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Time relaxation of residual resistance of HTSC-based composites

D.A. Balaev *, A.A. Dubrovskiy, K.A. Shaykhutdinov, S.I. Popkov, M.I. Petrov

Kirensky Institute of Physics, Krasnoyarsk 660036, Russia

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Abstract

Magnetoresistance curves $R(H)$ and time relaxation of the residual resistance of bulk YBCO + CuO composites have been studied. These composites represent the network of Josephson junctions, where CuO acts as a barrier between YBCO grains. It has been shown that hysteresis of the $R(H)$ dependences is related to the flux trapping within the YBCO crystallites. This flux induces magnetic field in the intergrain media. Time relaxation of the residual resistance is caused by relaxation of the magnetization of YBCO grains. The time dependence of the residual resistance obeys a logarithmic law, which describes the Anderson-like relaxation processes in the YBCO grains.

Keywords: Granular HTSC; Resistance; Relaxation; Magnetic flux

1. Introduction

The time relaxation of the residual resistance of granular HTSCs after application of external magnetic field was under investigation in [1,2]. This effect was attributed to the processes of outcrop of the Abrikosov vortices from HTSC. In this paper, we report time relaxation of the residual resistance of YBCO + CuO composites. These composites are considered to be a network of Josephson junctions [3]. A non-superconducting component acts as a material that forms barriers between HTSC crystallites [3].

2. Experimental

The composite sample with 60 vol.% of $Y_{3/4}Lu_{1/4}Ba_2Cu_3O_7$ (YBCO) and 40 vol.% CuO was prepared by fast backing technique [3]. Addition of CuO results in suppression of the critical current density j_C of the composite ($j_C(4.2\ K) \approx 10^{-1}\ A/cm^2$). This made it possible to investigate magnetoresistance $R(H)$ in the case, when the bias current I is higher than I_c. Measurements of the $R(H)$ dependences were performed by the standard four-probe technique at different I values (0.5–5 mA, while $I_C(4.2\ K) \approx 1.5$ mA; the cross section of the sample is $\approx 1.5 \times 1\ mm^2$) in applied magnetic fields H up to 5 kOe, $I \perp H$. The samples were cooled in zero magnetic field. After the external magnetic field was switched off, time relaxation of the residual resistance R_{res} was recorded.

3. Results and discussion

The $R(H)$ curves of the composite show the presence of hysteresis (Fig. 1). This specific feature is typical for granular superconductors [4] and explained by hysteresis of magnetization of HTSC [4]. The total magnetic flux in the intergrain media is the superposition of the external field and magnetic flux induced by superconducting grains. They have positive residual magnetization after removal of the external field due to the flux trapping [4]. The condition $R(H) = R_{res}$ at $H = H^*$ means the equality of effective fields in the intergrain media H_{eff} at external fields $H = 0$ and $H = H^*$. Abscissa of the cross point of the line $R = R_{res}$ and $R(H)$ curve establishes the external field value $H = H^*$, at which $H_{eff}(H = 0) = H_{eff}(H = H^*)$. The value H^* was found to be ≈440 Oe for the forward branches of the $R(H)$ curves after cycling the external field to $H_{max} = 5$ kOe. This value is the same for all the bias

* Corresponding author. Tel.: +7 3912 43 26 35; fax: +7 3912 43 89 23.
E-mail address: smp@iph.krasn.ru (D.A. Balaev).

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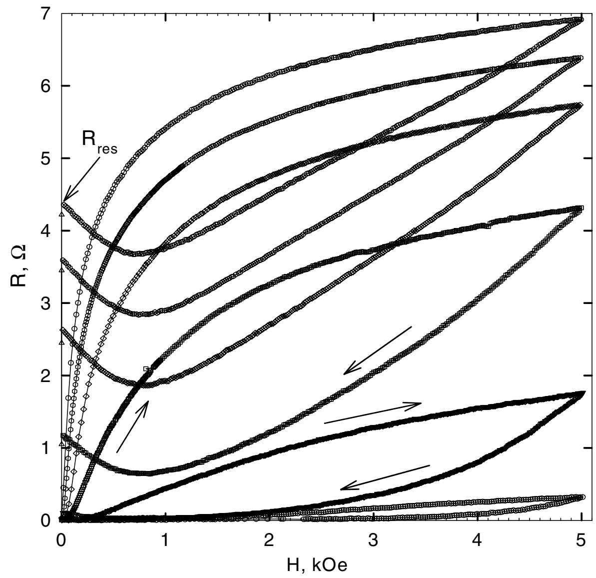

Fig. 1. The $R(H)$ dependences of YBCO + CuO at $T = 4.2$ K at different bias currents (0.5, 1, 2, 3, 4, 5 mA from bottom to top).

