Magnetic investigations of the high-T_c superconductor Hg-1212

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Abstract

The magnetic properties of several powder samples of the high-T_C superconductors Hg-1212 and (HgTl)-1212 are investigated by means of ac and dc susceptibility measurements. The temperature dependence of irreversibility fields is determined up to magnetic fields of 14 T. It can be described in the framework of a depinning model developed by Matsushita. In case of Tl substitution the irreversibility line is clearly enhanced. For this sample further analysis of the real and imaginary parts of the ac susceptibility leads in zero field without any free parameters to a good agreement with the Bean-model, whereas in higher fields additional mechanisms seems to occur.

Key words: Irreversibility field; AC-susceptibility; High-T_C superconductor

1. Introduction

Hg-based ceramics [1] exhibit the highest superconducting transition temperatures among the high-T_c superconducting materials and therefore are of high interest for potential applications. Their properties can be improved by partial substitution of Hg by other elements [2,3]. For characterisation and comparison of different samples the knowledge of the temperature dependence of the respective irreversibility fields is especially important [4]. A common method to determine irreversibility lines is the evaluation of the peak values of the imaginary parts of the ac susceptibility signals. More accurate, however, is the use of a basis point on the high temperature side of this peak, i.e. 1 %. In this contribution such investigations of the systems Hg-1212 and (HgTl)-1212 are presented.

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2. Experimental

Several powder samples of the system Hg-1212 and (HgTl)-1212 were prepared in sealed silica tubes using a one-temperature furnice. Mixtures of oxides with the nominal composition were annealed at 880°C during 10 hours. The superconducting transition temperature and the irreversibility lines were determined by susceptibility measurements in magnetic fields up to 14 T.

3. Results and discussion

Fig. 1 shows some results obtained from ac susceptibility measurements. The real and imaginary parts are plotted for Hg-1212 and (HgTl)-1212 taken in zero field and with an applied field of 3 T. The curves of the Tl-substituted sample are clearly shifted to higher temperatures. This can also be seen in the irreversibility lines (Fig. 2), which was determined from the imaginary signal at 1% of the peak value on the high temperature side. The temperature dependence of the irreversibility lines are analyzed by the theory of Matsushita [5], which is based on a depinning mechanism caused by

thermally activated flux creep. According to this theory the temperature dependence of the irreversibility field can be described by [4]

$$B_i(T) = (K/T)^{4/(3-2\gamma)}[1-(T/T_c)^2]^{2m/(3-2\gamma)}, \qquad (1)$$

where K, m and γ are parameters of the theory. In Fig. 2 fit curves using this expression are given with the resulting parameters plotted in Tab. 1. It can be seen that the theoretical description fits well in the whole temperature range.

In general, the interpretation of ac susceptibility results of high-T_c superconductors is not quite clarified in the literature. Several models have been proposed based on different flux dynamic conditions. Ling and Budnick [6] discussed three of the main types of models in connection with irreversibility line measurements: besides the classical Bean-model [7] a relaxation and a diffusive motion model. The curves in Fig.3 are taken from their work showing the respective prediction in a plot of the imaginary part against the real part of the ac susceptibility. The experimental results can be compared with these predictions. Fig. 3 shows as an example the data obtained from the (HgTl)-1212 sample for fields of 0.01 and 3 T. There is almost now difference in the behaviour of the two samples. The only adaption in Fig. 3 is a linear extrapolation of the main slope on the left of the experimental curves. As can be seen there is an excellent agreement with the prediction of the Bean-model in case of the low field data whereas for the 3 T data an additional mechanism of flux dynamics seems to occur. Further investigations of this kind are in progress now.

Table 1
Transition temperature and fit parameters according to the theory of Matsushita for Hg-1212 and (HgTl)-1212

Sample	T_c (K)	γ	m	$k = K/T_c$
Hg-1212	123	0.48	2.0	1.5
(HgTl)-1212	125	0.25	2.6	1.7

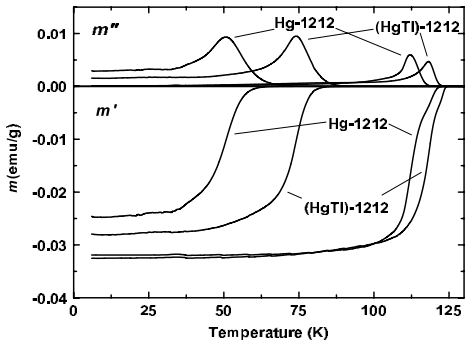

Fig. 1. Real and imaginary part of the ac susceptibility of Hg-1212 and (HgTl)-1212 superconductors without an applied dc field (curves at higher temperatures) and with a dc field of 3 T (curves at lower temperatures)

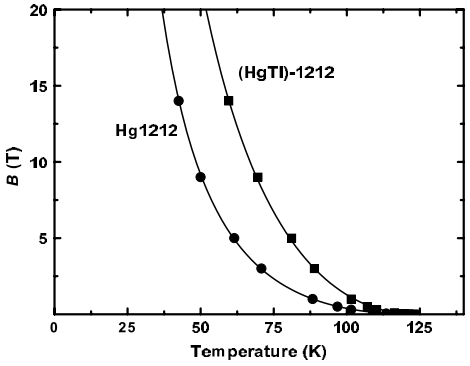

Fig. 2. Irreversibility fields for Hg-1212 and (HgTl)-1212 superconductors. The upper curve shows the enhanced irreversibity field for the Tl doped sample. The solid curves are fit lines according to Eq. 1.

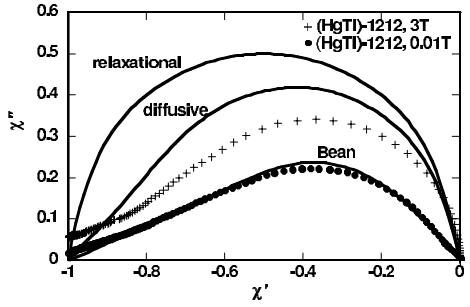

Fig. 3. Comparison of the correlation of the real and the imaginary part of the magnetic susceptibility for (HgTl)-1212 with the predictions [6] of a relaxational, a diffusive and the Bean-model

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