

THERMOELECTRIC POWER OF STRONTIUM UP TO 6.5 GPa

C. Divakar, M. Mohan and A.K. Singh

Materials Science Division, National Aeronautical Laboratory, Bangalore 560 017, India

(Received 15 October 1981 by M. Cardona)

The thermoelectric power of Sr has been measured up to 6.5 GPa using an opposed anvil set up. The results have been compared with those for Yb.

THE PRESSURE–TEMPERATURE PHASE diagrams of Yb and Sr exhibit striking similarities [1–4]. The electrical resistance at room temperature increases with pressure in both cases and drops at 4.0 GPa in case of Yb and 3.6 GPa in case of Sr [5]. This drop in electrical resistance is associated with f.c.c. \rightarrow b.c.c. transformation [6, 7]. We have measured at room temperature, the thermoelectric power (TEP) of Sr up to 6.5 GPa. In this communication we report the results of these measurements and compare them with those of Yb reported earlier [8, 9].

The TEP as a function of pressure was measured using a tungsten carbide opposed anvil (12 mm flat face) set up with pyrophyllite gasket and either talc or epoxy as pressure transmitting medium. A temperature gradient was established across the sample by heating one end of the sample. The temperature and the potential differences between two points on the sample were measured with chromel–alumel thermocouples and K-5 (Leeds Northrup) nanovolt potentiometer. The pressure on the sample was determined by calibrating the ram pressure using Bi_{I–II} (2.55 GPa), Tl_{II–III} and Bi_{III–IV} (7.6 GPa) transitions. The details of the experimental arrangement are published elsewhere [9]. The Sr sample used in the present measurements was 99.5% pure from Research Organic/Inorganic Co., U.S.A. A small piece of Sr was pressed between two flat surfaces to give a 0.1 mm thick sheet. The specimens measuring nearly 0.1 x 0.5 x 5 mm were cut from this sheet. During the entire operation the sample surface were covered with machine oil. Finally, the specimens were scraped clean and loaded under argon atmosphere in the cell. The specimen pressure was increased in steps of 0.1 GPa. After each increase in pressure 5 mt were allowed for the cell to stabilise, and then the measurements were made. The f.c.c. \rightarrow b.c.c. transition was sluggish and it was found necessary to allow for 15 mt waiting time.

A typical plot of TEP of Sr against pressure is shown in Fig. 1. It is seen that TEP increases with the increase in pressure and reaches a maximum at 3.6 GPa. The subsequent drop in TEP is associated with the f.c.c. \rightarrow b.c.c. transition. In the b.c.c. phase TEP decreases

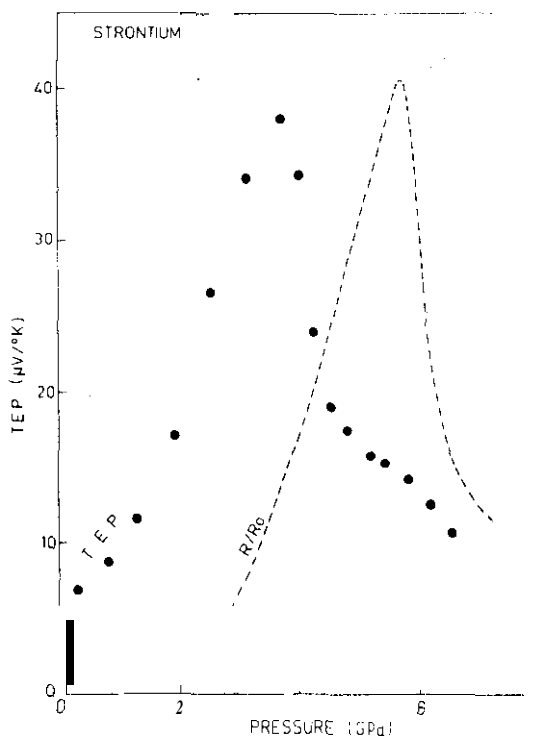


Fig. 1. Thermoelectric power and resistivity of strontium as a function of pressure. For clarity, pressure scale for resistivity is shifted to the right by 2 GPa.

smoothly. For a ready reference the electrical resistivity measured on the same batch of specimens is also plotted as a function of pressure.

