Cu-NQR study for stripe ordering in La-based cuprate

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Abstract

Cu-NQR spectra were measured in $La_{2-x-y}M_ySr_xCuO_4$, (M=Nd, Gd, Eu, Pr and Y), and $La_{2-x}Ba_xCuO_4$ with x=1/8. The low temperature tetragonal (LTT) structure is stabilized below T_{d2} in all the samples other than M=Pr. The usual NQR spectra observed in $T > T_{d2}$ in all the samples change to abnormally broad ones after a complete *wipeout* of NQR signal below T_{d2} except for the cases of M=Nd, Gd and Pr. In the cases of M=Nd and Gd, the complete wipeout continues to 1.5 K probably due to the extrinsic nuclear relaxation path through the paramagnetic fluctuation of Nd and Gd moment. In the case of M=Pr with no LTT phase, usual NQR spectrum continues to 1.5 K. These results support a pinning model for the static stripe ordering in the LTT phase.

1. Introduction

After the discovery of the superlattice peaks for the static spin-charge stripe order by the elastic neutron scattering in the low temperature tetragonal (LTT) phase in $La_{2-x-y}Nd_ySr_xCuO_4$ (x≃1/8)[1,2], the stripe order has attracted a special interest whether it is a general property or not of the doped CuO_2 plane in the high-T_c cuprates. Since the incommensurability δ of the inelastic neutron peaks at x=1/8 is almost equal to the static superlattice peak[3], the static stripe order is regarded as a result of pinning of the dynamical one. Such a pinning model is also supported by Zn doping effect to $La_{2-x}Sr_xCuO_4$ with x≃1/8 (LSCO1/8 (y=0))[4]. The enhanced suppression of superconductivity is interpreted as the pinning of the stripe order by Zn impurity which acts as a pinning center.

In order to investigate the relation of the static stripe ordering to the structural transition, we have measured Cu-NQR spectra in $La_{2-x-y}M_ySr_xCuO_4$ (M=Nd, Gd, Eu, Pr and Y), and $La_{2-x}Ba_xCuO_4$ with x=1/8 (LBCO1/8 (y=0)). Except for M=Pr, the re-

placement La site with various M ions stabilizes LTT phase[5]. The structural transition temperature from the low temperature orthorhombic (LTO) to LTT phase, T_{d2}, for present samples are equal to 70 K, 110 K, 138 K and 80 K for M=Nd (y=0.4), Gd (y=0.06), Eu (y=0.2) and Y (y=0.04), respectively.

2. Results and Discussions

Figure 1 shows the normalized Cu-NQR spectra at 300 K and 1.5 K for respective samples. Normal NQR spectra observed at 300 K imply that the stripe order is dynamical if it exists. At 1.5 K, the spectral results are classified into following three groups. (1) The spectra for M=Pr and LSCO1/8(y=0) which keeps LTO phase down to 1.5 K do not show any change from the normal NQR spectra. (2) In the case of M=Nd and Gd, where doped rare earth ion has a localized paramagnetic moment, no NQR signals were detected. The NQR signal was wiped out completely below T_{d2} as described later. (3) In the case of M=Eu, Y, and LBCO1/8(y=0), where any localized moments as group (2) do not exist, the NQR signal was wiped out completely in the in-
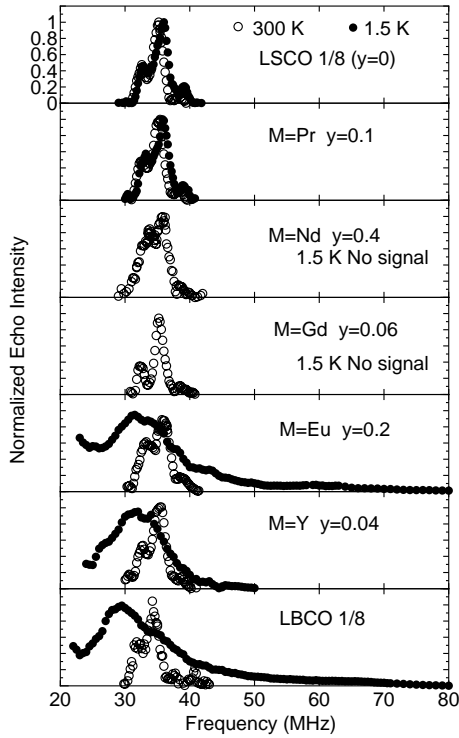
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Fig. 1. Cu NQR spectra at 300 K and 1.5 K in $La_{2-x-y}M_ySr_xCuO_4$ and $La_{2-x}Ba_xCuO_4$ with x=1/8

