Tranport, Themal and Magnetic Properties of $Bi_3Os_3O_{11}$ and $Bi_3Ru_3O_{11}$

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Abstract

Transition metal oxides $Bi_3T_3O_{11}$(T=Os and Ru) has been synthesized and their macroscopic physical quantities have been measured. Characteristics of the observed data are reminiscent of those of heavy electron systems, though the electronic specific heat coefficient γ is not significantly large. The electrical resistivity and the specific heat of $Bi_3Ru_3O_{11}$ suggest the possible non-Fermi liquid behavior of the electrons. It seem to be necessary, however, to consider that the Hall coefficient and the thermoelectric power, suggest the existence of the phase change at low temperature.

Key words: $Bi_3Os_3O_{11}$; $Bi_3Ru_3O_{11}$; transport properties; magnetic properties; non-Fermi liquid behavior

$Bi_3Os_3O_{11}$ and $Bi_3Ru_3O_{11}$ have structural units of edge-sharing pairs of OsO_6 or RuO_6 octahedra and by the three dimensional linkage of these units, the structure is formed [1,2]. To investigate what kinds of physical properties their electrons exhibit, we have synthesized polycrystalline samples of the systems and studied various kinds of their physical quantities.

In the preparation of $Bi_3Os_3O_{11}$, mixtures of Bi_2O_3 and Os with proper molar ratio were ground and pressed into pellets. They were sealed in quartz tubes with $KClO_4$, heated at 1000 °C for 20 h and then cooled in the furnace. In the preparation of $Bi_3Ru_3O_{11}$, mixtures of Bi_2O_3 and RuO_2 were ground and pressed into pellets. These pellets were put in a Au tube, heated for three days at 790 °C and furnace cooled. They were reground and pelletized again and heated in the Au tube at 790 °C for one day and furnace cooled. The samples of these systems were found to be the single phase by the X-ray diffraction.

The electrical resistivities ρ were measured by the standard four probe method by using an AC resistance bridge. The thermoelectric powers S were measured by the DC method. The Hall coefficients R_H were measured with the magnetic field of 7 T by rotating the sample with respect to the magnetic field direction. The magnetic susceptibilities χ were measured by us-

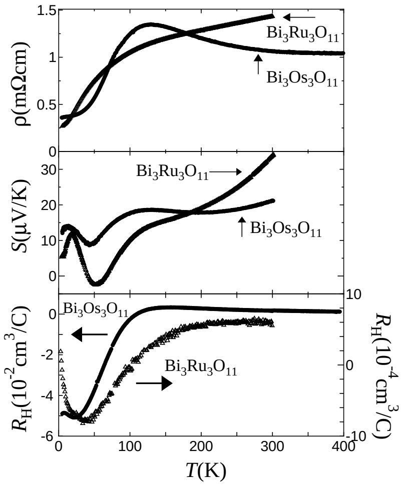

Fig. 1. T-dependences of the electrical resistivities ρ(top), the thermoelectric powers S(middle) and the Hall coefficients R_H(bottom) of $Bi_3Os_3O_{11}$ and $Bi_3Ru_3O_{11}$.

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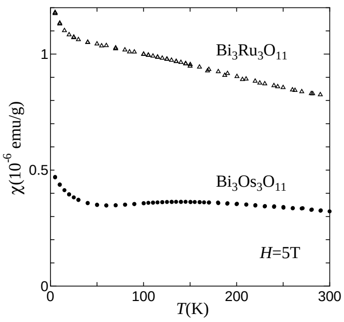

Fig. 2. Magnetic susceptibilities χ of $Bi_3Os_3O_{11}$ and $Bi_3Ru_3O_{11}$ are shown against T.

ing a SQUID magnetometer under the magnetic field of 5 T. The specific heats were measured by a thermal relaxation method.

In Fig. 1, results of the measurements of ρ(top), S(middle) and R_H(bottom) of $Bi_3Os_3O_{11}$ and $Bi_3Ru_3O_{11}$ are shown against T. Although ρ of $Bi_3Os_3O_{11}$ has a peak at around 125 K, while that of $Bi_3Ru_3O_{11}$ does not, gross features of the transport behaviors of the two systems are rather similar. The ρ of $La_3Ru_3O_{11}$ and $La_4Ru_6O_{19}$, which have the similar network of edge-sharing RuO_6 pairs to those of the present systems also exhibit the similar gross features [3]. S and R_H also begin to exhibit significant decrease at around 100 K, indicating the characteristic change of their electronic states below 100 K.

