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The critical current density J_c in high quality $YBa_2Cu_3O_{7-\delta}$ thin films

A. Ramzi[a,*], A. Taoufik[a], S. Senoussi[b], A. Tirbiyine[a], A. Abaragh[a]

[a]*Laboratoire des Matériaux Supraconducteurs à Haute Température Critique, Département de Physique, Faculté des Sciences, Université Ibn Zohr, B.P. 8106, Agadir, Morocco*
[b]*Laboratoire de Physique des Solides (associé au CNRS. URA. 0002), Université Paris Sud, Bâtiment 510, 91405 Orsay Cedex, France*

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Abstract

We have studied the critical current density J_c in high quality c-axis oriented $YBa_2Cu_3O_{7-\delta}$ thin films. To determine J_c as a function of temperature, magnetic field, we have realized the systematical measure of the J-E characteristic in large range of temperature with an increment of 0.2 K for each magnetic field value. The critical current density decreases as the temperature increases. For each magnetic field value, we observed two regimes in the critical current density $J_c(T)$ behavior. The same behavior was obtained in the $J_c(H)$ variations.

Keywords: The critical current density; Thin films; Magnetic field; Intrinsic pinning

1. Introduction

Since the discovery of high-temperature superconductors (H.T.S.Cs), a great deal of effort has been devoted to the investigation of their transport properties and the associated critical current density J_c. In conventional superconductors, the critical current density is imposed essentially by the physical and chemical defects present in

*Corresponding author. Tel.: +212 48 22 09 57; fax: +212 48 22 01 00.
E-mail address: ab_ramzi@yahoo.fr (A. Ramzi).

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the material. However, because of the layered structure of H.T.S.Cs and the associated anisotropy, the relationship between the defect structure and the critical current density is much more complicated in these systems than in conventional superconductors. It is found that in some experimental conditions, the critical current density is imposed exclusively by intrinsic pinning [1,2].

In $YBa_2Cu_3O_{7-\delta}$ films, J_c is orders of magnitude larger up (to $10^{12}\,A/m^2$) at small magnetic fields and low temperatures than in single crystals. This high J_c is generally attributed to strong pinning of vortices by extended defects. Recently Dam et al. [3] have shown, that in thin films of $YBa_2Cu_3O_{7-\delta}$ vortices are pinned by linear defects extending throughout the whole film-thickness. They have shown that dislocations are responsible for the high critical current density in $YBa_2Cu_3O_{7-\delta}$ films.

In high critical temperature superconductors, the CuO_2 layers are strong pinning centers for vortices which are aligned along these layers. The defects and precipitates cannot act strongly as the pinning centers when the applied magnetic field is adjusted with the *c*-axis. This is because the coherence length along the *c*-axis in high T_c-superconductors is very short [4–8] and thus the vortex core size is very small.

It is so very interesting from both viewpoint of fundamental research and practical application to understand the vortices pinning mechanisms of high T_c-superconductors. On the other hand from a practical point of view the problem is to find the mechanism of strong pinning of vortices and to obtain samples with higher critical current density.

2. Experimental detail

C-axis up $YBa_2Cu_3O_{7-\delta}$ thin film used for this study was deposited on (1 0 0) $SrTiO_3$ substrate by means of laser ablation. The transition temperature is 90 K in zero applied magnetic field. The film thickness and width were 400 nm and 7.53 μm, respectively. Electrodes of power measurement are in gold and deposited by in situ evaporation. The distance which separate this electrode was 135 μm. Contact resistance's were less than 1 Ω. Measurements were realized by using the DC four-probe method.

In order to rule out distortions of the *E-J* curve by extensive heating that could be induced by the very high extensive heating that could be induced by the very high dissipation levels employed here, a pulsed current power supply was used with a time duration $\tau = 10\,ms$, a waveform repeat time of 2 s and an average over 64 pulses at the same fixed J, T and H.

Transmission electron microscopy (T.E.M) observations performed on our sample revealed not only the presence of the usual twin boundaries as the major visible defect but also, a set of columnar-like defects. In addition, the sample certainly contains also point defects, in particular oxygen vacancies.