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Synthesis of high quality infinite-layer superconducting compound of $Sr_{0.9}Sm_{0.1}CuO_2$ and its pinning properties

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Abstract

We report high pressure synthesis of $Sr_{0.9}Sm_{0.1}CuO_2$. Powder x-ray diffraction showed that the synthesized compounds have infinite layer structure as a major component. Slow heating at the first stage of heating processes after pressurization resulted in several larger grains. The largest grain was found to have the longest edge length of about 100 micrometer. Through magnetic property measurement in superconducting state, we found that pinning in this compound has substantial difference from that of La doped infinite layer, which has no unpaired spin at Sr site.

Keywords: Pinning, Critical current density, Vortex , infinite layer

I. Introduction

The "infinite-layer"(IL) structure is the simplest one which contains "CuO_2" layers sandwiched by alkaline-earth metal cation(A)"[1], [5]". Hole-doped"[1],[2]" and electron-doped"[3], [4], [6]-[8]" IL superconductors have the same tetragonal with space group *P*4/mmm structure. Ikeda *et. al.* Showed that for the n-type IL superconductors the saturation in the lattice parameters took place around 10% doping but there is no change in T_c (~ 43 K) with doping rate and other lanthanide.[4] So, we synthesized 10 % doping compounds. Jung *et. al.* synthesized $Sr_{0.9}La_{0.1}CuO_2$(La112) successfully with the highest superconducting volume fraction and quality and explored various superconducting properties.[8]

Recently, we also fabricated $Sr_{0.9}Sm_{0.1}CuO_2$(Sm112) compound, one of the n-type IL superconductors, with high shielding fraction. We compared the properties at Sm doped IL with La doped IL to see the effect of magnetic moment at Sr site. In this paper, we report the synthesis of IL Sm112 compound and study its pinning properties.

First, we measured low filed magnetization, *M(T)*, for seeing its superconducting volume fraction, critical temperature, and sharpness of superconducting transition. Then, we also measured high filed hysteresis curve to observe pinning properties.

II. Experiments

High-pressure and high-temperature synthesis was done with a 12 mm cubic-multi-anvil type press. Precursors were prepared by conventional solid-state reaction with two steps. For synthesizing target material Sm112 compound, first we made two precursors, Sm_2CuO_4 and $SrCuO_2$, respectively and mixed two components with the mechanical method. In case of $SrCuO_2$, a powder mixture of $SrCO_3$ and CuO was calcined at 850 ¢ J for 12 hours in air and O_2 gas with several intermittent grindings. After these calcination the last sintering was performed at

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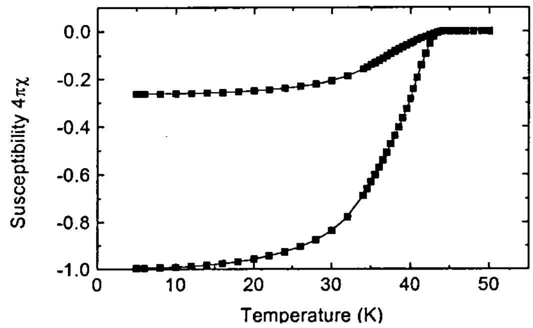

Fig. 1 Low field susceptibility taken at 10 Oe
Our sample shows much larger shielding volume fraction and far sharper transition than the results

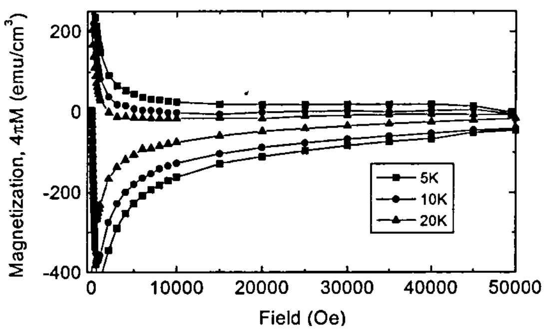

Fig. 2 Magnetic hysteresis curve taken at 5, 10, and 20 K. Compared with La doped one the width between increasing and decreasing branch is narrower and the two branch is highly asymmetric with respect to 0 value.[8] The latter means bulk pinning is much smaller than the pinning due to surface barrier.

