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NQR STUDY OF COPPER IN $REBa_2Cu_3O_{7-y}$

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Abstract. – By measuring T_1 of Cu NQR lines in Sm, Nd, Gd-$Ba_2Cu_3O_{7-y}$ the signals which is observed at 20-23 MHz and 30-33 MHz in $YBa_2Cu_3O_{7-y}$ are assigned as arising from Cu1 and Cu2 site, respectively. $1/T_1$ follows the Korringa law in $YBa_2(Cu_{0.98}Zn_{0.02})_3O_{7-y}$ below 90 K, although it is saturated above 100 K.

Since the discovery of the high T_c superconductor [1], much efforts have been devoted to investigate the chemical and the physical properties of $YBa_2Cu_3O_{7-y}$, which has T_c well above 90 K [2]. There have been many discussions on the mechanism of the hifh T_c superconductivity. The study including the substituted system is considered to be important for the further understanding of the system. The high T_c does not decrease with the replacement of Y with rare earth elements,while it decreases rapidly with doping nonmagnetic Zn impurities. We performed a Cu NQR study (Nuclear Quadrupole Resonance in zero magnetic field) of the $REBa_2Cu_3O_{7-y}$ (RE = Sm, Nd and Gd) and $YBa_2Cu_3O_{7-y}$, with doping Zn impurities to obtain an information of the high T_c superconductor $YBa_2Cu_3O_{7-y}$.

All specimens were fired and slowly cooled in the air, the resistivity measurements yield $T_c = 87$ K for $SmBa_2Cu_3O_{7-y}$ and 90 K for $GdBa_2Cu_3O_{7-y}$. T_c of $YBa_2Cu_3O_{7-y}$ with doping 2 % Zn is 65 K. Details about the preparation and the characterization of the specimens were written in papers by Kaneko *et al.* and Oda *et al.* [3, 4].

In these systems, two sets of NQR lines, which are similar to $YBa_2Cu_3O_{7-y}$ are observed around 20-23 MHz and 30-33 MHz. Each pair is composed of signals from ^{65}Cu and ^{63}Cu on the same atomic site.

We measured the nuclear spin lattice relaxation time, T_1, of ^{63}Cu at the respective site. Results for RE based system are shown in figure 1. These data are already published in our previous papers [5, 6] and also similar results of Gd- based system are obtained by Hammel *et al.* [7] and Walstedt *et al.* [8]. $1/T_1$ is nearly temperature independent and is much larger than that in $YBa_2Cu_3O_{7-y}$ [9] at low temperatures, where $1/T_1$ is governed by the RE spin fluctuations. $1/T_1$ at 32.5 MHz is more than one order of magnitude larger than that at 22.0 MHz. In the crystal structure of $REBa_2Cu_3O_{7-y}$, Cu(Cu2) in CuO_2 plane is located nearby RE ions, while Cu (Cu1) in CuO chain is located far from the magnetic ions. It is expected that the fluctuations of RE spin induce significant relaxation effects at Cu2 site nuclei, while influence on Cu1 site nuclei is much weaker. As long as the coupling is dominated by the dipolar fields, the ratio is calculated to be 21 [5, 6]. From these results, we conclude that the signal at 30-33 MHz is arising from Cu2 site, 20-23 MHz is from Cu1 site. In $SmBa_2Cu_3O_{7-y}$, the experimental ratio decreases gradually with increasing temperature and approaches unity above 100 K. This is attributed to the rapid increase of the other contributions than RE spins, and also the increase of the correlation frequency of Sm spin fluctuations (the correlation frequency is determined by conduction electron scattering at high temperatures).

