Upper Critical Fields of Single-Crystalline and Polycrystalline Ca–Sr–Bi–Cu–O Compounds

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Abstract. The ac resistivity of a “110 K phase” multiphase polycrystalline Ca–Sr–Bi–Cu–O compound and an “85 K phase” single-crystalline Ca₀.⁹Sr₁.¹Bi₂.¹Cu₂.o₀₈₊₈ has been measured in various magnetic fields up to 8 T. Values for Bₑ(0) of 71.5 T and for Bₑ²(0) of 542 T are found for the “85 K phase” sample. A value for Bₑ²(0) of 57.9 T is estimated for the “110 K phase” compound.

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The discovery of high-ₜₜ superconductivity around 110 K in the multiphase Ca–Sr–Bi–Cu–O system by Maeda et al. [1] initiated another direction of research in the oxide superconductors. Until now, it has been known that there are two major phases with superconducting properties above liquid nitrogen temperature in this system. One transition temperature is around 110 K (“110 K phase”), another is around 85 K (“85 K phase”), and there are also some phases with transition temperatures in between [2–7]. The anisotropy and upper critical field of the “85 K phase” single crystal have been reported before [8–10]. The behaviour of the “110 K phase” in a magnetic field has also been announced [11, 12]. In this letter, we present resistivity measurements on a “110 K phase” multiphase polycrystalline sample as well as on an “85 K phase” single-crystalline sample in various magnetic fields up to 8 T.

The “110 K phase” sample (sample A) was prepared by a solid state reaction method. The starting materials (CaCO₃, SrCO₃, Bi₂O₃, and CuO) were well mixed in the ratio Ca : Sr : Bi : Cu equal to 1 : 1 : 1 : 2, pressed into pellets and heated at 870 °C for 20 h. Milling, pressing and heating were repeated twice. Finally, the sample was heated at 880 °C for 10 h, then slowly cooled down to room temperature: The growth of the “85 K phase” single-crystalline sample (sample B) was described in [6] and the composition is Ca₀.⁹Sr₁.¹Bi₂.¹Cu₂.o₀₈₊₈ [6]. The ac susceptibility of both samples is shown in Fig. 1. It is clear that the onset temperature of sample A

is about 110 K and that some other phases exist in this sample with the superconducting transition around 80 K. This seems to be a common property of the “110 K phase” due to the intergrowth of additional Cu–O layers [5]. On the other hand, sample B shows one single superconducting transition at about 85 K.

The dimensions of the single-crystalline sample B were approximately 1.4 × 1.0 × 0.15 mm³. The pellet of sample A was cut into a piece with dimensions 2.7 × 0.70 × 0.65 mm³. Four point contacts were made by using silver paste and annealing at 500 °C for half an
hour to improve the contacts. The contact resistance was about 0.7 \, \Omega \, \text{for sample} \, A \text{ and about } 5 \, \Omega \, \text{for sample} \, B. \text{ After finishing the measurements, the contact resistance turned out to be increased by less than } 20\%.

The ac resistivity was measured using a superconducting magnet at various fields up to 8T. The excitation current was 0.1 mA with a frequency of 90 Hz. In sample B the direction of the current was always perpendicular to the field direction. The resistivity was measured with the field both parallel and perpendicular to the c-axis, see Figs. 2 and 3. For sample A, the resistivity was measured with the current perpendicular to the field (Fig. 4). The resistivity of sample A with the current parallel to the field was also checked. We could not find any difference for the current direction parallel and perpendicular to the field. It can be noted in Figs.2–4 that the onset temperature is not very much affected by the magnetic field, but in the tail region the effect of the field is very large. This behaviour is also found in [8–12] and may be an intrinsic property of high-\( T_c \) materials.

Because the superconducting transition in a magnetic field is so broad for this compound, it is difficult to determine exactly the field-induced shift of \( T_c \). We extrapolate the normal state resistivity from the region well above \( T_c \) and defined \( T_c \) by the midpoint resistivity \( 0.5 \rho_N(T) \). The temperature dependence of the upper critical field \( B_c^2(T) \) deduced with this definition of \( T_c \) is shown in Figs. 5 and 6 for both phases. The zero-temperature upper critical field \( B_c^2(0) \) is estimated by the Werthamer-Helfand-Hohenberg theory [13] (Table 1).

For the multiphase sample A, the resistivity in zero field reaches zero completely at 95 K. The zero resistivity has been checked by resistivity measurements. Our value for \( B_c^2(0) \) is almost the same as that of Maeda et al. [11] if we use the same definition of \( T_c \). The resistivity curve in a field is very broad in sample A. This large broadening could be caused not only by the intergrowth of additional Cu–O layers but also by the presence of other (not superconducting) phases as found in the Y–Ba–Cu–O compounds [14].