Neutron Scattering Studies on In-Plane Longitudinal phonons of $YBa_2Cu_3O_y$

M. Ito [a], H. Harashina [a,1], Y. Yasui [a], M. Sato [a,2] and K. Kakurai [b]

[a] *Department of Physics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8602 Japan*
[b] *Advanced Science Research Center, JAERI, Tokai, Ibaraki 319-1195 Japan*

Abstract

Neutron measurements have been carried out to clarify if effects of dynamical "stripes" can be seen in the behavior of in-plane longitudinal phonons of $YBa_2Cu_3O_y$ with the dispersions between $18 \sim 34$ meV. Due to the twin nature of the crystals, two branches with the main polarization along the *a*- and *b*- axes, are simultaneously observed in the single energy scan at slightly different energies. Although the widths of the profiles are significantly larger for one of the modes than for the other one, detailed consideration indicates that it is not an effect of the "stripes", but due to the oxygen deficiency at the chain sites. No anomaly has been found in their dispersion curves.

Key words: $YBa_2Cu_3O_y$; neutron scattering; phonons; "stripes"

The T_c suppression found in $La_{2-x}Ba_xCuO_4$ and $La_{2-y-x}Nd_ySr_xCuO_4$ at around the hole concentration $p=x=1/8$ is called 1/8 anomaly, and considered to be caused by the formation of the one dimensional charge order or "stripes" in the CuO_2 planes. To study whether the fluctuations of the "stripes" or the dynamical "stripes" are essentially related to the occurrence of the superconductivity, we have searched effects of dynamical "stripes" on the physical quantities of $YBa_2Cu_3O_y$ ($YBCO$, $YBCO_y$) and reported that magnetic excitation spectra of YBCO can be understood without effects of dynamical "stripes"[1,2]. The present paper reports results of phonon measurements.

Mook *et al.* [3,4] measured the in-plane longitudinal modes with the energy of $\sim(43\text{-}52)$ meV and observed the significant energy broadening for the mode which mainly polarizes along *a*-axis, at the wave vector $q(//a^*)$, corresponding to the twice of the incommensurability δ of the magnetic excitation peak. They sug-
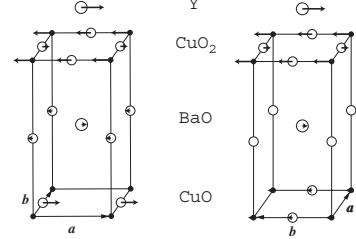
Fig. 1. Left and right panels show the vibration patterns of B_{3u}- and B_{2u}- modes at the Γ point, respectively. Note that the directions of the *a*-and *b*-axes are changed in these figures.

gest that the broadening is the effect of the dynamical "stripes". Dispersion anomaly at the scattering vector $Q=(4+2\delta,0,0)$ is also reported.

We have measured the similar in-plane longitudinal phonon modes, which are assigned as the B_{2u}/B_{3u} modes at Γ point [5]. Hereafter, we just call these branches B_{2u}/B_{3u} modes. Figure 1 shows the vibration patterns of these phonons at the Γ point. In the B_{3u} modes, atoms in the CuO_2 plane mainly vibrate perpendicular to the chain direction, while the B_{2u} modes
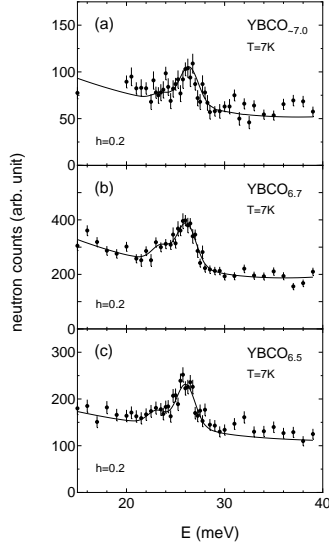
Fig. 2. In (a),(b) and (c), energy-scan profiles obtained at h=0.2, where Q=(3+h,0,0) are shown, for samples YBCO$_{\sim7.0}$, YBCO$_{6.7}$ and YBCO$_{6.5}$, respectively. Solid lines show the results of profile fittings.

vibrate mainly along the chain direction(//b). Another difference between these modes is in the fact that the B$_{3u}$ mode has larger amplitude of the chain oxygen motion than that of the B$_{2u}$ one.

