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Single-crystal growth and superconducting state of $LaO_{0.5}F_{0.5}Bi(S_{0.8}Se_{0.2})_2$

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Abstract

Single crystals of $LaO_{0.5}F_{0.5}Bi(S_{0.8}Se_{0.2})_2$ were grown by a CsCl-flux method. Electrical resistivity $\rho(T)$ measurements were performed to reveal its superconducting properties. The $\rho(T)$ of the single crystal shows semiconducting-like behavior and superconducting transition at 3.4 K. The value is slightly higher than that of the polycrystalline sample with substitution amounts of x = 0.2 (T_c ~ 2.5 K). From $\rho(T)$ measurements in several magnetic fields, $\mu_0H_{c2}^{//ab}(0)$ and $\mu_0H_{c2}^{//c}(0)$ are estimated to be 17.2 T and 0.59 T, respectively. The superconducting anisotropic parameter γ is determined to be 29.2.

Keywords: superconducto; BiS_2-based compound

1. Introduction

Since the discovery of superconductivity with superconducting transition temperatuure T_c at 8.6 K in the layered bismuth oxysulfide $Bi_4O_4S_3$ [1], other BiS_2-based superconductivity have been studied. $LaOBiS_2$ crystallizes with a space group $P4/nmm$ (No. 129) and this structure is composed of alternating superconducting BiS_2 layers and blocking LaO layers, which are similar to Fe-based superconductors. Substituting F for O induces superconductivity with T_c = 2.5 K [2], as well as tetravalent elements (Ti, Zr, Hf and Th) for La [3]. In addition, by replacing S atoms

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to Se atoms, T_c is enhanced: T_c = 4.2 K for $LaO_{0.5}F_{0.5}BiSSe$ [4], 3.7 K for $LaO_{0.5}F_{0.5}BiSe_2$ [5]. The enhancement of T_c in Se doped compounds is induced by an in-plane chemical pressure [6].

In this article, we report the single crystal growth of $LaO_{0.5}F_{0.5}Bi(S_{0.8}Se_{0.2})_2$ and its superconducting properties. In order to clarify superconducting state, we measured the electrical transport properties of $LaO_{0.5}F_{0.5}Bi(S_{0.8}Se_{0.2})_2$ at low temperature and strong magnetic fields up to 11 T.

2. Experimental Details

Single crystals of $LaO_{0.5}F_{0.5}Bi(S_{0.8}Se_{0.2})_2$ were grown by a CsCl-flux method similar to the previous reports [5,6]. The starting materials of 0.8 g and CsCl of 5 g were mixed and sealed in an evacuated quartz tube. The tube was heated up to 880 °C in 10 h and to 900 °C in 2 h, then kept for 10 h and cooled down to 650 °C for 125 h. The obtained materials were washed by water, ethanol, and acetone in order to remove the flux materials. The obtained single crystals were plate-like shape with approximately 1.0 × 1.0 mm^2. The crystal structure of the single crystal was examined by an X-ray diffraction (XRD) method using a conventional X-ray spectrometer equipped with Cu-Kα radiation and a monochromator (RAD-2X, Rigaku). Electrical resistivity $\rho(T)$ from 0.5 K to 300 K was measured under magnetic fields up to 11 T along the *ab*-plane and *c*-plane by dc-four-probe method in a ^{3}He cryostat (Oxford Heliox VL).

3. Experimental Result

3.1. X-ray diffraction

Figure 1 shows the XRD diffraction pattern of several single crystals $LaO_{0.5}F_{0.5}Bi(S_{0.8}Se_{0.2})_2$ at room temperature. Only (00*l*) diffraction peaks were observed, indicating the crystallographic *c*-axis is perpendicular to the crystal plane. All the reflections can be indexed as the space group of *P*4/nmm and no extra peaks due to impurity phase can be detected from the XRD pattern. To estimate lattice constants, powder X-ray diffraction was performed by using powder crashed from single crystals. The lattice constants of $LaO_{0.5}F_{0.5}Bi(S_{0.8}Se_{0.2})_2$ are obtained to be *a* = 4.0856 Å and *c* = 13.453 Å. These values are slightly larger than those of the single crystal $LaO_{0.5}F_{0.5}BiS_2$, which suggest that S atoms are substituted with Se atoms.

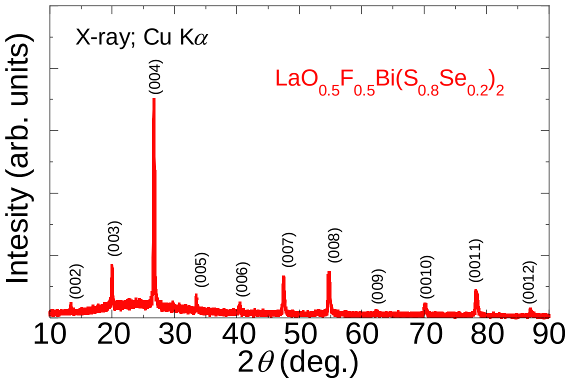

Fig. 1. XRD diffraction pattern of single crystals $LaO_{0.5}F_{0.5}Bi(S_{0.8}Se_{0.2})_2$ at room temperature.

3-2. Electrical resistivity

Figure 2 shows temperature dependence of the electrical resistivity $\rho(T)$ of $LaO_{0.5}F_{0.5}Bi(S_{0.8}Se_{0.2})_2$ down to 0.5 K with electrical current along the *ab*-plane. A semiconducting-like behavior was observed and superconducting transition was detected. T_c is defined as 50 % drop from residual resistivity ρ_0 and determined to be 3.4 K. ρ_0 is defined at just above T_c (ρ_0 = 3.5 mΩcm). Compared with polycrystalline sample of $LaO_{0.5}F_{0.5}Bi(S_{0.8}Se_{0.2})_2$ [7],