Third harmonic *ac* susceptibility measurements on MgB_2 bulk: irreversibility line and frequency dynamic behaviour

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Abstract

The third harmonic of the *ac* susceptibility of MgB_2 high pressure (HP) bulk samples have been measured at the frequency of 1070Hz as a function of the temperature for different *dc* magnetic fields. The irreversibility line (IL) has been extracted from the temperature onsets. The IL has a $(1-t)^n$ dependence, with an "effective power law" exponent n=1.27. This exponent takes into account the interaction between the thermal fluctuations and flux pinning feature. Another IL data of HP samples, drawn out of VSM measurements at few Hertz has similar behaviour. This shows that the superconducting response is indipendent from frequency in the ranges of the temperature and the magnetic field studied. This analysis supports the fact that when the magnetic field is on and the critical state is formed the frequency creep decay is outside the frequency range analyzed.

Key words:
MgB_2; irreversibility line; dynamic transport

1. Introduction

The recent discovery of the superconductivity in MgB_2 [1], has stimulated large interest as this material shows various peculiar behaviours [2]: a) an electron-phonon superconducting behaviour, like conventional BCS superconductors; b) grain alignment does not play a crucial role in superconducting current transport [3].

Thus, from the viewpoint of practical applications, it is important to understand the magnetic IL as a function of the temperature [4] [5]. IL is generally defined in a resistive way by the appearance of a resistive state at each field [2] [3], or by VSM magnetic measurements [3]. A different way to detect the IL and the non-linear dynamics of the vortex is to measure the high harmonic susceptibility components, $\chi_3^{'}+i\chi_3^{''}$ [6], in respect to the temperature and the DC magnetic field. This procedure permits to have a more sensitive method and the contribution of the linear losses that limit the superconducting properties is ignored [7]. In this paper we present the onset of χ_3, measured at 1070Hz as function of temperature and DC magnetic field of the MgB_2 bulk samples. Comparisons of the measured IL of MgB_2 samples with other IL data by VSM measurements of similar samples have been done.

2. Results and discussion

MgB_2 bulk samples of (1x2x5.6 mm^3) produced by sintered reaction [8] have been measured. The critical temperature is above 38K. The high harmonics susceptibility has been measured in a double coil susceptometer (TARI facilities). The sample is placed on a sapphire holder, this set-up is cooled in a thermally controlled He gas flow cryostat provided with 8 Tesla superconducting magnet. The ac driving field has 1070Hz frequency and 6 Gauss amplitude. The external mag-

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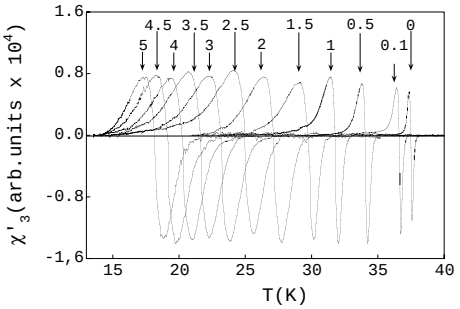

Fig. 1. $\chi_3^{'}$ of MgB_2 bulk sample at B_{ac}=6G, f=1070Hz, B_{dc}=0-5T.

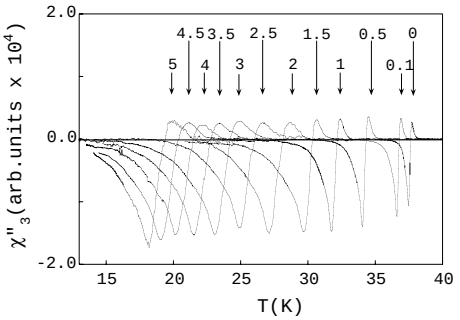

Fig. 2. $\chi_3^{''}$ of MgB_2 bulk sample at B_{ac}=6G, f=1070Hz, B_{dc}=0-5T.

netic field is parallel to the length of the sample. In fig.1 the real and imaginary parts of χ_3 are shown for dc magnetic field B_{dc} in the range (0-5) Tesla.

The χ_3 signal rises when the current-voltage characteristic becomes non-linear and the multiharmonic components are generated. The criterion used to define the IL is determined by the temperature at which the third harmonic amplitudes χ_3 start to deviate from the zero value. IL determined by the onset of χ_3 measurements and the fit function $(1 - T/T_c)^n$, described in the vortex glass/liquid theory, are shown in fig. 2. The n adjustable parameter describes how the thermal fluctuations can give rise to the vortex lattice melting [9]. In presence of quantum fluctuations n is smaller than 2 [10]. This description of the melting line with an "effective power law" exponents is a compact way description because it depends on: disorder, dimensionality, lattice flux elastic response; normally described as scaling law of the pinning versus temperature and magnetic field [11]. However, it is difficult to extract clear physical evidence from the above power law [10].

Moreover, in fig.2 another IL data (x), determined by VSM measurements at few Hertz [3] are shown. The data comparison shows that in MgB_2 bulk, under these magnetic fields and temperature conditions, the flux dynamics remains similar in the frequency range of induced current. Infact [12] in the three-dimensional phase diagram H-T-J of superconductor, the current

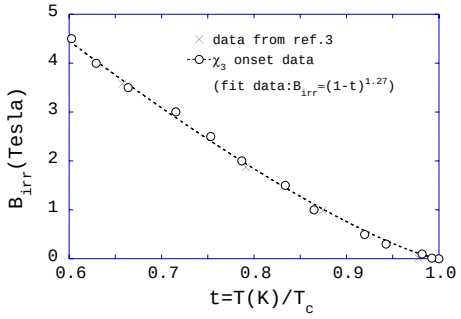

Fig. 3. IL line of the MgB_2 bulk sample based of χ_3 onsets (-o-). (x) are IL data based on VSM measurements .

axes can be interpreted as time axes (or 1/frequency) via the relation:

$$j(t) \propto [ln(\frac{t}{t_0})]^{-\frac{1}{\mu}}. \quad (1)$$

3. Conclusion

An accurate measurement of the irreversibility line (IL) of the MgB_2 bulk sample has been done from the third harmonic of the *ac* susceptibility temperature onsets. The temperature behaviour of the IL like $(1 - T/T_c)^{1.27}$ has been found which shows a correction of the simple quadratic power-law. This value takes into account the complex interaction beetween the thermal fluctuations and flux pinning feature. Moreover there is an indication that the critical state formed in the presence of magnetic field (0-5 Tesla) is indipendent from the frequency range (1Hz-1KHz) of the induced current.

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