Neutron measurements were carried out with the triple axis spectrometer ISSP-PONTA installed at JRR-3M of JAERI in Tokai on single crystals of YBCO$_{6.5}$ ($T_c \sim$ 50 K), YBCO$_{6.7}$ ($T_c \sim$ 62 K), and YBCO$_{\sim7.0}$ ($T_c \sim$ 91 K). Oxygen numbers y of the crystals were controlled by the annealing temperature. The horizontal collimations were 40'-40'-40'-80', and to eliminate the higher order contamination, we introduced the Pyrolytic Graphite (PG) filter after the samples. Calculated profiles obtained by convoluting the Lorentzian type intrinsic phonon profiles with the resolution function, were fitted to the energy-scan profiles at constant reciprocal points Q=(3+h,0,0).

Figure 2 shows examples of the energy scan profiles at h=0.2 and at $\sim$7 K, where h value is close to 2δ obtained from the magnetic excitation spectra. We have two peaks: The higher energy mode has the smaller widths and larger intensities than the lower energy one. It is tempting to attribute the broadening or smearing observed for the lower energy mode to an effect of the dynamical "stripes". However, the smearing is found in the wide region of h, suggesting that it is not related to the value of 2δ. It is insensitive to the carrier number p or y. Moreover, it seems to be insensitive to the temperature T, too. These facts cannot be explained by considering effects of the dynamical "stripes", which are expected to be stronger in the region of $p \sim 1/8$ and at lower T. Instead, we simply attribute the smearing
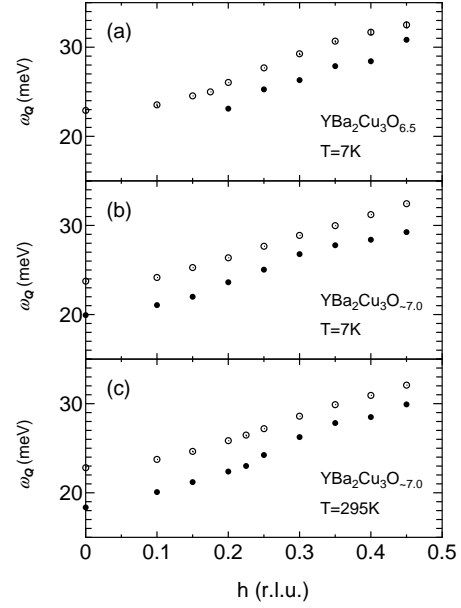

Fig. 3. The dispersion curves of ⟨B$_{2u}$/B$_{3u}$⟩ modes obtained by the profile fitting for several samples (YBCO$_{6.5}$ and YBCO$_{\sim7.0}$) and temperatures (7 K and 295 K).

to the oxygen deficiency at the chain sites, assigning that the lower energy mode is the B$_{3u}$ one which has the larger amplitude of the chain oxygen vibration than the B$_{2u}$ one. (We think that there exist, even in the sample with y=7, enough amount of oxygen deficiency to bring about the observed smearing of the mode.)

In Fig.3, dispersion curves obtained in the present studies are shown, where just the smooth q-dependence can be observed for all the samples at all temperatures. This result is contrasted to that reported by Mook et $al.$[3,4], where an anomaly was observed at q=2δ.

In summary, although the smearing of B$_{3u}$ phonon mode has been found, its h-, y- and T- dependences indicate that the dynamical "stripes" cannot be considered to be the origin of the smearing. Instead, it is attributed to the chain oxygen deficiency. No anomalous feature has been found in the dispersion curves.

References

[1] M. Sato, M. Ito, H. Harashina, M. Kanada, Y. Yasui, A. Kobayashi and K. Kakurai, J. Phys. Soc. Jpn. **70** (2001) 1342.

[2] M. Ito, H. Harashina, Y. Yasui, M. Kanada, S. Iikubo, M. Sato, A. Kobayashi and K. Kakurai, J. Phys. Soc. Jpn. **71** (2002) 265.

[3] H. A. Mook and F. Dogan, Nature **401** (1999) 145.

[4] H. A. Mook, P. Dai, F. Dogan and R. D. Hunt, Nature **404** (2000) 729.

[5] T. Yasuda and S. Mase, J. Phys. Soc. Jpn. **58** (1989) 195.