Zeitschrift: Helvetica Physica Acta

Band: 65 (1992)

Heft: 2-3

Artikel: Temperature dependence of critical current and activation energy due to layered structure in oxide superconductors

Autor: Fukami, R. / Yamamoto, T. / Nishizaki, T.

DOI: https://doi.org/10.5169/seals-116455

Temperature Dependence of Critical Current and Activation Energy Due to Layered Structure in Oxide Superconductors

T. Fukami*, T. Yamamoto**, T. Nishizaki**, Y. Horie**, F. Ichikawa**,
V. Soares, T. Aomine** and L. Rinderer
Institut de Physique Expérimentale, Université de Lausanne, CH-1015 Lausanne, Switzerland
*On leave from Department of Physics, Kyushu University, Fukuoka 812, Japan
**Department of Physics, Kyushu University, Fukuoka 812, Japan

Abstract: To investigate the pinning property of flux lines in two dimensional layered structure of oxide superconductors, temperature T and θ (an angle between magnetic fields vector $\boldsymbol{H}$ and the basal plane) dependences of critical current density $J_c(T,H)$ were measured for $Bi_2Sr_2CaCu_2O_8$ films. $J_c(T,H)$ vs. T and θ were calculated using the intrinsic pinning model given by Tachiki and Takahashi and the results are discussed comparing with the experimental results.

In order to explain different temperature dependences of activation energy of flux lines for different oxide superconductors, the intrinsic pinning model based on a two dimensional layered structure of oxide superconductors [1,2] has been used and could explain the temperature T dependence of activation energy for some oxide superconductors [3,4]. In the present paper, temperature and angular dependences of critical current density $J_c(T,H)$ in magnetic fields H based on the intrinsic pinning model are discussed mainly for $Bi_2Sr_2CaCu_2O_8$ (BSCC) films.

BSCC films were prepared by laser ablation technique on single crystalline MgO (100) substrates kept at room temperature. The c-axis of BSCC films was oriented preferably along the vertical direction of the surface of the substrate after a few steps of thermal treatment.

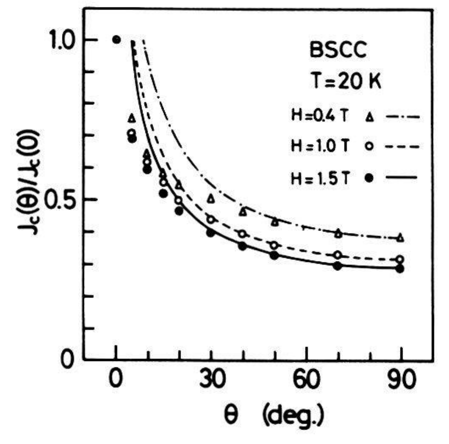

Fig.1 $J_c(\theta)/J_c(0)$ vs. θ for $\boldsymbol{H}$ applied perpendicularly to a current density $\boldsymbol{J}$ in the basal plane.

Figure 1 shows the normalized critical current density $J_c(\theta)/J_c(0)$ $(=J_c(T,H,\theta)/J_c(T,H,0))$ vs. the angle θ between $\boldsymbol{H}$ and the basal plane. The closed and open circles, and triangles are experimental values and lines are calculated ones which are described below. Figure 2 shows $J_c(T,H)$ vs. $1/T$ for BSCC in magnetic fields for $\boldsymbol{H}$ // the basal plane keeping $\boldsymbol{H}$ perpendicularly to current density $\boldsymbol{J}$.

By the way, according to the intrinsic pinning model given by Tachiki-Takahashi [2], $J_c(\theta)$ vs. θ under the condition of $\boldsymbol{J} \perp \boldsymbol{H}$ is represented by

$$J_c(\theta)/J_c(0°)=[J_c(90°)/J_c(0°)]/|\sin\theta|^{1/2}. \qquad (1)$$

The calculated results are shown by lines in Fig. 1. These data show that the angular dependence of $J_c(T,H)$ seems to obey qualitatively the intrinsic pinning model.

Furthermore we calculated $J_c(T,H)$ vs. $1/T$ using the next formula based on the intrinsic pinning model [1],

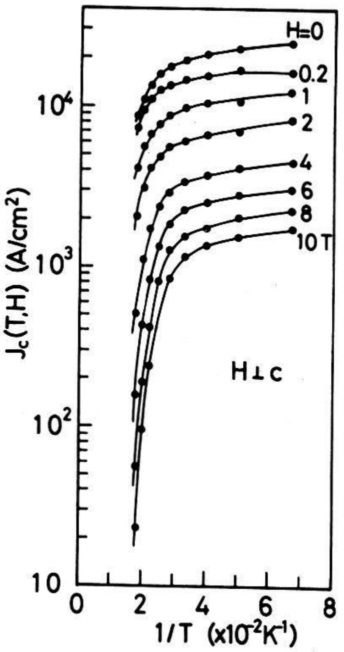

Fig. 2 $J_c(T,H)$ vs. $1/T$.

