Electrical properties of a quasi-one-dimensional Nb_3Te_4 inserted with indium

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Abstract

Indium inserted effect to electrical properties of Nb_3Te_4 has been studied in the temperature range from 0.5 to 250 K. With addition of In, the resistivity remains largely unchanged, but shows resistivity anomaly at $T_R > 100$ K, around 84 K and near 49 K depending upon to In concentration. The superconducting transition temperature is enhanced from 1.8 to 3.3 K by addition of In and the coherence length ξ parallel to the c axis increases sharply at $x = 0.2$, but ξ perpendicular to the c axis is insensitive to In concentration.

Key words: Quasi-one-dimensional matter; CDW; coherence lengths

1. Introduction

The electrical properties of transition metal chalcogenides with low dimensional structures are markedly influenced by intercalation. Such effects are mainly caused by a charge transfer and an increase in the lattice constants. The lattice constants in layered compounds remarkably increase by intercalation. However Nb_3Te_4 has negligible influence on the lattice constants as compared with layered compounds. Then the compound is suitable to study the effect of intercalation on the electrical properties of host material without changing its energy band structure. The crystal structure of Nb_3Te_4 is a hexagonal crystal system. The unit cell contains six Nb atoms and eight chalcogens. Nb is surrounded by six chalcogens and constructs zigzag Nb chains along the c axis. Electrical properties of $In_xNb_3Te_4$ have been measured using powder samples [1]. However detailed electrical properties on single crystals have not been studied yet. The present measurements are the first in detail on single crystals. We report the electrical resistivity and the superconducting properties on single crystal $In_xNb_3Te_4$.

2. Experimental procedure

Single crystals of Nb_3Te_4 were prepared by an iodine-vapor-transport method [2,3]. For In insertion, In and single crystals of Nb_3Te_4 were sealed in an evacuated quart tube and the tube was kept at about 750 °C for 10 days. The In concentration was determined by an electron prove microanalyser (EPMA). The electrical resistivity was measured using a dc four contacts method in the temperature range from 0.5 to 250 K. The upper critical fields parallel and perpendicular to the c axis have been measured near T_C.

3. Results and discussion

Figure 1 shows the typical resistivities, normalized to the value at 250 K along the c axis. $In_xNb_3Te_4$ shows three resistivity anomalies at $T_R > 100$ K, 84 K and 49 K. The characteristic of these anomalies is as follows: (i) The anomaly at $T_R > 100$ K appears at $x < 0.06$ and $x > 0.08$. The T_R at $x < 0.06$ is $113 \sim 121$ K, being insensitive to x and agrees well

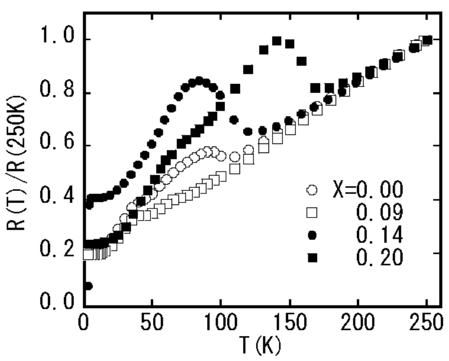

Fig. 1. Temperature dependence of the normalized resistivity of $In_xNb_3Te_4$.

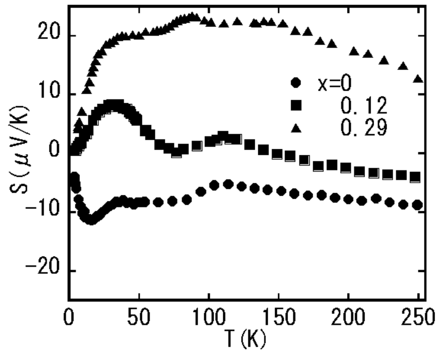

Fig. 2. Temperature dependence of the thermoelectric power S of $In_xNb_3Te_4$ for typical concentration.

with charge-density-wave (CDW) formation temperature, $T_{\rm CDW}$ of Nb_3Te_4. At $x > 0.08$, a giant increase in resistivity appears and $T_{\rm R}$ changes continuously from $T_{\rm CDW}$ of pure Nb_3Te_4 to that of highly inserted Nb_3Te_4. (ii) The anomaly at 84 K appears at $x \geq 0.2$ and $T_{\rm R}$ is insensitive to x. (iii) The anomaly at 49 K appears at $x < 0.13$ and $T_{\rm R}$ is insensitive to x.

Figure 2 shows the thermoelectric power S for $x = 0$, 0.12 and 0.29. As the temperature decreases, S for $x = 0$ increases and below 115 K, it falls down rapidly to a shallow minimum at about 75 K. Below 75 K, S increases slowly with decreasing temperature and reaches a peak near 38 K, followed by a shallow minimum at 20 K and finally S decreases toward zero. The S for $x = 0.12$ increases monotonically with decreasing temperature, changing a sign at 149 K from negative to positive and reaches a positive maximum at 114 K. Below 114 K, S decreases toward a minimum at 76 K, and then it rises rapidly to a sharp maximum at 31 K. The S for $x = 0.29$ increases with decreasing temperature, but it takes two maximum at 148 K and 37 K and a minimum at 95 K. Below 37 K, S decreases toward to zero. The sign of S is positive over the entire temperature range. The result indicates that the conduction band of Nb_3Te_4 consists of electron-like and hole-like carriers.

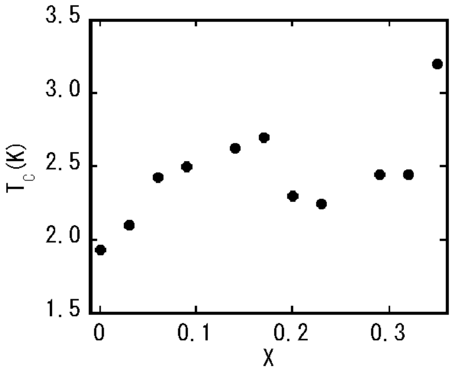

Fig. 3. Concentration dependence of $T_{\rm C}$. The $T_{\rm C}$ is defined as the midpoint of a resistivity-transition curve.

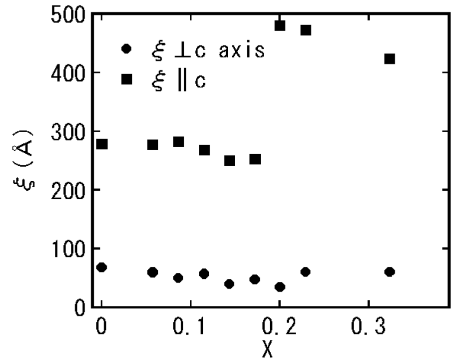

Fig. 4. Indium concentration dependence of the coherence length ξ.

Figure 3 shows the In concentration dependence of $T_{\rm C}$. The $T_{\rm C}$ increases gradually with increasing In concentration. Figure 4 shows the In concentration dependence of the coherence length ξ parallel ($\xi_{\parallel}$) and perpendicular ($\xi_{\perp}$) to the c axis. The $\xi_{\perp}$ is insensitive to In concentration, but $\xi_{\parallel}$ increases abruptly at $x = 0.2$ and turns to decrease slightly thereafter.

On the basis of the multiband model the anomalous transport property of $In_xNb_3Te_4$ can be explained in terms of CDW formation. The x dependence of ξ may be explained on the basis of the multiband model.

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