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Hysteretic behavior of the magnetoresistance and the critical current of bulk $Y_{3/4}Lu_{1/4}Ba_2Cu_3O_7 + CuO$ composites in a magnetic field

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Abstract

The hysteretic behavior of critical current $j_C(H)$ and magneto-resistance $R(H)$ of composites Y–Ba–Cu–O + CuO have been studied and presented. The composites represent the network of tunnel-type Josephson junctions where copper oxide acts as a material forming barriers between superconducting (YBCO) crystallites. The characteristic features of $R(H)$ and $j_C(H)$ dependences are discussed in the frames of the conception of ''two level superconducting system'' (the Josephson media and HTSC crystallites) which is realized in the composites under study.

Keywords: HTSC; Resistivity; Magnetic field; Relaxation

1. Introduction

The study of hysteretic properties of transport characteristics of granular HTSC in magnetic fields is of considerable interest [1–5]. Here we report on experimental data obtained on YBCO based composites [6]. The composites represent artificially created networks of Josephson junctions where the non-superconducting component separates the superconducting crystallites.

2. Experimental

Composite sample with 85 vol.% of $Y_{3/4}Lu_{1/4}Ba_2Cu_3O_7$ (YBCO) and 15 vol.% of CuO was prepared by fast backing technique described in [6]. A sample was cut as parallelepiped with dimensions ($1.5 \times 1 \times 8$ cm^3). The magnetoresistance $R(H)$ curves have been measured by standard four-probe technique, transport current $j \perp H$. The value of the critical current density j_C was determined from the initial part of the current–voltage characteristics (CVCs) using the criterion 1 μV/cm. The sample was cooled in zero magnetic field. To measure the $j_C(H)$ dependence at fixed temperature the magnetic field H was applied to the sample with rate ~100 Oe/min. At certain H points, the initial part of the CVC was measured and j_C value was recorded. Then the magnetic field was varied to the next H point, etc.

3. Results and discussion

The Fig. 1 shows hysteretic behavior of $R(H)$ dependences of the composite. These data have been obtained by cycling of the external magnetic field from $H = 0$ to maximal value H_{max} and then to $H = -H_{max}$ and than back to $H = 0$. After that, the cycle was repeated for higher value of H_{max}. Let us discuss the $R(H)$ dependences in the frames of conception of ''two level superconducting system'' [7]. Really, the composite may be considered as two-level superconducting system: YBCO crystallites (''strong'' superconductivity) and network of Josephson junctions. The whole dissipation takes place in the Josephson media because the used values of transport current density j and external field H are much less than critical ones for the YBCO grains at 4.2 K. The intergrain media is characterized by local magnetic fields [4]. The local field in the intergrain media is the superposition of the external

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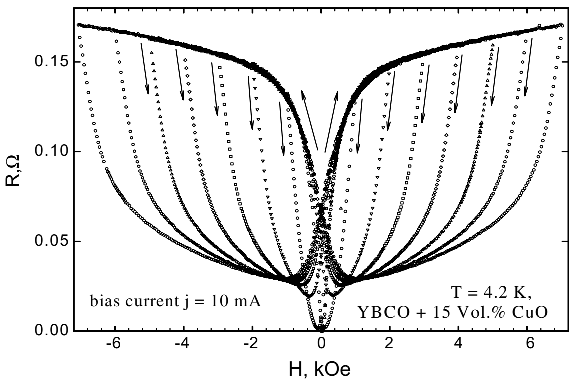

Fig. 1. $R(H)$ dependences of composite HTSC at 4.2 K. Arrows indicate direction of scanning of magnetic field.

field H and the field originated from the diamagnetic response of superconducting grains. By averaging these fields on the intergrain media, one comes to consideration of the effective magnetic field H_{eff}. When H is increased, the HTSC grains have negative magnetic response. This result in H_{eff} in the intergrain media is more than H value [4,7] on ascending branch of $R(H)$ curve. When H is removed the magnetization of YBCO grains is less in absolute value and than becomes positive [4,7]. So, H_{eff} on the descending branch of $R(H)$ curve is less than H. At the point $H = H_{min}$ maximal cancellation of H and the field induced by YBCO grains takes place and minimum of $R(H)$ is observed. Further decrease of H results in growth of R due to domination of field induced by YBCO grains. The induced field mainly gives contribution opposite to external H. Reverse of H results in additional growth of resistance because external field is no longer opposite to averaged local fields from YBCO grains. In the sequel, the "negative" branch of $R(H)$ curve replicates its "positive" part. All these features are seen on experimental curves of Fig. 1. Also monotonous growth of H_{min} with increase of H_{max} is observed. On rising of H_{max}, more flux is trapped within YBCO grains and as a consequence, more magnetic field is induced in the intergrain media.

The $j_C(H)$ dependence would behave as a mirror image of the $R(H)$ one: descending branch of $j_C(H)$ should correspond to ascending one, and conversely. The Fig. 2 shows $R(H)$ and $j_C(H)$ dependences for the same composite sample. Both $R(H)$ and $j_C(H)$ dependences have been measured by cycling of external field to $H_{max} = 3$ kOe. For this reason, trapped and effective fields at the same H points are identical for both $R(H)$ and $j_C(H)$ measurements. As can be seen from Fig. 2, the external fields corresponding to positions of extremums of $j_C(H)$ (maximum) and $R(H)$ (minimum) dependences coincides.

Thus, the magnetoresistance and critical current of bulk composites YBCO + CuO have been studied. Hysteretic

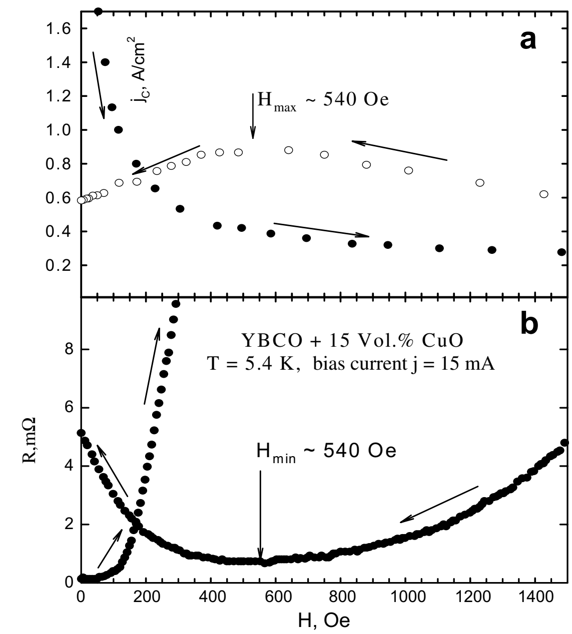

Fig. 2. Portions of $j_C(H)$ (a) and $R(H)$ (b) dependences of the composite. Arrows indicate direction of scanning of H. The positions of extremums of $j_C(H)$ and $R(H)$ curves are pictured.

magnetic field dependences of $R(H)$ and $j_C(H)$ can be qualitatively explained using the concept of "two level superconducting system" [7]. We believe that the hysteresis of transport properties is mainly determined by the flux trapped within superconducting YBCO grains.

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