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AC Susceptibility of the $YBa_2Cu_3O_7$ Coated Conductor in High Magnetic Fields

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The AC susceptibility of the $YBa_2Cu_3O_7$ coated conductor in the perpendicular applied AC magnetic field was investigated using an inductive experimental setup with a pair of coils connected in opposite. A harmonic homogeneous AC magnetic field was applied perpendicularly to the wide face of the $YBa_2Cu_3O_7$ coated tape. Together with this AC field, a parallel background DC magnetic field up to 14 T was applied perpendicularly to the tape. The measurements were performed at several constant temperatures in the range 3–50 K. In the region of high background DC fields (8–14 T) no influence of the tape's ferromagnetic substrate was detected, despite of the low measurement temperatures employed. The estimate of the critical current density (j_c) at 20 K and 14 T, based on the position of the imaginary AC susceptibility peak, gives the value $j_c = 0.53$ MA/cm^2.

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1. Introduction

The $YBa_2Cu_3O_7$ (YBCO) coated conductors [1] are being considered as the next generation of high-temperature superconducting wires and are believed to allow broader application of the superconducting wires in the practice, due to their lower cost and better performance in magnetic field compared to the $Bi_2Sr_2Ca_2Cu_3O_{10}$ (BSCCO) tapes.

The YBCO coated conductor has the form of a long flat tape with the thickness of typically 0.1–0.2 mm and the width 3 mm to 10 mm. It is composed of a metallic substrate tape on which a thin buffer layer is deposited, followed by a few micron thick layer of YBCO superconductor. One of the mayor issues to be solved in the coated conductors' development is the cut down of the AC losses.

2. Experiments

In our experiments, we measured the 1st harmonic complex AC susceptibility of a short piece of the YBCO coated tape made by the American Superconductors company (the 344 wire). The tape is 4.4 mm wide and we have used a 6 mm long sample. The substrate tape of this wire is of a ferromagnetic Ni–W alloy.

In our experimental setup, the sample was placed in the middle plane of the pick-up coil, with its wide face perpendicular to the coil's axis. A homogeneous harmonic AC magnetic field was applied on the sample, perpendicular to the sample's face. Parallel to this AC field also a homogeneous constant DC magnetic field was applied. A second coil, called compensatory, stood empty during the measurement and sensed the pure induced voltage from the applied AC magnetic field. The differential voltage from the pick-up and compensatory coil, proportional to the sample's magnetization, was measured by a phase sensitive lock-in amplifier. The AC system was placed inside the variable temperature insert of the helium--cooled superconducting DC magnet system from Oxford Instruments.

Our interest was focused on the coated tape's properties at low temperatures and high DC magnetic fields. We performed susceptibility measurements in 14 T DC magnetic field at 50 K, 40 K, 20 K, and 3 K and made a short series of measurements in 8 T, 12 T, and 14 T DC field at 20 K. The maximal AC field amplitude was approximately 60 mT and all the measurements were performed at the frequency 21 Hz.

3. Results

The normalized plots of the measured dependences of the real (χ') and imaginary (χ'') part of the internal AC susceptibility on the amplitude of the applied magnetic field (B_a) are shown in Fig. 1. The applied field amplitude is normalized to the value $B_{\mathrm{a,max}}$ at which the maximum of the imaginary susceptibility (denoted as $\chi''_{\max}$) is reached. The values of χ'' are normalized to the maximal value $\chi''_{\max}$.

The predictions of two theoretical models applicable in the case of thin flat superconducting tape in a perpendicular field are also shown in the figure. The full black line represents a curve predicted by the model of thin rectangular strip [2] and the full gray line is the prediction of the model of elliptical strip [3].

It is visible that the experimental data are in much better agreement with the prediction of the model of thin rectangular strip. Nevertheless, some discrepancies exist in the region of low amplitudes, more pronounced in the χ'' plots. This can be a consequence of the presence of a ferromagnetic layer (substrate tape) in the vicinity of the YBCO layer. Although the hysteretic losses in the ferromagnetic substrate should be negligible in the magnetic field range 8–14 T, and indeed we did not see any sign of such losses in the χ'' curves, the ferromagnetic layer still influences the local distribution of the magnetic field near the superconductor, possibly increasing the perpendicular field component at the tape edges.

