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^{89}Y NMR AS PROBE FOR THE SPIN DYNAMICS IN THE Cu(2)O-PLANES

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ABSTRACT

The ^{89}Y nuclear relaxation rates in the orthorhombic 90 K superconducting and the tetragonal semiconducting modification of $YBa_2Cu_3O_{7-\delta}$ are almost similar. These results are correlated to Y line shift data and Cu- NMR results. A relaxation process via magnetic excitations in active regions of the Cu(2)O planes allows a consistent picture.

INTRODUCTION

Resonance is usually a suitable tool to probe the charge and spin dynamics in conducting and/or magnetic systems. In $YBa_2Cu_3O_{7-\delta}$ (YBCO), ESR is only of limited use, because of the absence of a signal in single crystals of the 90 K superconductor [1]. In this contribution we will discuss our Y-relaxation measurements obtained in the orthorhombic 90 K superconducting (O-YBCO) and the tetragonal semiconducting (T-YBCO) modification of YBCO [2]. Recently also Y-line shift data have become available [3]. Furthermore, since the univocal assignment of the NMR quadupolar lines to the Cu sites far reaching conclusions were possible [4,5,6] about the oxygen vacancies and their relation to the resonance spectra.

We will try to give a consistent explanation of these various results. It will be shown that our data corroborate the suggestion of Warren et al. [6] of the existence of active and inactive regions in the Cu(2)O- planes, and further that it is the spin dynamics rather that the conduction electrons, that is probed via the Y relaxation rate.

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EXPERIMENTAL

In our mainly home-built NMR set-up the Y-NMR data were taken at a frequency of 9.8 MHz by using a comb of $\pi/2$ pulses followed by a reading pulse of $\pi/2$. A decay time of 200-300 μs was allowed to suppress the effect of 'electronic noise' in the signal without too severe loss of sensitivity - for T-YBCO a decay time of about 0.4 ms compared to 1 ms for O-YBCO was typical. The magnetic field was provided by an Oxford Instruments 4.7 T NMR-magnet with a room temperature bore of 5 cm, allowing insert of a flow cryostat. Temperatures were measured with a Pt-resistor and Au-chromel thermocouple.

RESULTS AND DISCUSSION

The main result of our Y-NMR data is that above 100 K there is only a slight decrease in relaxation rate [2,7], if one goes from the 90 K superconducting compound to the tetragonal non-superconducting material. The linear temperature dependence then suggests coupling to spin excitations with Fermi-Dirac statistics, like e.g. ordinary conduction electrons or holes or spinons, as proposed in the Resonant Valence Bond (RVB) model [8]. In the first interpretation the large difference in conductance between the 90 K superconductor and the tetragonal semiconductor (we measured a factor of more than 10^3) requires additional modelling.

The accurate line shift measurements of Alloul et al. [3] show apart from the dominance of the chemical shift, a gradual decrease of the superposed Knight shift with increasing δ-value. For $\delta > 0.6$ only the chemical shift is observed: the δ-value of a quenched sample as ours is estimated to be around $\delta = 0.7$. If the same conduction electrons that are responsible for the Knight shift determine the relaxation, a decrease in relaxation rate of a few orders of magnitude had to be observed between the 2 samples - in contrast with experiment. If magnetic excitations are the source of the relaxation rate, there is no such contradiction. Because of the fast fluctuations of the spin direction it is the averaged spin component which determines the resultant shift: there is no such direct relation between shift and relaxation rate as for a Korringa process.

The Y-NMR data of Warren et al. [6] in the 60 K superconductor confirm our finding that the Y relaxation rate is only modestly affected by oxygen loss. Also on basis of the Cu-NMR data, they conclude that there is still ample though possibly quite inhomogeneous dynamical character at a sizeable fraction of planar sites.

In such a picture it might be assumed that mainly those Y nuclei that are coupled to the excitations in the active regions are observed. Indeed a typical time constant for Y spin diffusion in YBCO will be a few hundred seconds [7], which is longer than the observed nuclear relaxation rate. If the spin dynamics in active regions hardly changes under variation of δ ($\delta < 0.7$), then the same holds for the observed Y relaxation rate (the Y-sites in non-active regions are unobservable).

In conclusion we have shown that a consistent interpretation of the available NMR data is possible if the observed Y nuclei are relaxed by magnetic spin excitations on 'active'regions in the Cu(2) planes. More precise data about these active regions are required to draw further conclusions.

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