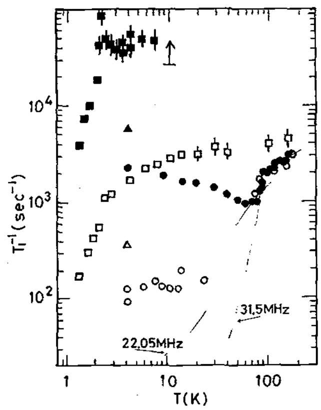

Fig. 1. – Temperature dependence of $1/T_1$ of ^{63}Cu in $REBa_2Cu_3O_{7-y}$. (▫) and (▪) is in $GdBa_2Cu_3O_{7-y}$, (○) and (•) is in $SmBa_2Cu_3O_{7-y}$, and (△) and (△) is in $NdBa_2Cu_3O_{7-y}$. The open mark represents $1/T_1$ at 22.05 MHz and the closed mark represents $1/T_1$ at 32.5 MHz. $1/T_1$ of $YBa_2Cu_3O_{7-y}$ is also shown in the solid lines.

In $SmBa_2Cu_3O_{7-y}$, the temperature dependence of $1/T_1$ is exactly the same as that in $YBa_2Cu_3O_{7-y}$. $1/T_1$ at Cu2 shows a weak temperature dependence in the normal state. Similar behavior is also observed in $EuBa_2Cu_3O_{7-y}$.

Next we will discuss the results of $YBa_2(Cu-Zn)_3O_{7-y}$ system. The temperature dependence of T_1 in $YBa_2Cu_3O_{7-y}$, which is obtained by Kitaoka *et al.* is shown in figure 2. $1/T_1$ does not follow the Korringa law, T_1T = constant, but has weak temperature dependence above T_c. In the superconducting state, $1/T_1$ decreases rapidly without the enhancement just below T_c, and varies in proportion to T^3 at low temperatures [9]. This behavior is quite different from that of ordinary superconductor. In order to analyse T_1 in the superconducting state, T_{1s}, we have to know T_1 in the normal state, T_{1n}. Usually T_{1n} is obtained by the extrapolation from the high temperatures. This is difficult in $YBa_2Cu_3O_{7-y}$, as T_1 has complex temperature depence above 100 K. It is also difficult to suppress the superconductivity by the external magnetic field, as $YBa_2Cu_3O_{7-y}$, has extremely high critical field. Fortunately T_c decreases drastically with doping Zn impurity [4]. Hence in order to see the temperature dependence of T_{1n} in wider temperature range, we measured T_1 in $YBa_2(Cu-Zn)_3O_{7-y}$ system. The result is shown in figure 2. $1/T_1$ in $YBa_2(Cu_{0.98}Zn_{0.02})_3O_{7-y}$ is proportional to T between 65 K (T_c) and 100 K, and

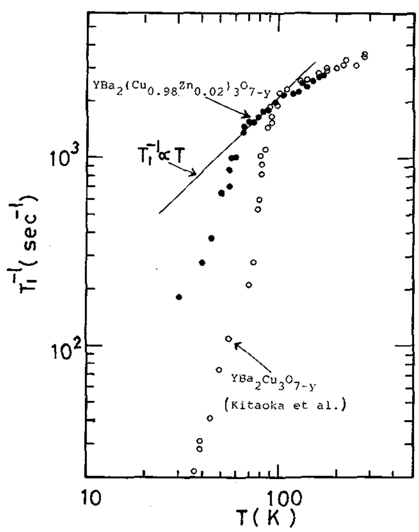

Fig. 2. – Temperature dependence of $1/T_1$ in $YBa_2Cu_3O_{7-y}$ and $YBa_2(Cu_{0.98}Zn_{0.02})_3O_{7-y}$.

has nearly the same value as that in $YBa_2Cu_3O_{7-y}$ above 100 K. In the superconducting state, it decreases rapidly without enhancement below T_c. From this result, we suppose that $1/T_{1n}$ in $YBa_2Cu_3O_{7-y}$ may follow the Korringa law below 90 K. Hence the fact that $1/T_{1s}$ in $YBa_2Cu_3O_{7-y}$ varies in proportion to T^3 implies that T_{1s}/T_{1n} is in proportion to T^2. This indicates that $YBa_2Cu_3O_{7-y}$ has anisotropic energy gap, which vanishes on lines. The anisotropy also suppresses the enhancement below T_c. Thus T_{1n} in $YBa_2(Cu_{0.98}Zn_{0.02})_3O_{7-y}$ provides the firm ground for the analysis of $1/T_{1s}$ in $YBa_2Cu_3O_{7-y}$.

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