Resistivity and irreversibility line of $(Hg_{0.9}Re_{0.1})Ba_2CaCu_2O_{6+\delta}$ HTS thin films

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Abstract

High-quality epitaxial $(Hg_{0.9}Re_{0.1})Ba_2CaCu_2O_{6+\delta}$ HTS thin films were successfully prepared by pulsed laser deposition (PLD) of Hg-free precursor material on (100)-oriented $SrTiO_3$ substrates with subsequent Hg vapour annealing. $(Hg_{0.9}Re_{0.1})Ba_2CaCu_2O_{6+\delta}$ HTS thin films exhibit sharp superconducting transitions at $T_c \approx 122$ K. The electrical resistance for c-axis oriented HgRe-1212 films has been studied as a function of temperature and dc magnetic fields up to 10 T parallel to the crystallographic c-axis. The irreversibility line for the HgRe-1212 has been deduced from the data and investigated as a function of reduced temperature T/T_c. The result of the irreversibility line is compared with published data for other high T_c cuprates.

Key words: Hg-1212 superconductors; vortex dynamics; irreversibility line.

1. Introduction

The mercury based cuprate high-temperature superconducting (Hg-based HTS) family $HgBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ [Hg-12(n-1)n, n=1-4], [1,2] has gathered much attention due to its highest T_c [3]. However, the highly volatile nature and toxicity of Hg combined with the complexity of processing has retarded the development of thin film technology, though thin Hg-Ba-Ca-Cu-O films are of great interest for basic research. The critical current densities at 77 K are of the order $10^5 A/cm^2$ and irreversibility fields of $B^*= 0.5$ T at 100 K demonstrate the great potential of these superconductors [4]. A HgRe-1212 based SQUID operating at 112 K has recently been demonstrated [5]. For many practical applications and also for an understanding of intrinsic properties, the behavior of superconductive transition in magnetic fields is very important. Therefore the resistive transitions of $(Hg_{0.9}Re_{0.1})Ba_2CaCu_2O_{6+\delta}$ HTS thin films have been investigated in magnetic fields up to 10 T parallel to the c-axis. From the data we extracted the irreversibility line in the B-T phase diagram.

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2. Experimental results and discussion

After successfull preparation of Hg-1212 HTS thin films the measurements of the magnetoresistance versus the temperature were performed with dc magnetic fields up to 10 T parallel to the *c-axis*. The current direction was in the plane of the film and perpendicular to the magnetic field.

Fig.1 shows the electrical resistance as a function of temperature in zero field. The temperature dependence of the resistivity is shown in Fig. 2 in the presence of different values of the magnetic field.

In zero magnetic field the transition is sharp, whereas in the presence of the magnetic field the resistive transition shows a remarkable broadening, that is generally discussed within the framework of thermally activated flux-flow [6], superconducting fluctuations [7], and the vortex-glass transition [8].

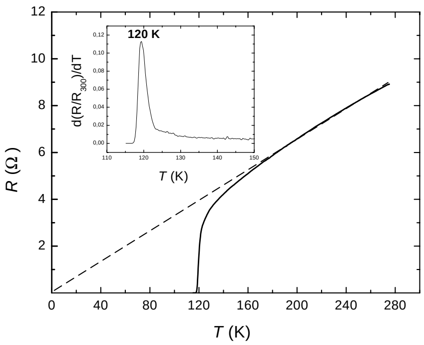

Fig. 1. Temperature dependence of the electrical resistivity for a HgRe-1212 film zero field with an onset temperature of 120 K. The inset is a relation between the temperature derivative of the resistive transition and temperature.

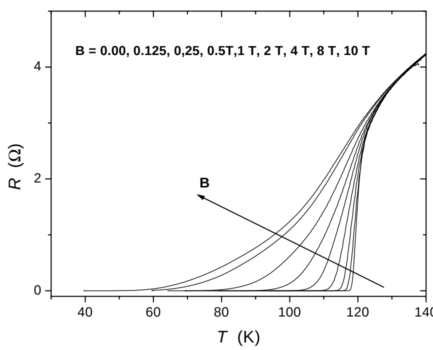

Fig. 2. Temperature dependence of the electrical resistivity for a HgRe-1212 film in various magnetic fields oriented parallel to the c-axis.

The resistive transition behavior in a magnetic field can be used to determine the irreversibility line B^*_T. The irreversibility line $B^*(T) = \mu_0 H^*(T)$ for the magnetic field parallel to the c-axis of HgRe-1212 obtained from our measurement is plotted in Fig. 3. The upper-limit criterion for the determination of the irreversible temperature T^*(B) was 0.5 Ω and provides a contour line in the $B(T)$ plane. This line divides the B-T phase diagram in two regions of irreversible (low B, T) and reversible magnetic behavior. Above this line no loss free current transport is possible due to flux motion. In this region of the B-T phase diagram the superconducting material is not useful for technical applications. For comparison, published data for $[YBa_2Cu_3O_{7-\delta}$ (Y-123), $(Tl, Bi)Sr_2Ca_2Cu_3O_x(Tl-1223)]$[9] and $Bi_2Sr_2CaCu_2O_x$ [10] are also included in Fig. 3. The irreversibility line for the HgRe-1212 film is observed to be at higher magnetic fields than those for Tl-1223 and Bi-2212, but at lower fields than that of Y-123.

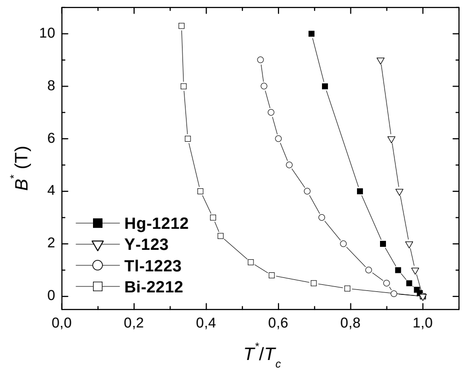

Fig. 3. Irreversible field B^* as a function of reduced temperature T^*/T_c with the magnetic field oriented parallel to the c-axis for the HgRe-1212 film from our measurement and published data for other high T_c cuprates.

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