is not perfectly 1D and that interchains coupling is substantial. As a consequence, there is a place for physical properties at a dimension larger than unity at low temperature, such as Fermi liquid transport properties [8–10]. For example, 3D Fermi liquid properties are recovered at low temperature in the quasi-1D cuprate PrBa$_2$Cu$_4$O$_8$ [12]. Opposite temperature dependence for the in plane and out of plane resistivity have been reported in KRu$_4$O$_8$ for a temperature $T > 180$ K [4], as expected for quasi-1D electronic transport showing incoherent transverse conduction. However, the electronic anisotropy appears strongest at low temperature, a result which is not expected in quasi-1D materials where the interchains hopping takes place at low temperature leading to a more 3D behavior. Note that another hollandite Ba$_{1.2}$Rh$_6$O$_{16}$ [5] shows a behavior more in line with this expected dimensional crossover. It suggests that if

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KRu$_4$O$_8$ presents the quasi-1D Fermi surface, some additional resistive processes could take place at low temperature.

The characterization of a Fermi liquid is often based upon the thermal variation of the resistivity. A quadratic term $AT^2$ is expected at low temperature for Landau quasiparticle-quasiparticle interaction, i.e. a Fermi liquid behavior, for dimensions greater than or equal to two [8]. Its observation can indicate that the system has free quasiparticle excitations and invalidates a priori the existence of a more exotic electronic state imposed by a 1D motion of interacting electrons [8]. Then, the transition from a $T^2$ to a different power law can indicate a transition from a Fermi Liquid to non-Fermi-liquid behavior, i.e. from a 2D or 3D to a 1D behavior. Experimentally, the analysis of the low-temperature resistivity is, however, not trivial due to the unavoidable sample disorder and impurities [13]. In particular, metallic oxides present different kind of structural defects and disorder (cations and oxygen disorder for instance) which result in a large residual resistivity $\rho_0$.

Assuming the Matthiesen rule to hold, the resistivity can be written in the form

$$\rho = \rho_0 + AT^2 + \rho_{ph} \quad (1)$$

with $\rho_{ph}$ the resistivity due to phonon scattering. At a low temperature, $\rho_{ph}$ is negligible and the $T^2$-dependence can be observed. As discussed in [14], the quadratic temperature dependence can also arise from different mechanisms: not only carrier-carrier scattering through strong coulomb interactions [8,15] but also from carrier magnetic moment scattering [16]. Another possible mechanism is the so-called Koshino-Taylor effect describing inelastic scattering against impurities [17,18]. This effect is particular in the sense that $\rho_0$ cannot be simply subtracted to extract the intrinsic resistivity. Including all terms, the low-temperature resistivity should be rewritten as [14]

$$\rho = \rho_0(1 + BT^2) + AT^2 + \rho_{ph}$$

$$= \rho_0 + (B\rho_0 + A)T^2 + \rho_{ph}$$

$$= \rho_0 + \alpha T^2 + \rho_{ph}. \quad (2)$$

In principle, extracting the coefficient $A$ of strong correlations requires then to plot the slope $\alpha$ of $\rho$ vs. $T^2$ (at low temperature where the phonon contribution to the resistivity freezes out). Different values of $\rho_0$ can be obtained by tuning the pressure or by measuring samples with different amount of disorder. If $\alpha$ does not depend on $\rho_0$, then a Fermi liquid scenario can be inferred. Otherwise, inelastic scattering by impurities is likely the relevant mechanism. In classical metals, the Koshino-Taylor effect is a small effect but can be observed [19]. It has been shown to be more important for at least two recent and highlighted materials, in superconducting pnictides [20] and in graphene [21]. In the latter case, the low-dimensional character of graphene was shown to be a possible reason of a reinforced strength of the Koshino-Taylor effect compared to ordinary metals.

$$\rho_0 = \frac{\rho}{\rho_{300 K}}(\rho/\rho_{300 K})$$

as a function of the temperature $T$. Inset: normalised resistivity of KRu$_4$O$_8$ as a function of $T^2$.

We report here measurements of the magneto-transport properties of the metallic and paramagnetic low-dimensional oxide KRu$_4$O$_8$ for samples from the same batch but with different residual resistivities. The Koshino-Taylor effect is observed to be strong and dominant at low temperature, and is simultaneous with a large-resistance noise.

