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Transport properties of $CoS_{2-x}As_x$ ($0 \leqslant x \leqslant 1$)

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Abstract

Electrical resistivity and Hall coefficient were measured for sintered samples of $CoS_{2-x}As_x$ ($0 \leqslant x \leqslant 1$) at temperatures from 77 to 600 K. The results of measurements show that with increasing x the change from metallic conduction to semiconduction is observed just above $x = 0.6$. This concentration corresponds to the concentration of disappearing the ferromagnetism.

Keywords: $CoS_{2-x}As_x$; Electrical resistivity; Hall coefficient

1. Introduction

CoS_2 with the cubic crystal structure of pyrite type is a typical itinerant ferromagnet with the Curie temperature of 120 K and magnetic moment of $0.89\mu_B$ per Co atom [1]. The magnetic property of CoS_2 is strongly affected by the cation- and anion-substitution. Mikkelsen and Wold reported that in the anion-substituted system $CoS_{2-x}As_x$, the ferromagnetic moment and the Curie temperature decrease with increase in x [2]. We have measured the magnetization at 4.2 K for $CoS_{2-x}As_x$ with $0 \leqslant x \leqslant 1$ and found that the ferromagnetism disappears for the compounds with $x \geqslant 0.6$ [3]. In this paper, the transport properties of $CoS_{2-x}As_x$ are studied in order to make clear an origin of the disappearance of ferromagnetism.

2. Experimental

Polycrystalline samples of $CoS_{2-x}As_x$ ($0 \leqslant x \leqslant 1$) first were prepared by reacting high purity elements with desired proportion at 800°C in a vacuum silica tube for a week. Reaction products were then pulverized and heated at 800°C for two weeks. The results of powder X-ray diffraction measurements showed that all the diffraction lines for prepared samples were indexed with the cubic pyrite-type structure. CoAsS exhibits the cobaltite structure which is the pyrite one with ordering of As and S atoms. The superstructure lines due to the ordering of As and S atoms appear for the compounds with $x \geqslant 0.6$. Lattice parameter of $CoS_{2-x}As_x$ ($0 \leqslant x \leqslant 1$) increase linearly with x from 5.533 Å for CoS_2 to 5.575 Å for CoAsS. The positional parameter u decreases nonlinearly from 0.390 for CoS_2 to 0.380 for CoAsS. The Co–S(As) distance has the minimum near $x = 0.6$, because $a = 5.5570$ Å and $u = 0.383$ in $x = 0.6$. The electrical resistivity and Hall coefficient were measured with conventional methods for sintered samples of $CoS_{2-x}As_x$ ($0 \leqslant x \leqslant 1$) at temperatures from 77 to 600 K.

3. Results and discussion

Figs. 1 and 2 show the temperature dependences of the resistivity ρ. As seen in Fig. 1, for the

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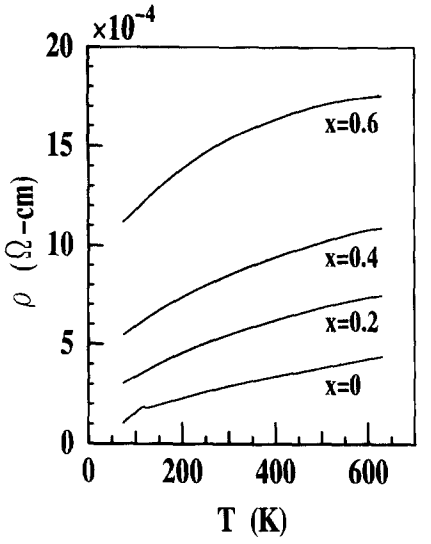

Fig. 1. ρ–T curves for $CoS_{2-x}As_x$ ($0 \leqslant x \leqslant 0.6$).

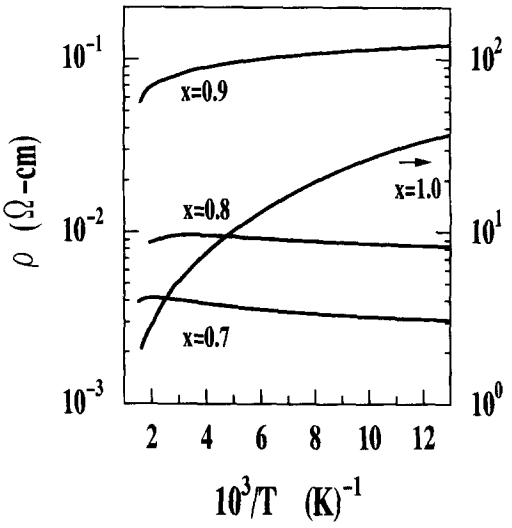

Fig. 2. Log ρ–$1/T$ curves for $CoS_{2-x}As_x$ ($0.7 \leqslant x \leqslant 1$).

compound with $x \leqslant 0.6$, ρ shows metallic temperature dependence of $d\rho/dT > 0$. As seen in Fig. 2, $\log\rho$–$1/T$ curves for $x = 0.7$ and $x = 0.8$ exhibit a degenerated semiconductive behavior at low temperatures and an intrinsic semiconductive one at high temperatures. For the compounds with $x = 0.9$ and $x = 1.0$, the temperature dependence of ρ is typically semiconductive. The energy gaps determined from the slope of $\log \rho$–$1/T$ curves in the high-temperature range are 0.04, 0.02, 0.17 and 0.18 eV for $x = 0.7$, 0.8, 0.9 and 1.0, respectively. The sign of the Hall coefficients R_H for all samples are negative in the whole temperature range investigated. The values of R_H around 450 K are almost constant for $x < 0.6$ with the value of $\sim 1.5 \times 10^{-4}$ cm^3/C and then increases abruptly from 3.3×10^{-4} cm^3/C ($x = 0.6$) to 50×10^{-4} cm^3/C ($x = 0.9$) with further increase of x.

As mentioned above, E_G increases with x for $x \geqslant 0.7$. The rapid increase of R_H and ρ with x may be understood on the basis of the increase of E_G with x. This increase of E_G is considered to be due to the increase of Co–S(As) distance and the formation of the ordered arrangement of As and S with increase of x. It is noted that this critical value of x corresponds to the concentration where the ferromagnetism disappears in $CoS_{2-x}As_x$. It is of interest to examine the details of magnetic properties of $CoS_{2-x}As_x$ in the semiconductive state.

References

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