Fig. 2. The integrated intensity for Cu NQR spectra in $La_{2-x-y}R_ySr_xCuO_4$ with x=1/8 is plotted against T/T_{d2}

termediate temperature, but reappears as an unusual broad line with the common feature of a peak shift to lower frequency and of a long tail to higher frequency. Such unusual spectra in M=Eu and LBCO1/8(y=0) are the same as those in previous report[6].

From these results, we guess that the dynamical stripe ordering exists in doped CuO_2 plane in La-based cuprate, and become static below T_{d2}. The unusual broad spectra at 1.5 K in the group (3) corresponds to a static manifestation of the stripe order slowing down to the NQR time scale (a few μsec). The disappearance of the signal in the group (2) may be attributed to an extremely short relaxation time through the extrinsic relaxation path owing to the slow fluctuation of the paramagnetic moment at low temperature. Thus the same broad line will be expected also in group(2) if the additional fluctuation were suppressed.

Figure 2 shows the variation of the integrated intensity $(I \cdot I)$ corrected for the spin echo decay against the reduced temperature T/T_{d2}. Above T_{d2}, $I \cdot I$ for all samples increases with decreasing temperature following the Boltzmann line. While, in the LTT phase, $I \cdot I$ decreases drastically below the temperature T_W. This behavior is called *wipeout* first pointed out by Hunt et al.[7], which means the existence of nuclei relaxed within the *dead time* in the spin echo method. After the complete wipeout, $I \cdot I$ partially recovers as the un-
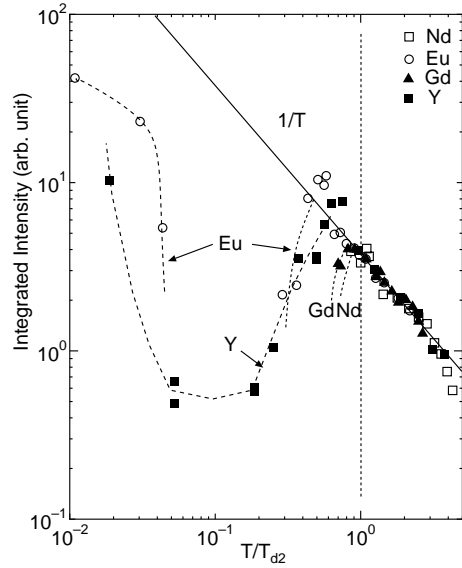
usual broad line as shown in Fig. 1. This recovery of $I \cdot I$ and the wide temperature range of the wipeout imply glassy slow down toward to the static stripe ordering. In the case of M=Nd and Gd (group(2)), T_W is relatively close to T_{d2}. While, in the case of M=Eu and Y (group(3)), $T_W \simeq 0.4 \sim 0.5 T_{d2}$. In a first sight, static stripe ordering process seems not to be related to the structural transition. However, as we have stressed in ref. 8 and 9, the enhancement below T_{d2} of the nuclear spin-lattice and henceforth nuclear spin-spin relaxation rate suggest the beginning of the slowing down of the stripe ordering at T_{d2}.

Combining the results of the spectral change with those of $I \cdot I$, we consider that the glassy slowing down through the pinning in the LTT phase is a reasonable model for the static stripe ordering process.

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