**Experimental.** – KRu$_4$O$_8$ is an alkaline ruthenium hollandite. Single crystals of KRu$_4$O$_8$ were grown by using a flux method as described in [4]. The obtained crystals have a needle-like form with a typical dimension of $1 \, \text{mm} \times 0.05 \, \text{mm} \times 0.05 \, \text{mm}$. Unit-cell parameters are $a = 9.913(5) \, \text{Å}$, and $c = 3.108(5) \, \text{Å}$. For the resistance measurements, four gold wires with a diameter of $20 \, \mu\text{m}$ were glued with silver paste. To obtain a low contact resistance, the sample was annealed at 673 K during 10 min in air. The samples present low residual resistivities, typically in the $\mu\Omega \cdot \text{cm}$ range, close to the best crystals of Sr$_2$RuO$_4$ where unconventional superconductivity has been observed [22]. Transport measurements have been performed in a PPMS Quantum Design equipped with a 14 T magnet and a rotator. For the noise measurements, we use a homemade sample holder. The sample is biased with a noise free current supply of 100 mA, voltage time series are amplified using ultra-low-noise preamplifiers (SA-400F3) enclosed in a thick box and the signal is then anti aliased and Fourier transformed in real time using a PCI acquisition card (see details in [23]). In what follows, $\rho$ will stand for the resistivity along the chains, i.e. along the $c$-axis.

**Galvanomagnetic properties and Koshino-Taylor effect.** – In fig. 1 is shown a typical $\rho(T)$ curve, very similar as previous reports [1,4]. The metallic character is pronounced, and the residual resistivity is low for an oxide (in the $\mu\Omega \cdot \text{cm}$ range), giving a RRR ratio $\rho_{300 K}/\rho_0 \approx 96$ for the purest sample. Contrarily to another quasi-1D hollandite Ba$_{1.3}$Rh$_8$O$_{16}$ [5], no upturn of the zero-field resistivity is observed at low temperature. An estimation of

$$\rho(T) = \rho_0 + \alpha T^2$$

for samples from the same batch but with different residual resistivities. The Koshino-Taylor effect is observed to be strong and dominant at low temperature, and is simultaneous with a large-resistance noise.

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of the electronic mean free path $\ell$ along the chain using the relation $\rho = a^2 \pi h/(2e^2)\ell [24]$ gives a rather large mean free path $\ell \approx 130 \text{ nm}$ at 2K.

At low temperature where the phonon resistivity freezes out, a classical approach is to fit $\rho(T)$ as a power law $T^{\beta}$. $\beta = 2$ is expected for electron-electron (Baber-Landau) scattering [15], carrier-magnetic moment scattering [16] and scattering by impurities and dislocations [14,17,18,25]. Since KRu$_4$O$_8$ is a Pauli paramagnet [1,4], only the first and third cases have to be considered. An exponent of $\beta = 2.7$ has been previously reported in KRu$_4$O$_8$ for temperature lower than 62 K and was discussed as arising from electron-electron umklapp scattering in a 1D conductor [4], as described by Oshiyama et al [26]. However, the two pairs of warped Fermi surface needed to realize this umklapp scattering were not observed in [7]. We have measured three samples of the same batch exhibiting different residual resistivity $\rho_0$, implying different impurities concentration. Depending on $\rho_0$, the thermal variation of the resistivity at the lowest temperatures (typically below 50 K) exhibits different power law dependences. This variation is at least partly due to the resistivity saturation, i.e., its intrinsic nature is difficult to prove. Contrarily, a $T^2$ component is observed for all samples and for temperatures slightly larger than the temperature where $\rho$ starts to saturate (inset of fig. 1). An important observation is that the slope $\alpha$ of $\rho = f(T^2)$ in eq. (2) is different for the three measured samples (fig. 2), with differences significantly larger than the uncertainty in the values of $\alpha$ (error bars are due to approximations when measuring the sample size and the distance between contacts). As discussed above, it implies that electron-electron scattering alone cannot explain the $T^2$-dependence of the resistivity. As shown in fig. 2, the data can be describe by the equation $\alpha = A + B\rho_0$, with a slope $B \approx 5 \times 10^{-4} \text{ K}^{-2}$ and $A \approx 0$. We conclude that the Fermi liquid component $A$ is extremely low here, and the Koshino-Taylor component is dominating. Note that the Sommerfeld coefficient of KRu$_4$O$_8$ is about 3 mJ/mol K$^2$ [1]. It corresponds to a moderately renormalized mass of carriers, in agreement with a “non-strongly-correlated” character implied by the very low value of $A$. The value of $B$ is orders of magnitude larger than Koshino-Taylor effects reported in the literature. More precisely, Taylor’s prediction was $B \sim 0.1/\theta_D^2$ for conventional metals, i.e., $B \sim 7 \times 10^{-8} \text{ K}^{-2}$ using $\theta_D \approx 370 \text{ K}$ [1] what is largely lower than our experimental value. In the layered iron arsenide LaFeAsO$_{0.5}$Fe$_{0.5}$, a value of $B \approx 6 \times 10^{-6} \text{ K}^{-2}$ was reported [20], and $B \approx 10^{-5} \text{ K}^{-2}$ in Nb-Ti [14]. Our value is closer to what was reported in A$_3$Zr where $B \approx 1 \times 10^{-4} \text{ K}^{-2}$ [25]. An unusual large transverse electron-phonon coupling was then suggested [25]. A large Koshino-Taylor effect was recently discussed for the graphene, taking into account the low-dimensional character of the lattice fluctuations [21]. We propose that a similar argument should be applied to KRu$_4$O$_8$ which presents a quasi-1D lattice. The predicted $T \ln T$-dependence of the Koshino-Taylor correction to the resistivity [21] is not observed however, in a reasonable temperature range. Note that a $T^2 \ln T$-dependence gives a slightly better agreement than a pure $T^2$-dependence in our data because it extends down to lowest temperature. This dependence was deduced in the extension of electron phonon impurity interference theory of Reizer-Sergeev at low dimension [27]. It could explain the non-Fermi-liquid-like dependence reported in some KRu$_4$O$_8$ samples [4]. We would like to stress that if it is difficult to conclude on the exact temperature dependence, i.e., $T^2$ or $T^2 \ln T$, the dependence on the residual resistivity is a strong support to consider here inelastic scattering against impurities as a major process.