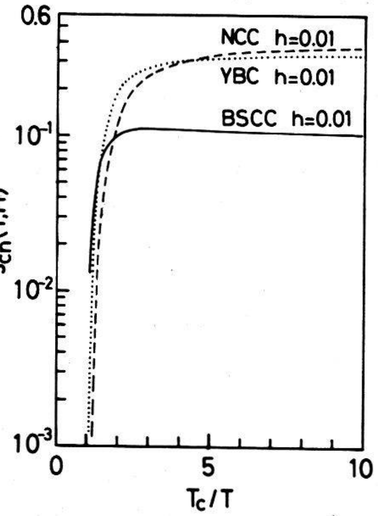

Fig. 3 $J_{cn}(T,H)$ vs. T_c/T. Here $h=H/H_{c2}(0)$.

$$J_c(T,H)=c[H_c^2(0)/(8\pi B_0 a_c)][\xi_{ab}/\xi_c]\eta_M(1-t^2)^2[1-H/H_{c2}(T)]$$
$$= c[H_c^2(0)/(8\pi B_0 a_c)][\xi_{ab}/\xi_c]\ J_{cn}(T,H), \qquad (2)$$

where c is the light velocity; $H_c(0)$ the thermodynamic critical field at T=0 K and $H_{c2}(T)=\sqrt{2}H_c(T)\kappa_1(T)$ the upper critical field [5]; B_0 is defined by $\phi_0/2\pi a_c^2$ with the unit of magnetic flux $\phi_0=hc/2e$ and an inter-distance a_c between CuO_2 planes; ξ_{ab} and ξ_c are coherence lengths parallel and perpendicular to the basal plane, respectively; $t=T/T_c$ with the critical temperature T_c. η_M is the maximum value of $\eta(z_0)$ given by Eq. (6) in [1] with respect to the position of a magnetic flux line. Since BSCC and $YBa_2Cu_3O_7$ (YBC) have two and one pairs of CuO_2 planes in a crystallographic unit cell, respectively, the original formula was changed a little and it is assumed that one pair of CuO_2 planes is located at z=0 and $z=z_1$ along the c-axis. $J_{cn}(T,H)$ vs. T_c/T in Eq. (2) was calculated for H//the basal plane using $\xi_{ab}(0)$=15 Å, $\xi_c(0)$=1.0 Å, $a_c=c/2$=15.4 Å with the lattice constant c and z_1= 3.38 Å for BSCC; $\xi_{ab}(0)$=70 Å, $\xi_c(0)$=2.3 Å and $a_c=c/2$=6.05 Å for $(Nd_{1-x}Ce_x)_2CuO_4$ (NCC); $\xi_{ab}(0)$=15 Å, $\xi_c(0)$=2.5 Å, $a_c=c$=11.7 Å and z_1= 3.25 Å for YBC. The results are shown in Fig. 3 for δ=0.6 which is a measure of spatial variation of the superconducting order parameter [1].

Characteristics of calculated results are as follows; (i) There exists a weak maximum in $J_{cn}(T,H)$ vs. T_c/T for BSCC with the smallest value of $\xi_c(0)/a_c$ (=0.08), which is different qualitatively from the others. (ii) Temperature dependence of NCC with the largest value of $\xi_c(0)/a_c$ (=0.38) is stronger than one for YBC ($\xi_c(0)/a_c$=0.21).

We have not observed the maximum for BSCC films prepared by laser ablation. In order to confirm the validity of the intrinsic pinning model in oxide superconductors, it would be necessary that the maximum of $J_c(T,H)$ vs. $1/T$ in BSCC can be observed by using improved samples in quality.

References

[1] M. Tachiki and S. Takahashi, Solid State Commun., 70 291 (1989).
[2] M. Tachiki and S. Takahashi, Solid State Commun., 72 1083 (1989).
[3] T. Fukami, V. Soares and L. Rinderer, to be published in Helv. Phys. Acta (1991).
[4] T. Fukami, K. Hayashi, T. Nishizaki, Y. Horie, F. Ichikawa, V. Soares, T. Aomine and L. Rinderer, Proc.of High Temperature Superconductor thin Films of Intern. Conf. on Advanced Materials, Strasbourg, France, 1991.
[5] A. L. Fetter and P. C. Hohenberg, *Theory of Type II Superconductors* in Chap. 14 in *Superconductivity* ed. R. D. Parks (1969), Marcel Dekker, Inc., New York.