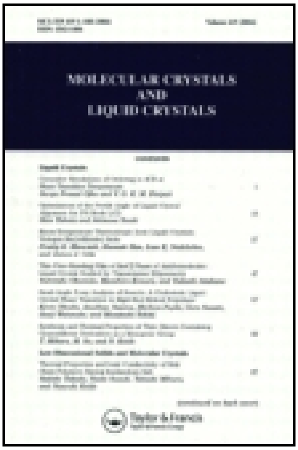

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Superconducting Properties in Metallic Phase of NbS_3

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SUPERCONDUCTING PROPERTIES IN METALLIC PHASE OF NbS_3

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Abstract Metallic phase of NbS_3 was synthesized by heating the crystal of semiconducting NbS_3. Metallic NbS_3 undergoes superconducting transition around 2 K. The analysis of the angular dependence of the upper critical magnetic field suggests that the effect of filmy or fibrous morphology plays an important role in the superconducting properties.

INTRODUCTION

Niobium trisulfide has been known as a Peierls semiconductor.[1] Recently several kinds of polytypes have been discovered.[2] However, correlation between the electrical property and the crystal structure has never been well established for each crystal. We have reported electrical properties on semiconducting NbS_3 and the existence of the superconductivity in the newly synthesized metallic one.[3] In this paper we shall report the new result on the superconductivity and some related properties of the metallic phase of NbS_3.

SYNTHESIS AND CHARACTERIZATION OF CRYSTAL

Metallic crystal is obtained by heating the semiconducting NbS_3.[3] The semiconducting crystals were placed in the silica ampoule. It was evacuated and sealed. Then crystals were heated above 600°C. A semiconducting crystal was denaturalized to a metallic one. A little amount of sulfur which evaporated from host crystals was found out. The shape and dimension of the metallic crystals were as they had been before heating. Scanning-electron-microscope (SEM) photograph has shown that the surface is clean in contrast with that of semiconducting crystal. Any other related compound such as NbS_2 was not found by the SEM photograph. Chemical analysis for Nb showed that the composition of the crystal is $NbS_{2.5-3.4}$. X-ray oscillation photograph and preliminary work on Weissenberg photograph indicated that the values of the lattice constants remain almost the same as those of type-I material.[1] However, we note that the length of the b axis of the samples heated at 680°C (T_c=2.15 K), is the half of that of type-I crystal (i.e., no distortion of Nb atom along the b axis). In this work we shall focus on the properties of the samples heated at 620°C. Dc electrical resistivity at 280 K was 10^{-2} to 10^{-3} ohm-cm. Hall voltage was measured up to 14.5 kG for three samples. The observed Hall voltage was proportional to the magnetic field within our experimental accuracy. The typical Hall coefficient was 1.1×10^{-7} m^3C^{-1}. The sign of the Hall coefficient was not determined. We estimated the carrier density under the assumption that only one type of carrier contributes to the conduction. The result for a typical sample was 5.7×10^{19} cm^{-3}.

SUPERCONDUCTING PROPERTIES

Figure 1 shows the typical behavior of the normal-to-superconducting resistive transition as a function of temperature. The transition temperature (T_c) was 1.65 K. Some of the samples clearly showed zero resistance within our instrumental accuracy. Magnetic field dependence of the resistive-transition curve (Fig. 7 of ref. 3) at several temperatures and large critical magnetic field suggest that the material is a type-II superconductor. Since high-current density affects the measurement of T_c and the upper-critical magnetic field (H_{c2}), the low-current density (0.3 to 2.2 A/cm^2, which was much smaller than the typical critical current density 100 A/cm^2) was used. Current flow was along the b axis. Figure 2 shows the angular dependence of the H_{c2} in the limited configuration at 1.16 K. To analyze the result we fitted the experimental data to two theoretical models. Broken and solid curves correspond to the results of the best fitting by the effective mass model[4] and the model of Harper and Tinkham,[5] respectively. In the latter model the anisotropy is due to sample-size limitations when the thickness of the sample is much less than the isotropic coherence length. Fairly good agreement was obtained with the latter model. The result suggests that the filmy or fibrous morphology plays an important role in the superconducting properties. Precise measurement of the angular dependence of the H_{c2} is now in progress to clarify the superconducting properties.

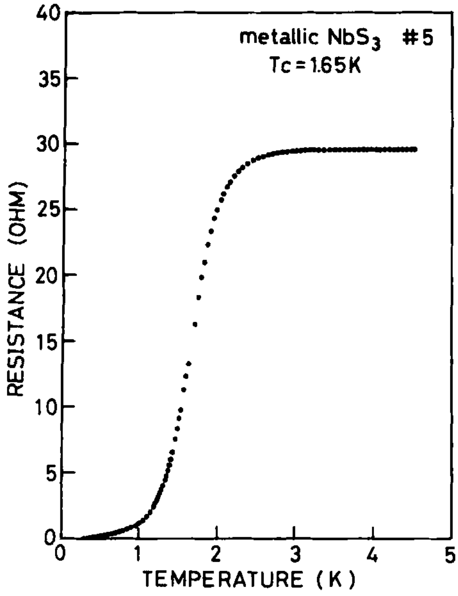

FIGURE 1 Dc-resistive-transition curve in metallic NbS_3 obtained by heating semiconducting NbS_3 at 620°C. Transition temperature T_c was 1.65 K. We define T_c as the temperature at the midpoint in the resistive-transition curve.

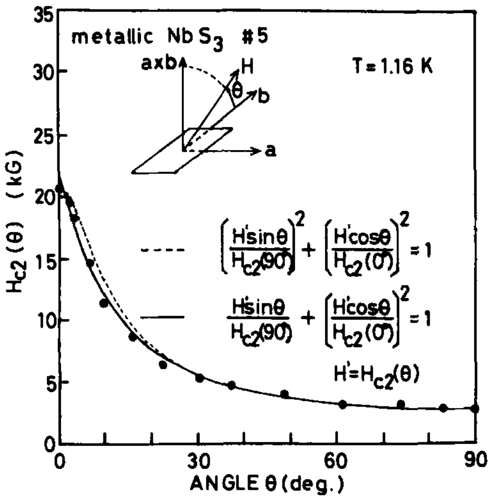

FIGURE 2 Angular dependence of the upper critical magnetic field $H_{c2}(\theta)$ at 1.16 K. The angle between the b axis and the direction of magnetic field is denoted as θ. The broken curve represents the theory based on the anisotropy of Fermi surface (ref. 5). The solid curve represents the theory of thin film with isotropic Fermi surface (ref. 6). We take $H_{c2}(\theta)$ as the magnetic field at the midpoint in the resistive-transition curve.

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