The magnetoresistance $MR = (\rho(B) - \rho(0))/\rho(0)$ is positive for all temperatures and shows strong angular angular dependence (see fig. 3), being consistent with both a Lorentz force driven MR and a large anisotropy of the Fermi surface in our geometry. A MR of more than 90% is observed at 14T and at low temperature ($T = 1.8 \text{ K}$, fig. 3). This large value is consistent with the large mean free path of KRu$_4$O$_8$. As shown in fig. 3, the MR at low field has a non-quadratic field dependence, and can be fitted by a 1.3 power law. A conventional and metallic MR is supposed have a low-field $B^2$ component, but lowest exponents in the range 1.3–1.5 have been already reported in low-dimensional bronze oxides [28], organic conductors [29] or in metallic nanowires such as Bi [30]. No clear saturation of the MR can be observed up to 14T. At the lowest temperature that we have measured ($T = 1.8 \text{ K}$), the MR tends to curve downward at large field, indicating an incipient saturation. This can be described by a two band model with uncompensated carriers [31], similarly to [28].

The Kohler plot $\Delta \rho/\rho_0 = F(B/T)$ of MR shows that the galvanomagnetic processes can be separated in two temperature ranges (fig. 4). For $T < T^* \approx 18 \text{ K}$, the MR
curves are superimposed on the same plot. For $T > T^*$, the Kohler rule is not supported by the data. As a general rule, the Kohler rule applies in the case of a single scattering process \[32\]. This is the case for $T < T^*$ where the resistivity becomes temperature independent and tends to the residual resistivity value. At larger temperature $T > T^*$, the contribution of the Koshino Taylor resistivity becomes apparent and breaks the Kohler rule, as expected if the two scattering processes have different magnetic-field dependence. Note that the magnetic-field dependence of MR is unchanged when crossing $T^*$, strongly suggesting that the Koshino-Taylor mechanism contributes to the zero-field resistivity but not significantly to the MR.

**Noise properties.** – Noise is a powerful tool to investigate the low-frequency dynamics of electronic processes \[33\], and appears particularly interesting for low-dimensional systems since fluctuations increase in principle when dimensions shrink. The experimental quantity is here the noise spectrum $S_{VV}$ of the fluctuating voltage from the sample, using the set-up described in the experimental part. The noise values present a quadratic dependence with the applied current, as expected for noise driven by the fluctuations of resistance. After analyzing the time series of noise spectra, there is no evidence of non-Gaussian components of the noise (it corresponds to a white so called second spectrum \[34\]). It can be assumed then that the noise arises from uncorrelated random processes.