Figure 2 shows the χ-T curve of $Bi_3Os_3O_{11}$ and $Bi_3Ru_3O_{11}$. The broad peak structure observed for $Bi_3Os_3O_{11}$ is very similar to that of $La_4Ru_6O_{19}$, for which non-Fermi liquid behavior [3] is recently reported. The T-dependence of χ of $Bi_3Ru_3O_{11}$ seems to have a peak structure, too, but the position of the peak is shifted much lower temperature. This T-dependence seems to be slightly different from that of $La_3Ru_3O_{11}$ [3].

The observed characteristics of χ and transport quantities are reminiscent of those of heavy Fermion systems. Another point to be studied, is the low temperature behavior of the resistivities ρ. For $Bi_3Os_3O_{11}$, ρ approaches a constant value, as $T \to 0$, while ρ of $Bi_3Ru_3O_{11}$ seems to remain T-dependent at least down to the lowest T studied here. Kalifah *et al.* [3] reported that $La_4Ru_6O_{19}$ exhibits non-Fermi liquid behavior of ρ and C, while $La_3Ru_3O_{11}$ does not. Then, it is interesting to study if the behavior of ρ of $Bi_3Ru_3O_{11}$ arises from the non-Fermi liquid nature of its electron system.

In Fig. 3, C/T-T^2 curves of $Bi_3Os_3O_{11}$ and $Bi_3Ru_3O_{11}$ are shown in the form of C/T-T^2. Because the systems have very heavy element(Bi), the data do not show the linear behavior even in the low T region. The solid line is the result of the polynomial

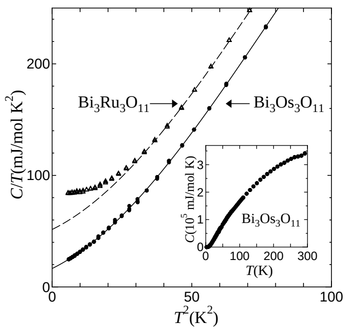

Fig. 3. Specific heat data divided by T, C/T of $Bi_3Os_3O_{11}$ and $Bi_3Ru_3O_{11}$ are shown against T. Inset shows the specific heat data of $Bi_3Os_3O_{11}$ in the wider T range. Details are in the text.

fit to the data of $Bi_3Os_3O_{11}$. We have found that the broken line obtained by a vertical shift of the data by 35 mJ/K^2/mol can well reproduce the result of $Bi_3Ru_3O_{11}$above $\sim$ 6 K. Based on this fact, we assume that the phonon contributions to C/T in both systems can, roughly speaking, be described commonly by the difference between the solid line and γ of $Bi_3Os_3O_{11}$ ($\sim$ 17 mJ/K^2/mol).

Then, the upward deviation of the data of $Bi_3Ru_3O_{11}$ from the broken line observed at low temperatures is considered to be due to a similar origin to that of the C-increase reported for $La_4Ru_6O_{19}$, that is, the non-Fermi liquid behavior may have been observed in $Bi_3Ru_3O_{11}$. (Its γ value at the lowest T studied here is about 64 mJ/K^2/mol, which is not so large as compared with the typical heavy electron system.) The Ru-Ru distances of $Bi_3Ru_3O_{11}$ is 2.60 Å [2], which is larger than 2.448 Å for $La_4Ru_6O_{19}$, but smaller than 2.994 Å for $La_3Ru_3O_{11}$ [4]. The present observation of the anomalous deviation is consistent with the idea that the small Ru-Ru distance is important for the realization of the non-Fermi liquid behavior [3].

However, we have to point out that the anomalous and rather complicated T-dependence of S and R_H shown in Fig. 1 indicate that there seems to exist a certain kind of phase change at low temperature, even though no anomalous behavior has been detected in the resistivities. Systematic and careful studies are required to clarify this point.

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