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BRIEF COMMUNICATIONS

Novel Two-Dimensional Conductor Sr_2RhO_4

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A new complex oxide Sr_2RhO_4 with K_2NiF_4-type structure has been synthesized. The crystal symmetry of Sr_2RhO_4 is orthorhombic, and the temperature coefficient of resistivity is positive down to 10 K. Magnetic susceptibility measurement revealed a two-dimensional nature of the magnetic ordering.

Introduction

In the previous paper (*1*), we reported that a low spin state of Rh^{3+} (d^6) and Rh^{4+} (d^5) ions is stable in $La_{1-x}M_xRhO_3$ (M = Sr, Ba, and Ca). Rh^{4+} with a low spin state at the center of oxygen octahedron has empty $4d\gamma$ (e_g) orbitals and mostly filled $4d\varepsilon$ (t_{2g}) orbitals containing one hole. This state is comparable to that of V^{4+} ion in $Sr_{n+1}V_nO_{3n+1}$, where V^{4+} ion has empty $3d\gamma$ (e_g) orbitals and mostly empty $3d\varepsilon$ (t_{2g}) orbitals having one electron. The temperature coefficient of resistivity is negative for Sr_2VO_4 ($n = 1$), but it is positive for $Sr_3V_2O_7$ ($n = 2$), $Sr_4V_3O_{10}$ ($n = 3$), and $SrVO_3$ ($n = \infty$) (*2*). $LaRhO_3$ (*3*) with a perovskite-type structure has been known for 35 years, but a K_2NiF_4-type Sr_2RhO_4 is not yet known. In this note we report the synthesis of Sr_2RhO_4 ($n = 1$) and its positive temperature coefficient of resistivity and a magnetic ordering.

Experimental

Sr_2RhO_4 was prepared by a conventional solid reaction method. Raw materials were $SrCO_3$ and Rh_2O_3 with the high-temperature form (*4*); their purities were 99.9%. Stoichiometric amounts of $SrCO_3$ and Rh_2O_3 were mixed in an agate mortar, and the powder was pressed into a pellet 12 mm in diameter. The pellet was calcinated at 1473 K for 12 hr in O_2 gas flow and cooled to room temperature. The pellet was reground in an agate mortar and again pressed into a pellet. This pellet was sintered at 1523 K for 36 hr in O_2 gas flow and cooled to room temperature.

Identification of the phase was carried out by powder X-ray diffraction analysis. Diffraction data were collected by step scanning between 20° ~ 120° at intervals of 0.02° for 4 sec using a Rigaku θ–θ X-ray diffractometer equipped with the curved graphite monochromator. The lattice constant was

0022-4596/92 $5.00

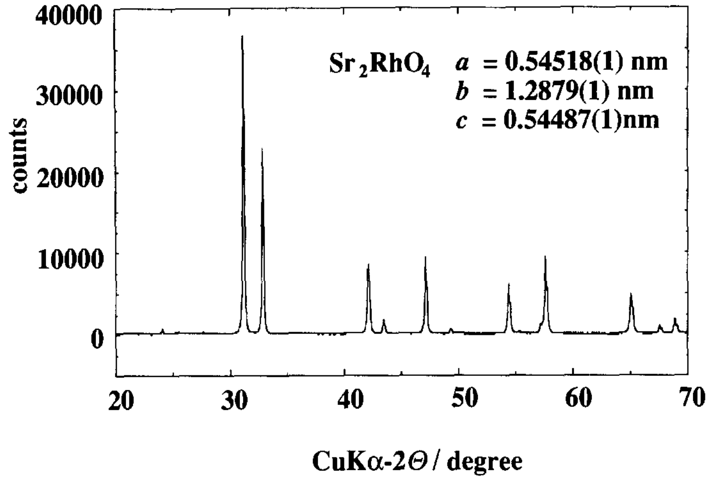

FIG. 1. Powder X-ray diffraction pattern of Sr_2RhO_4.

determined using the structural analysis program of Izumi *et al.* (*5*). Electrical resistivity was measured from 10 to 300 K by the dc four-probe method, and magnetic susceptibility was measured from 5 to 300 K by a SQUID magnetometer.

Results and Discussions

Figure 1 shows the powder diffraction pattern of Sr_2RhO_4. The symmetry of crystal is orthorhombic and the possible space groups are *Fmmm* (No. 69) or *Cmca* (No. 64). The crystallinity of the sample was not excellent so that the space group, which mainly depends on the tilting of the RhO_6 octahedra, could not be perfectly determined from the X-ray diffraction data. However, the analysis assuming the space group *Cmca* gave the smaller *R* factor. The lengths of the *a*, *b*, and *c* axis are 0.54518(1) nm,

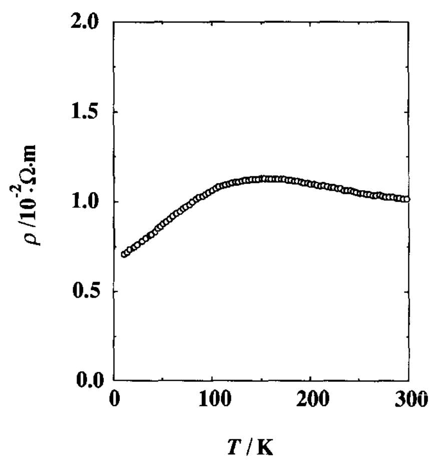

FIG. 2. Temperature dependence of electrical resistivity of Sr_2RhO_4.