We have measured $S_{VV}$ of KRu$_4$O$_8$ as a function of the temperature under a constant 100 mA current. Noise values are large when comparing with conventional metals, but also large compared to another hollandite Ba$_{1.2}$Rh$_4$O$_{16}$ where the noise was not measurable with the same experimental set-up \[5\]. To discuss normalized values between different materials of different resistances, the Hooge parameter $\gamma = S_{VV}/V^2 n_c \tau f^\alpha$ is usually employed \[35\]. $n_c$ is the carrier density ($n_c \approx 2 \cdot 10^{22}$ cm$^{-3}$ \[4\]), $\tau$ is the noisy (probed) volume and $\alpha \approx 2$ here. We deduce $\gamma \sim 450$, i.e. four order of magnitude larger than metallic values which are around 0.01 \[35\]. Such a large value is not rare in oxides, as, for example, reported in colossal magnetoresistance manganites, Fe$_3$O$_4$ (\(\gamma \sim 80\)) and in CrO$_2$ (\(\gamma \sim 2000\)) \[36\]. Note that for low-dimensional conducting processes, assuming that the noisy volume $V$ corresponds to the whole volume between the probes is an overestimation if inhomogeneous charge propagation paths exist. The temperature dependence of $\gamma$ is shown in fig. 5. Interestingly, it increases sharply in the same temperature range where the $T^2$ component of resistivity dominates, and then tends to saturate at low temperature. It shows a direct correlation between the change in the scattering processes and the electronic fluctuations. Consequently, we have to associate the reinforced resistance fluctuations with the scattering from impurities due to the Koshino-Taylor effect. It has to be emphasized that the spectral shape of the noise is $1/f^\alpha$ with $\alpha \approx 2$ for the whole temperature range.
To increase of \( \gamma \) processes can have an intrinsic Lorentzian spectrum. The motion of defects, dislocations or impurities. These (inset of fig. 5). Noise usually arises from the activated resistance noise is strongly reinforced to the importance of the local fluctuations of the lattice. We note that an anomalous temperature dependence of the Seebeck coefficient was reported in the same temperature range [4].

In conclusion, we have measured the galvanomagnetic properties and the resistance noise of quasi-1D hollandites KRu\(_4\)O\(_8\). Despite the relative cleanest of the samples revealed by the low residual resistivity, a very large inelastic scattering of carriers by impurities is revealed by the analysis of the transport properties. It can be due to the importance of the local fluctuations of the lattice in this highly anisotropic material as discussed in [21]. Accordingly, the resistance noise is strongly reinforced at low temperature and the \( 1/ f^2 \) spectral form of the noise is likely characteristic of the 1D nature of the carriers paths.

