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NMR study of the low temperature magnetic excitations in $RBa_2(Cu_{1-y}Ni_y)_3O_6$ (R = Y, Tm)

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Abstract

Cu(1) NQR, Cu(2) Zero Field NMR and Tm NMR spin-lattice relaxation data have been found quite different in the two AF states of the 123 compounds. In the usual AF-I phase of the pure compounds T_1 is short and nearly T-independent at low T. With Ni or Co substitutions in the above by about 2% concentration, the Cu(2) bilayers are ordered ferromagnetically with respect to each other (AF-II phase), which is evidenced by a splitting of the Cu(1) NQR. In this case, T_1^{-1} is much smaller and exhibits a strong T dependence, which might be associated with a 5 K gap in the magnetic excitation spectrum. We suggest that magnetic defects apparently unavoidable on the Cu(1) sites govern the spin dynamics. While they are frustrated in the "pure samples", they are not in the AF-II phase, which suppresses partly their spin fluctuations.

Keywords: Antiferromagnetic order; NMR spin-lattice relaxation time; Spin fluctuations; Substitution effects; Defects

1. Introduction

Since the discovery of high-temperature superconductivity major attention has focussed on experimental studies of superconducting compounds by various techniques, among others NMR and NQR. As copper ions in the Cu(2) planes play a decisive role in superconductivity, the study of the magnetic properties of compounds with non-superconducting composition is also expected to be quite important (in particular, of $YBa_2Cu_3O_{6+x}$ with x = 0–0.3). In such samples the antiferromagnetic ordering (AF-I phase) has been monitored, for instance, by Cu(2) Zero Field (ZF) NMR. The T dependence of the Larmor frequencies has been well explained in the context of the spin-wave model [1], but measurements of nuclear spin-lattice relaxation (NSLR) of Cu(2) in $YBCO_6$ had shown [2] that at $T \sim 1$ K $\ll T_N$ the value of T_1^{-1} is very large and does not display the strong temperature dependence predicted for a magnon mechanism in quasi-2D antiferromagnets [3]. Measurements of T_1^{-1} for Cu(1) at liquid helium temperatures had also shown [4] that the NSLR time T_1 is anomalously short and depends weakly on temperature. As Tsuda et al. [2] had pointed out, some low-energy magnetic excitations, besides magnons, should exist in the $YBCO_6$ compound. The most likely source of such excitations could be some paramagnetic defects of the $YBCO_6$ lattice. This could be checked by comparative studies of the relaxation properties of the various nuclear probes involved in the crystal structure. Such systematic work has not been performed up to now.

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