# Raman scattering study of electronic and magnetic excitations in $La_{2-x}Sr_xCuO_4$

Masayuki Udagawa [a,1], Norio Ogita [a], Shigenobu Sakita [b], Jun'ya Hori [b], Fumihiko Nakamura [c], Takashi Suzuki [c], Toshizo Fujita [c]

[a] *Faculty of Integrated Arts & Sciences, Hiroshima University, Higashi-Hiroshima, 739-8521, Japan*
[b] *Venture Business Laboratory of Hiroshima University, Higashi-Hiroshima, 739-8527, Japan*
[c] *Graduate School of ADSM, Hiroshima University, Higashi-Hiroshima, 739-8526, Japan*

**Abstract**

Electronic and magnetic excitations with $A_{1g}$-symmetry have been investigated by the polarized Raman scattering in the energy region between 0 and 4000cm$^{-1}$ for $La_{2-x}Sr_xCuO_4$ ($x$=0, 0.1, 0.113, 0.15, 0.22). In the $b(a,a)\bar{b}$ polarization both magnetic and electronic excitations are allowed, while only electronic excitation for $b(c,c)\bar{b}$. In $x \leq 0.15$, the intensity of $b(a,a)\bar{b}$ is larger than that of $b(c,c)\bar{b}$ due to the additional existence of the magnetic excitation, however, both spectra become the same for $x$=0.22. This result is the experimental evidence that dynamical magnetic fluctuation disappears in the over-doped region in $La_{2-x}Sr_xCuO_4$.

*Key words:* $La_{2-x}Sr_2CuO_4$, Raman scattering, magnetic excitation, electronic excitation

## 1. Introduction

Recently, magnetic interaction models seem to be accepted as a pairing mechanism for hight-$T_c$ superconductors. However, the recent report of photoemission pointed out the importance of electron-phonon interaction.[1] Furthermore, our Raman scattering results reported the existence of electron-phonon coupling in $K_2NiF_4$-type crystals and also the correlation between $T_c$ and electron-phonon coupling parameter for LSCO.[2,3] These recent reports suggest that the electron-phonon mechanism cannot be excluded. Thus, to understand the mechanism, new experiments for the magnetic excitations are necessary. In this report, we have investigated the propagation-direction dependence of the magnetic and electronic excitations in the wide energy region by Raman scattering. Such a measurement has not been reported, since the most of the measurements have been done on only the c-plane.

[1] Corresponding author. E-mail: udagawa@hiroshima-u.ac.jp

## 2. Experimental

The single crystals of $La_{2-x}Sr_xCuO_4$ ($x$ =0, 0.1, 0.113, 0.15, 0.22) were grown by a traveling-solvent floating-zone method. After the surface polish, the samples were annealed in $O_2$ at 920 $^o$C for 50 h and 500 $^o$C for 50 h, in order to minimize strains and to obtain the better oxygen stoichiometric specimens. In the Raman scattering measurements, an $Ar^+$ laser light with a wavelength of 514.5 nm was employed as the incident beam and its output power was 12.5 mW. The scattered light into nearly-backward direction was analyzed by a triple monochromator (JASCO model NR-1800), and the analyzed light was detected by a CCD multi-channel detector (Princeton Instrument model LN/CCD-576E).

In this experiment, we studied two different polarization geometries of $b(a,a)\bar{b}$ and $b(c,c)\bar{b}$ with the same $A_{1g}$ symmetry. In the symbol of $k_i(p_i,p_s)k_s$, $k$ and $p$ are the directions of the propagation and polarization of light, respectively, and the suffix of $i$ and $s$ the incident

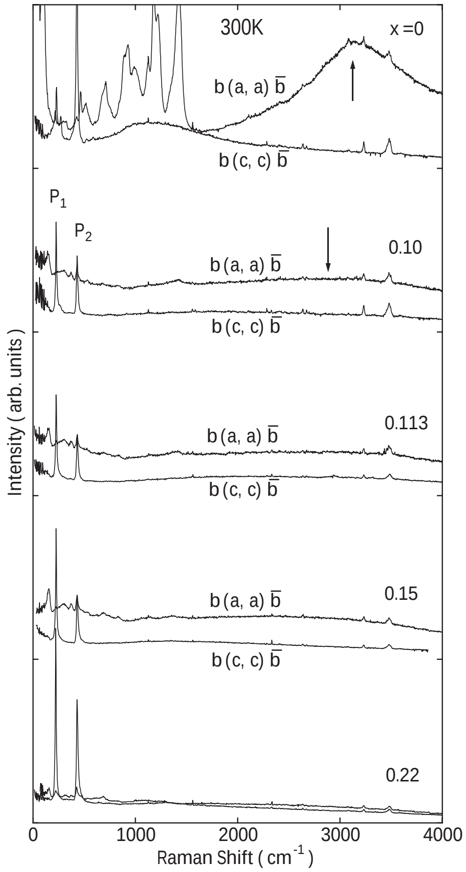


Fig. 1. $x$-dependence of $b(a,a)\bar{b}$ and $b(c,c)\bar{b}$ spectra of $La_{2-x}Sr_xCuO_4$ at 300K. The arrow shows the peak position of magnetic excitation. $P_1$ or $P_2$ indicates the phonon allowed for the tetragonal symmetry. Note, the intensities of $b(a,a)\bar{b}$ and $b(c,c)\bar{b}$ are comparabale for $x$=0.22.

and scattered light, respectively. Since two-magnon excitations are excluded from the selection rule in the $b(c,c)\bar{b}$ geometry[4], the $b(c,c)\bar{b}$ spectrum gives only electronic excitation, while $b(a,a)\bar{b}$ the mixed spectra of magnetic and electronic ones.

## 3. Results and Discussion

Figure 1 shows the concentration dependence of $B(c,c)\bar{b}$ and $b(a,a)\bar{b}$ for $La_{2-x}Sr_xCuO_4$ ($x$=0, 0.1, 0.113, 0.15, 0.22) at room temperature. Each set of $b(c,c)\bar{b}$ and $b(a,a)\bar{b}$ spectra in every Sr-concentration is shifted vertically to avoid the overlaps. The small spike-like peaks below 150 $cm^{-1}$ are the rotation spectra of air. The extra peaks between 480 and 1500 $cm^{-1}$ at $x$=0 have been assigned as two-phonon contributions.

The broad peak around 3000 $cm^{-1}$ in the $b(a,a)\bar{b}$ spectrum for $x = 0$ is ascribed to two-magnon process.

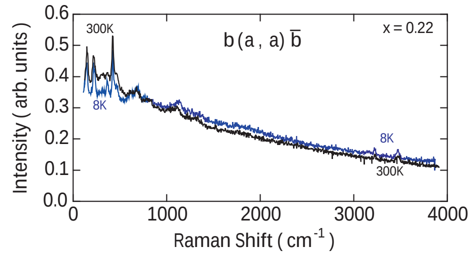


Fig. 2. Temperature dependence of $b(a,a)\bar{b}$. There is no remarkable change between 300K and 8K.

The arrows indicate the energy of the two-magnon peak and it shifts to lower energy with increasing $x$.

The intensity of the $b(a,a)\bar{b}$ exceeds that of $b(c,c)\bar{b}$ for $x$=0, 0.1, 0.113, and 0.15, however, both intensities becomes comparable at $x$=0.22. As described in the previous section, the magnetic excitation is excluded due to the symmetry for the $b(c,c)\bar{b}$ spectrum. In fact, the background intensity of $b(c,c)\bar{b}$ increases from $x$=0 to 0.22 with the increase of the carrier density at the low energy region. Thus, the intensity difference between $b(a,a)\bar{b}$ and $b(c,c)\bar{b}$ is considered as the existence of the magnetic excitation. The representative temperature dependence of $b(a,a)\bar{b}$ is shown in Fig.2. As shown in this figure, there is no remarkable change of electronic excitations between 300K and 8K. The fact, that the magnetic fluctuation vanishes at $x$=0.22, clearly shows that we should reconsider the crossover from the magnetic mechanism at the under-doped region to Fermi liquid model at over-doped region, since $T_c$ of $x$=0.22 was 28K and is not so lower than the maximum of 34K.

Finally, we note that the remarkable change of the phonon spectra has been found between $b(a,a)\bar{b}$ and $b(c,c)\bar{b}$. The detailes will be discussed elsewhere.

## Acknowledgements

This work is supported in part by a Grant-in-Aid for COE Research (No.13CE2002) of the Ministry of Education, Culture, Sports, Science and Technology of Japan. The Raman scattering experiment was also supported by the cryogenic center of Hiroshima University.

## References

[1] A. Lanzara, et al., Nature **412** (2001) 510.

[2] S. Nimori, S. Sakita, F. Nakamura, T. Fujita, N. Ogita and M. Udagawa, Phys. Rev. B**62** (2000) 4142.

[3] S. Sakita, S. Nimori, Z. Q. Mao, Y. Maeno, N. Ogita and M. Udagawa, Phys. Rev. B**63** (2001) 134520-1.

[4] J. B. Parkinson, J. Phys. C **2** (1969) 2012.