REFERENCES

[1] Foo M. L., Lee Wei-Li, Siegrist T., Lawes G., Ramirez A. P., Ong N. P. and Cava R. J., Mater. Res. Bull., 39 (2004) 1663.
[2] Mao Z. Q., He T., Rosario M. M., Nelson K. D., Okuno D., Ueland B., Deac I. G., Schiffer P., Liu Y. and Cava R. J., Phys. Rev. Lett., 90 (2003) 186601.
[3] Kobayashi W., Hébert S., Perez O., Pelloquin D. and Maignan A., Phys. Rev. B, 79 (2009) 085207.
[4] Kobayashi W., Phys. Rev. B, 79 (2009) 155116.
[5] Pautrat Alain and Kobayashi Wataru, Phys. Rev. B, 82 (2010) 115113.
[6] Maignan A., Lebedev O. I., Van Tendeloo G., Martin C. and Hébert S., Phys. Rev. B, 82 (2010) 035122.
[7] Toriyama T., Watanabe M., Konishi T. and Ohta Y., Phys. Rev. B, 83 (2011) 195101.
[8] Giamarchi T., Chem. Rev., 104 (2004) 5037.
[9] Voit J., J. Rep. Prog. Phys., 58 (1995) 977.
[10] Schulz J. H., in Fermi Liquids and Non-Fermi Liquids in Mesoscopic Quantum Physics, Les Houches LXI, edited by Akkermans E., Montambaux G., Pichard J. L. and Zinn-Justin J. (Elsevier, Amsterdam) 1995.
[11] Wakeham N., Bangura A. F., Xu X., Mercure J.-F., Hussey N. E., McBrien M. N., Balicas L., Brooks and Greenblatt M. and Hussey N. E., Nat. Commun., 2 (2011) 396.
[12] Hussey N. E., McBrien M. N., Balicas L., Brooks J. S., Horii S. and Ikuta H., Phys. Rev. Lett., 89 (2002) 086601.
[13] Capogna L., Mackenzie A. P., Perry R. S., Grigera S. A., Galvin L. M., Raychaudhuri P., Schofield A. J., Alexander C. S., Cao G., Julian S. R. and Maeno Y., Phys. Rev. Lett., 88 (2002) 076602.
[14] Garbarino G. and Nunez-Regueiro M., Solid State Commun., 142 (2007) 360.
[15] Baber W. G., Proc. R. Soc. London, Ser. A, 158 (1936) 383.
[16] Lederer P. and Mills D. L., Phys. Rev., 165 (1968) 837.
[17] Koshino S., Prog. Theor. Phys., 34 (1960) 484.
[18] Taylor P. L., Proc. Phys. Soc. London, 80 (1962) 755; Phys. Rev., 135 (1964) A1333.
[19] Mahan G. D. and Wang Z., Phys. Rev. B, 39 (1989) 4926.
[20] Garbarino G., Toulemonce P., Alvarez-Murga M., Sow A., Mezouar M. and Nunez-Regueiro M., Phys. Rev. B, 78 (2008) 100507(R).
[21] Cano A., Phys. Rev. B, 79 (2009) 153410.
[22] Mackenzie A. P., Haselwimmer R. K. W., Tyler A. W., Lonzarich G. G., Mori Y., Nishizaki S. and Maeno Y., Phys. Rev. Lett., 80 (1998) 161.
[23] Scolla J., Pautrat A., Goupil C. and Simon Ch., Phys. Rev. B, 71 (2005) 104507.
[24] Horii S., Takagi H., Ikuta H., Hussey N. E., Hirabayashi I. and Misutani U., Phys. Rev. B, 66 (2002) 054530.
[25] Fisher B., Chashka K. B., Patlagan L., Bazalitsky G. and Reisner G. M., Phys. Rev. B, 68 (2003) 014118.
[26] Oshiyama A., Nakao K. and Kamimura H., J. Phys. Soc. Jpn., 45 (1978) 1136.
[27] Reizer M. Yu. and Sergeev A. V., Zh. Eksp. Teor. Fiz., 92 (1987) 2291 (Sov. Phys. JETP, 65 (1987) 1291); Sergeev A. V., Reizer M. Yu. and Mitin V., Phys. Rev. B, 69 (2004) 075310.
[28] Tian M., Yue S. and Zhang Y., Phys. Rev. B, 65 (2002) 104421.
[29] Kriza G., Szeghy G., Kezsmarki I. and Mihaly G., Phys. Rev. B, 60 (1999) RS434.
[30] Kaiser Ch., Weiss G., Cornelius T. W., Toimil-Molares M. E. and Neumann R., J. Phys.: Condens. Matter, 21 (2009) 205301.
[31] Noto K. and Tsuzuku T., Jpn. J. Appl. Phys., 14 (1975) 46.
[32] Luo N. and Miley G. H., Physica C, 371 (2002) 259.
[33] Weissman M. B., Rev. Mod. Phys., 60 (1988) 537.
[34] Parman C. E., Israeloff N. E. and Kakalios J., Phys. Rev. Lett., 69 (1992) 1697; Pautrat A., Eng H. W. and Prellier W., Phys. Rev. B, 72 (2005) 233405.
[35] Hooge F. N., Phys. Lett. A, 29 (1969) 139.
[36] Raquet B., Coey J. M. D., Wirth S. and von Molnar S., Phys. Rev. B, 59 (1999) 12435.
[37] Dutta P., Dimon P. and Horn P. M., Phys. Rev. Lett., 43 (1979) 646.
[38] Bertotti G., Fiorillo F. and Mazetti P., Phys. Scr., T1 (1982) 134.
[39] Fleetwood D. M. and Giordano N., Phys. Rev. B, 28 (1983) 3625.
[40] Bellido Natalia, Pautrat Alain, Keller Clement and Hug Eric, Phys. Rev. B, 83 (2011) 104108.