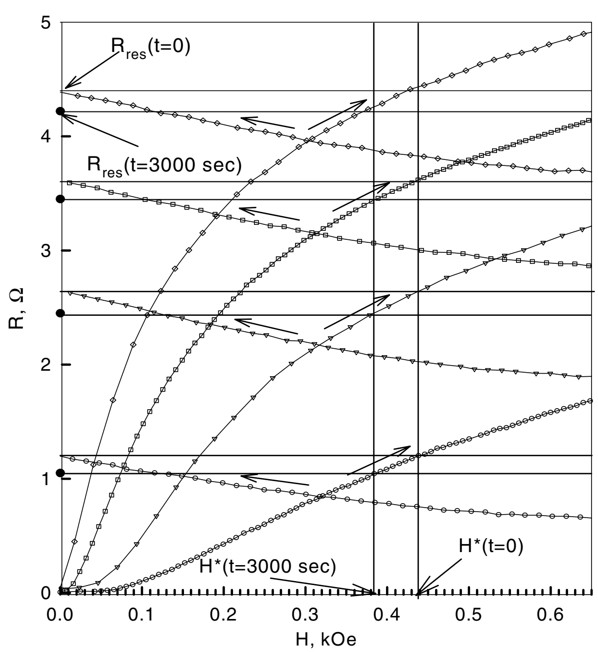

Fig. 2. $R(H)$ dependences in enlarged scale on H ($I = 2$, 3, 4, 5 mA from bottom to top). Large circles are R_{res} at $t = 3000$ s. For details see the text.

currents (Fig. 2). The used values of transport current are small enough to affect magnetization of HTSC grains. A bias current increase causes R_{res} growth, but does not affect the effective field in the intergrain media. Relaxation of magnetization of the HTSC grains results in relaxation of R_{res}. Since the magnetic flux in the intergrain media is proportional to magnetization of HTSC grains, the effective field in the intergrain media also decreases with time.

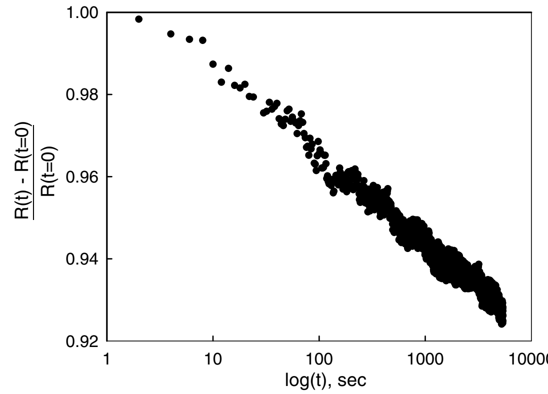

Fig. 3. The time relaxation of the residual resistance of YBCO + CuO at $T = 4.2$ K, $j = 3$ mA, $H_{max} = 5$ kOe.

Fig. 2 presents the R_{res} values at $t = 3000$ s after removal of the external field. A decrease of H_{eff} after $t = 3000$ s may be recognized via finding the H^* value, at which the line $R(H) = R_{res}$ ($t = 3000$ s) intercepts the $R(H)$ curve. Fig. 2 illustrates the H^* determination at $t = 3000$ s. Similar to the case $t = 0$ s, the $H^*(t = 3000\text{ s})$ value is the same for all the bias currents and equal to ≈385 Oe. A decrease of H^* with time reflects an effective field decrease in the intergrain media.

Fig. 3 shows time relaxation of R_{res} in a semi-logarithmic scale. It is seen that R_{res} (log(t)) can be fitted well by a straight line. This indicates that in the HTSC grains the Anderson-like relaxation processes take place [5].

Thus, we have proved experimentally that the resistance of the granular HTSC is determined by the magnetic flux in the intergrain media. This flux is superposition of the external field and flux trapped within the HTSC grains. Intergrain boundaries (Josephson junctions) act as "sensitive media", which provide an electrical response to this magnetic flux. Time relaxation of R_{res} is caused by relaxation of magnetization of HTSC grains.

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