1B/2001G238

Anomalous thermal expansion in the metallic phase of SmS under high pressure

Kazuaki Iwasa*[1], Toshitaka Tokuyama[1], Masahumi Kohgi[1], Noriaki K. Sato[2], Nobuo Môri[3]
[1]Tokyo Metropolitan University, Hachioji, Tokyo 192-0397, Japan
[2]Nagoya University, Nagoya 464-8602, Japan
[3]Satitama University, Saitama 338-8570, Japan

Introduction

SmS exhibits a pressure-induced transition of Sm valence [1, 2]. At ambient pressure, the Sm-ion state is considered to be divalent and semiconductive transport properties appear. The resistivity decreases with applying pressure and a semiconductor-metal transition occurs at 0.65 GPa [2-5], which is accompanied by large volume compression with keeping the NaCl-type cubic crystal structure. The temperature dependence of the electrical resistivity was found to be rather complicated. A remarkable phenomenon is that the resistivity increases below 20 K with anomalous humps in the region between 0.7 and 2 GPa. Thus, even in the metallic phase, some kind of energy gap is conserved. The valence state of Sm ions and carrier density are sensitive to the applied pressure together with the volume compression. In order to study the electronic state of SmS, we investigate a thermal property of crystal lattice under high pressure.

Experimental procedure

X-ray diffraction measurements were performed at BL-1B as well as the conventional diffractometer installed in Tokyo Metropolitan University. For both experiments, single-crystal samples of SmS were installed in a diamond-anvil cell together with a NaCl crystal and ruby powders as pressure markers, and pressures were applied up to 3 GPa. Sample temperatures were controlled by a closed-cycle refrigerator down to 10 K.

Results and discussions

Figure 1 depicts thermal expansion of SmS at various pressures, which are relative values to the lattice constant at 300 K and at ambient pressure. At ambient pressure, the lattice constant varies monotonically against temperature. On the other hand, at 0.6 and 1.1 GPa, local minima were observed at around 100 K. Above around 2 GPa, such local minimum disappears, while we could not measure the lattice constant above 150 K with keeping the constant pressures.

The pressure region of local minimum of lattice constant coincides with that of the low-temperature increase of electrical resistivity. Thus, electronic gap is expected to couple strongly with the crystal lattice. We adopted a phenomenological model of a thermal expansion based on the Debye approximation and the Grüneisen assumption for lattice vibration and an assumption of two-level state. We succeeded in reproducing the data at ambient pressure by considering only the lattice-vibration part, as shown in the figure, By taking into account also the two levels whose energy gap is suppressed by pressure, the data at 0.6 and 1.1 GPa are also reproduced. The obtained gap energies are 99 and 30 K at 0.6 and 1.1 GPa, respectively.

The present study revealed the electronic gap affected not only the electrical resistivity but also the thermal property of crystal lattice. The future subject is to investigate a role of Sm 4f-electron state.

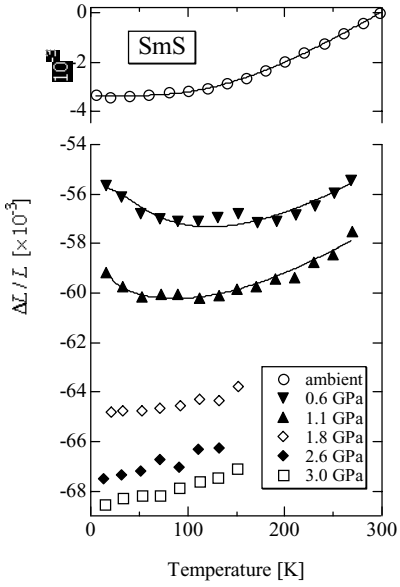

Figure 1. Thermal expansion of SmS under pressure.

Acknowledgement

H. Nakao, Y. Wakabayashi, R. Tazaki, H. Sawa, K. Kuwahara, H. Sagayama, M. Nakajima and D. Kawana are acknowledged for their experimental assistance.

References

[1] M. B. Maple and D. Wohlleben: Phys. Rev. Lett. **27**, 511(1971).
[2] J. Röhler *et al.*: in Valence Instabilities (eds. P. Wachter and H. Boppart) 215, (1982).
[3] F. Lapierre *et al.*: Solid State Commun. **40**, 347 (1981).
[4] M. Konczykowski *et al.*: J. Magn. Magn. Mater. **47&48**, 274 (1985).
[5] M. Ohashi *et al.*: Rev. High Pressure Sci. Technol. **7**, (1998) 611, N. Môri *et al.*: JJAP Series **11**, 129 (1999).

* iwasa@comp.metro-u.ac.jp