On the basis of the above-mentioned theoretical models of the thin rectangular and elliptical strip it is possible to estimate the critical current density j_c of the YBCO coated wire. Both models provide a simple relation between the $B_{\mathrm{a,max}}$

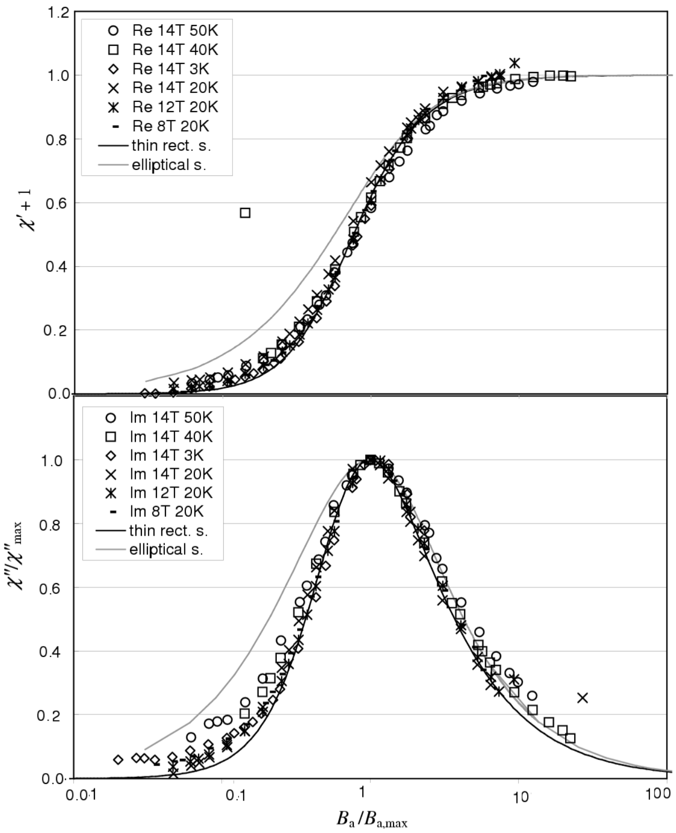

Fig. 1. Normalized dependences of the real (top) and imaginary (bottom) internal AC susceptibility measured on an YBCO coated tape (symbols), together with the theoretical prediction of the model of thin rectangular strip (black line) and elliptical strip (gray line). In the legend, the respective DC field and temperature is indicated for each series.

and j_c:

$$B_{a,max} = k\mu_0 t j_c, \tag{1}$$

where k is a numerical constant given by the model ($k \doteq 0.78$ for thin rectangular strip; 0.6 for elliptical strip), μ_0 is the permeability of vacuum and t is the thickness of the superconductor. We have estimated the YBCO layer thickness to be approximately 2 μm.

The values of the critical current density calculated according to Eq. (1) from the $B_{a,max}$ values obtained from the measurements in 14 T DC field are shown as a temperature dependence in Fig. 2.

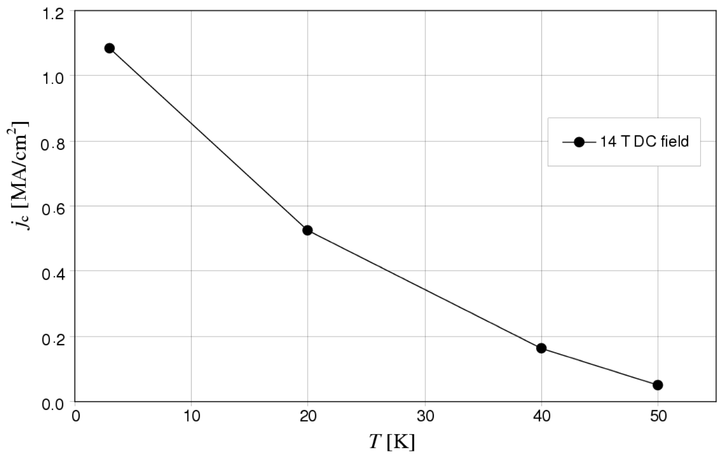

Fig. 2. Critical current density of the YBCO coated wire in dependence on the temperature in the 14 T DC magnetic field, as estimated from the AC susceptibility data on the basis of the model of thin rectangular strip ($k = 0.78$).

Acknowledgments

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