A simple consideration shows that a crystal composed of divalent atoms is insulating at large interatomic distances with filled s-band and empty p-band [10]. With a decrease in interatomic distance such a crystal can become a metal or a semiconductor. A detailed band structure calculation for f.c.c. calcium differs from the simple model in that there exists a line of degeneracy between the first and the second band [11]. This model predicts that a divalent f.c.c. metal will become under pressure a semi-metal but not a semiconductor. However, if the spin–orbit coupling is strong it can remove the band degeneracy. The Fermi

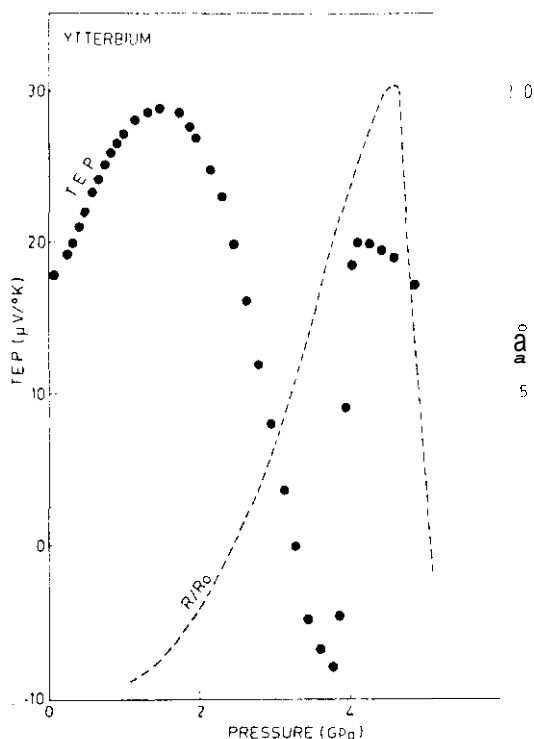


Fig. 2. Thermoelectric power and resistivity of ytterbium as a function of pressure. For clarity, pressure scale for resistivity is shifted to the right by 1 GPa.

surface in such a case can shrink to zero under pressure and a semiconducting state can result. The resistivity data under pressure suggest that Sr remains a semimetal up to 3.6 GPa before undergoing f.c.c.—b.c.c. transition [1, 12]. On the other hand Yb, a semimetal, becomes semiconductor near 1.3 GPa remains a semiconductor before undergoing f.c.c.—b.c.c. transition at 4.0 GPa. This difference in the behaviour is expected because of large spin—orbit coupling in Yb.

The TEP and the resistivity of Yb are plotted in Fig. 2 as a function of pressure. It is seen that for both

Sr and Yb, TEP is large positive at one atmosphere. The sign of TEP agrees in both cases with the sign of the Hall co-efficient [13]. The positive sign of the Hall coefficient has been interpreted in the frame work of two band model as arising from the fact that the mobility of the holes is larger than that of the electron [8]. In the initial stages, where both Yb and Sr are semimetals, the TEP increases with pressure because of a gradual removal of band overlap. In the case of Sr the increase in TEP with an increase in pressure continues until the f.c.c.—b.c.c. transformation pressure is reached. This is expected as Sr remains a semimetal up to the f.c.f.—b.c.c. transformation pressure. In the semiconducting region TEP of Yb decreases with the increase in pressure.

REFERENCES

1. P.C. Souers & G. Jura, *Science* **140**, 481 (1963).
2. A. Jayaraman, W. Klement Jr. & G.C. Kennedy, *Phys. Rev.* **132**, 1620 (1963).
3. A. Jayaraman, *Phys. Rev.* **135**, A1065 (1964).
4. D.R. Stephens, *J. Phys. Chem. Solids* **26**, 943 (1965).
5. P.W. Bridgman. Collected *Experimental Papers*, Harvard Univ. Press, Cambridge, Mass. (1964).
6. D.B. McWhan & A. Jayaraman, *Appl. Phys. Lett.* **3**, 129, (1963).
7. H.T. Hall, J.D. Barnett & L. Merrill, *Science* **139**, 111 (1963).
8. T.G. Ramesh, V. Shubha & S. Ramaseshan, *J. Phys. F: Metal Phys.* **7**, 981 (1977).
9. A.K. Singh & Geetha Ramani, *Rev. Sci. Instrum.* **49**, 1324 (1978).
10. N.F. Mott & H. Jones, *Theory of the Properties of Metals and Alloys*. Oxford University Press, New York (1936).
11. B. Basavari, A.O.E. Animalu & V. Heine, *Phys. Rev.* **154**, 535 (1967).
12. D.B. McWhan, T.M. Rice & P.H. Schmidt, *Phys. Rev.* **177**, 1063 (1969).
13. W.B. Halzapfel & D. Severin, *Phys. Lett.* **34A**, 371 (1971).