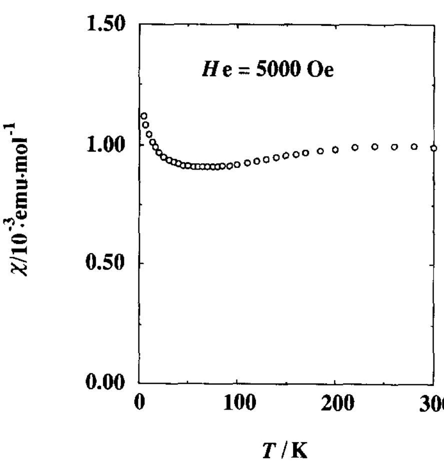

FIG. 3. Temperature dependence of magnetic susceptibility of Sr_2RhO_4.

TABLE I

LIST OF THE X-RAY DIFFRACTION ANALYSIS DATA

h	k	l	$d_{obs.}$ (nm)	$(I/I_0)_{obs.}$	$(I/I_0)_{calc.}$
1	1	1	0.3692	0.3	0.2
0	4	0	0.3219	0.4	0.5
1	3	1	0.2867	100	100
0	0	2	0.2725	31.7	32.8
2	0	0	0.2724	31.9	32.0
0	2	2	0.2510	0.13	0.17
2	2	0	0.2509	0.13	0.16
0	6	0	0.2146	18.5	17.0
1	5	1	0.2141	14.7	13.6
0	4	2	0.2080	2.8	2.4
2	4	0	0.2079	2.8	2.4
2	0	2	0.1926	30.2	30.9
2	2	2	0.1846	2.3	2.2
1	1	3	0.1708	0.13	0.12
3	1	1	0.1707	0.14	0.13
0	6	2	0.16864	11.3	10.7
2	6	0	0.16860	11.4	10.8
1	7	1	0.16603	0.7	0.6
2	4	2	0.16535	0.5	0.4
0	8	0	0.16099	3.0	2.8
1	3	3	0.15997	18.9	17.7
3	3	1	0.15991	18.6	17.4
2	6	2	0.14339	16.5	15.8
1	5	3	0.14327	3.5	3.4
3	5	1	0.14322	3.6	3.4
0	8	2	0.13862	2.1	2.2
2	8	0	0.13860	2.1	2.2
0	0	4	0.13629	4.2	4.3
4	0	0	0.13622	4.3	4.4
1	9	1	0.13415	4.4	4.4
0	2	4	0.13334	0.4	0.3
4	2	0	0.13327	0.3	0.3
0	10	0	0.12879	0.2	0.2
1	7	3	0.12580	0.3	0.3
3	7	1	0.12577	0.3	0.3
4	4	0	0.12545	0.1	0.1
2	8	2	0.12354	4.0	4.2
3	3	3	0.12307	7.0	7.3
2	0	4	0.12189	4.6	4.8
4	0	2	0.12185	4.7	4.9

Note. Cu$K\alpha_1$ (0.15405 nm) data ($I/I_0 < 0.1$) is not shown.

1.2879(1) nm, and 0.54487(1) nm, respectively. Table I shows the diffraction data for Sr_2RhO_4.

Figure 2 shows the temperature dependence of resistivity of Sr_2RhO_4. The temperature coefficient of resistivity is positive below 150 K. The oxygen octahedra in the K_2NiF_4 structure form a two-dimensional network perpendicular to the *b* axis; thus Sr_2RhO_4 is considered to be a two-dimensional conductor. Qualitative measurement of the Seebeck coefficient suggests hole conduction; therefore the carriers are expected to be holes in $4d\varepsilon$ orbitals of Rh^{4+}.

Figure 3 shows the temperature dependence of the magnetic susceptibility of Sr_2RhO_4. The shape of the susceptibility curve in Fig. 3 suggests an ordering of magnetic momenta. Since magnetic interactions among Rh^{4+} ions are possible only via O^{2-} ions in the two-dimensional RhO_2 plane perpendicular to the *b* axis, the magnetic ordering may be strong in the two-dimensional plane.

A solid solution system between Sr_2RhO_4 and $SrLaRhO_4$ (*6*), that is, $Sr_{2-x}La_xRhO_4$, has been synthesized similar to the way Sr_2RhO_4 was synthesized. A positive temperature coefficient of resistivity below 150 K and magnetic ordering have been observed in the region $0.00 \leq x \leq 0.15$. The details of the analysis of the properties of Sr_2RhO_4 and $Sr_{2-x}La_xRhO_4$ will be reported elsewhere.

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