

Study of the Charge Dynamics in $\text{Sr}_{14-x}\text{Ca}_x\text{Cu}_{24}\text{O}_{41}$ by Resonant Inelastic X-ray Scattering

M. Yoshida^{1,2}, K. Ishii², I. Jarrige², K. Ikeuchi³, Y. Murakami³, J. Mizuki²,
K. Tsutsui², T. Tohyama⁴, S. Maekawa⁵, K. Kudo⁶, Y. Koike⁷,
K. Kumagai⁸, Y. Endoh⁹, J. H. Kim¹⁰ and M. Upton¹⁰

Dept. of Phys., Tohoku Univ.¹, SPring-8, JAEA², IMSS, KEK³,
YITP, Kyoto Univ.⁴, ASRC, JAEA⁵, Dept. of Phys., Okayama Univ.⁶,
Dept. of Appl. Phys., