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A comparative study of transport properties of composites HTSC+$MgTiO_3$ and HTSC + $NiTiO_3$. The effect of paramagnetic $NiTiO_3$

M.I. Petrov, D.A. Balaev, K.A. Shaihutdinov, K.S. Aleksandrov
Kirensky Institute of Physics, 66036, Krasnoyarsk, Russia

Bulk composites $Y_{3/4}Lu_{1/4}Ba_2Cu_3O_7$+$NiTiO_3$ and $Y_{3/4}Lu_{1/4}Ba_2Cu_3O_7$+$MgTiO_3$ with insulator volume content 7.5% and 15% modelling a network of Superconductor-Insulator-Superconductor (S-I-S) junctions have been prepared. The ρ(T) dependences of composites HTSC+$MgTiO_3$ are described well by the mechanism of Thermally Activated Phase Slippage (TAPS). The anomalous behavior of resistivity ρ(T) of HTSC+$NiTiO_3$ composites manifesting as a kink on ρ(T) curves at some temperature T_m have been observed. In the temperature range $T_m < T < T_C$ the dissipation is Ohmic while below T_m the CVCs are strongly non-linear. This peculiarity is interpreted as arisen owing to Abrikosov vortices flow.

The composites HTSC+CuO prepared by fast sintering technique have been shown to be a network of S-I-S Josephson junctions [1]. It have been shown that the nickel incorporation in CuO (up to 6 at.%) results in the additional suppression of superconducting properties of the composites HTSC + $Cu_{1-x}Ni_xO$ [2]. But the interaction between the supercurrent carriers tunneling through insulator layers and magnetic scattering centers in the "dirty magnetic" limit $\xi_0 > a_0$ (ξ_0 – superconducting coherence length, a_0 – distance between the magnetic scattering centers) is not possible in the mentioned compounds due to the solubility level of nickel in CuO. The case $\xi_0 > a_0$ will be realized in a composite system HTSC + paramagnetic insulator (in this case a_0 is equal to the lattice constant of paramagnetic insulator (~5Å)). We choose $NiTiO_3$ as the paramagnetic insulator, which becomes an antiferromagnetic bellow 22K [3]. We also measured transport properties of composites HTSC+$MgTiO_3$ ($MgTiO_3$ has the same structure as $NiTiO_3$ and is non-magnetic) to recognize the "magnetic" effect on the transport properties of composites HTSC+$NiTiO_3$.

Composites were prepared as follows. At the first stage the initial compounds of composites were synthesized. The preparation of $Y_{3/4}Lu_{1/4}Ba_2Cu_3O_7$ is standard. $NiTiO_3$ and $MgTiO_3$ were synthesized from NiO and MgO by the solid state reaction technique at 1250 °C for 2 weeks with intermediate daily grindings. Composites on HTSC basis with 7.5 and 15 Vol.% of $NiTiO_3$ and $MgTiO_3$ were prepared by the method of fast sintering as described in [1,2]. (2 min at 910°C and than 3 h at 350°C). We denote composite samples as S+X(Ni) and S+X(Mg), where X – is the volume content of $NiTiO_3$ (Ni) or $MgTiO_3$ (Mg) respectively.

The XRD patterns of composite samples HTSC + $NiTiO_3$, HTSC + $MgTiO_3$ shows reflections from 1-2-3 and ilmenite structures only. The critical temperatures of composites determined from magnetic measurements are the same for all samples and are equal to that of initial HTSC. Above the on-set of superconducting transition in temperature range 93.5 - 300 K the ρ(T) curves of all composite samples show semiconducting-like behavior as HTSC + CuO composites [1]. The temperature dependences of resistance ρ(T) of samples S+7.5(Mg) and S+7.5(Ni) measured at different current densities are shown on fig.1. They are characterized by a sharp drop of resistivity at 93.5K corresponding to transition of HTSC crystallites and a broad foot structure coming from the transition of network of S-I-S junctions. The temperature at which the ρ comes to be zero (~ 10^{-6} Ohm×cm) decreases with increasing of transport current J. The ρ(T, J) dependences of sample S+7.5(Mg) are similar to that of HTSC + CuO composites [1] and are described in the frameworks of mechanism of (TAPS) [4]. The ρ(T) dependences of composites HTSC+$NiTiO_3$ reveal the quite different behavior. They are characterized by a sharp drop of resistivity at 93.5K, then the region with insignificant change in resistivity down to $T_m \approx$ 77K follows. Bellow the T_m resistivity transition curves drop sharply down to

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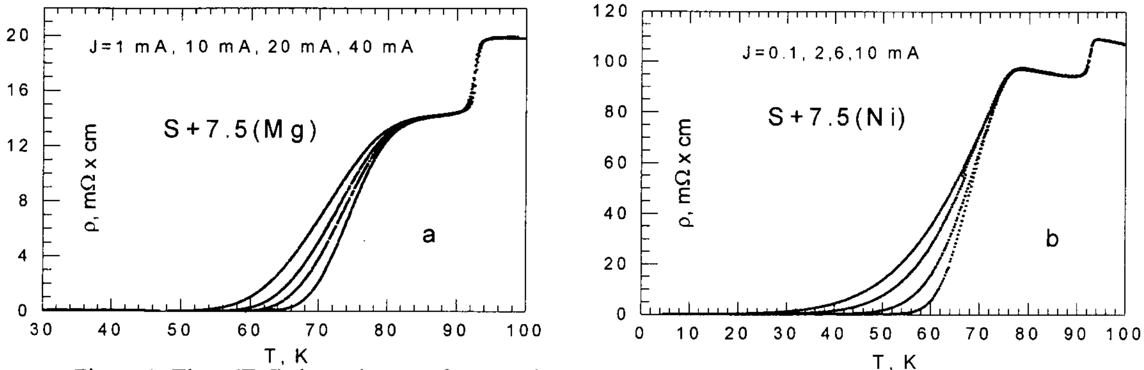

Figure 1. The ρ(T, J) dependences of composites measured at different applied current.

zero at small transport current and broaden with increasing of J.

It should be noted that in the temperature range $T_C \div T_m$ ρ(T) curves are independent on the value of transport current. This behavior is impossible to describe according to the mechanism of TAPS. These facts point out the paramagnetic $NiTiO_3$ to give the another and the dominant, besides TAPS, mechanism of the superconductivity reduction.

Our results shown on fig. 1b are surprisingly similar to the ρ(T) dependences measured on single crystals in Refs. [5,6]. This fact suggests the similar mechanisms to response for dissipation of transport current in such a different subjects of research.

In the Refs. [5,6] the resistivity measurements shown the broadening of resistive transition along *c* axis of $YBa_2Cu_3O_7$ [5] & $Bi_2Sr_2CaCu_2O_8$ [6] single crystals in the presence of strong magnetic field (up to 18 T) parallel to *ab* and the appearing of two distinctly different parts on ρ(T) curves divided by some temperature T_m. In the temperature range $T_m \leq T \leq T_C$ the dissipation is Ohmic while bellow T_m *I-V* behavior is strongly non-linear. The authors [5,6] propose the T_m is the Abrikosov vortex lattice melting temperature. Obviously, in such geometry the magnetic field penetrates into non-superconducting layers much than into superconducting ones giving rise Abrikosov vortices. Under these experimental conditions current carriers tunnel through non-superconducting layers with Zeeman interaction of carrier spins with magnetic field. At temperature up Abrikosov vortex lattice melting temperature Abrikosov vortices move without pinning result in peculiar temperature dependence of magnetoresistance.

Our composite materials can be consider as a macroscopic analog of experiment described above. Really, the tunneling of supercurrent carriers through paramagnetic layers and interaction of the current carrier spins with magnetic moments of nickel (analog of Zeeman interaction) takes place. The probability of such interaction is close to 1, because $a_0 < \xi_0$.

Besides, the paramagnetic $NiTiO_3$ can induce the some effective field which penetrates into the HTSC grains. This field forms the lattice of Abricosov vortices near HTSC surface. At the temperatures higher than the lattice melting temperature the resistivity of the sample will be independent on the value of the transport current.

Thus, if we exclude the non-conventional mechanisms of the high temperature superconductivity for interpretation of our experimental results the above hypothesis explains anomalous behavior of temperature dependences of resistivity of composites HTSC + $NiTiO_3$.

Temperature dependences of critical current $J_C(T)$ of the composites and effect of antiferromagnetic transition of $NiTiO_3$ on $J_C(T)$ will be presented and discussed in a separate publication.

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