950 ¢ J for 12 hours. As for Sm_2CuO_4, we paid attention to handle Sm powder because it absorbs CO_2 and moisture in the ambient air. Starting materials of Sm_2O_3 and CuO were calcined at 950 ¢ J to 1050 ¢ J for 12 hours with several intergrindings.

Every process was manifested by the Cu K x-ray diffractometer(XRD). Pelletized precursor and Ti getter were wrapped by a Au capsule of the pressure cell. With careful treatment, we pressurized slowly the pressure cell up to 5 Gpa then by using a graphite-sleeve heater we maintained the temperature of about 1050 ¢ J for one and a half hour. As the last step, we quenched the precursor to room temperature. The amount of the sample synthesized per one batch is about 210 mg. Our sample was characterized by powder x-ray diffractometer(RIGAKU) with Cu K source. For probing superconducting magnetic properties, we measured low zero field cool(ZFC) and field cool(FC) magnetization $M(T)$, 5 K to 30 K, and high field magnetization $M(H)$, 10 Oe to 50000 Oe, with SQUID magnetometer(QUANTUM DESIGN, MPMS*XL*).

III. Results and discussion

We have tried to improve the quality of the IL samples under careful control of temperature and pressure. Eventually, we found nearly optimal condition for the synthesis of the IL samples in our high-press furnace which controls power across the sleeve heater for obtaining a stable synthesis temperature. The key-point was the stabilization of temperature. we obtained the target temperature by very slow heating after pressurization.

The 10 Oe susceptibility data taken at one of the best samples is shown in Fig. 1. Here, we can calulate the nominial superconducting volume fraction and sharpness of transition. Clearly seen in the picture is that diamagnetic shielding fraction reaches nearly 100 % without consideration of demagnetizing factor and and the superconductign transition is rather sharp with high T_{mid} of 38.5 K, Where T_{mid} was defined as the temperature where magnetization value is one half of that at lowest saturated value at $T \ll T_c$. This definition is reasonable due to granular growth by high pressure synthesis method.

To know the intragranular current density, we measured magnetic hysteresis curve at several temperatures below T_c. At higher field region, the values of ΔM of Sm112 compound are about one order of magnitude smaller than that of La112. This means that the pinning of the Sm-112 sample is weaker than that of La112. Moreover the magnetization value at decreasing field branch is

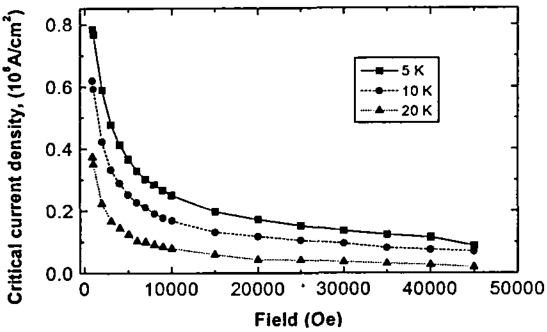

Fig. 3 Intragranular critical current density.
Intragranular critical current density was calculated from the magnetic hysteresis curve using Eq (1).

nearly zero. This means surface barrier is dominant over bulk pinning, which is opposite to the behavior of La112. This supports more evidence that the bulk pinning in Sm112 is really smaller than that of La112.

From the magnetic hysteresis curve, we calculated intragranular critical current density J_c as follows.[10]

$$J_c \cong 16.976\left|\frac{M_+ - M_-}{R}\right| \qquad (1)$$

where 16.976 is the conventional numerical factor, $M_+(M_-)$ in unit of gauss(emu/cm^2) is taken at an increasing(decreasing) field branch R is the average radius of the superconducting grain . W assumed that grains are spherical and the R as a average value is about 5 m.

The critical current density at 5 K at 4 T for Sm112 is calcualted to be $J_c \approx 0.2\times10^6$ A/cm^2, while that of La112 is about 1.4×10^6 A/cm^2. The suppression of pinning property in Sm112 with respect to La112 would be larger if we consider surface barrier effect mentioned above. Studies on this suppresson is under going.

Conclusion

We fabricated $Sr_{0.9}Sm_{0.1}CuO_2$ infinite layer compound with high superconducting shielding fraction and sharp transition. Low field magnetization study showed that our sample has best quality than thoese reported until now. This Sm doped compound seems to have weaker pinning than La doped analogue. Magnetic origin due to unpaired spin should be studied further.

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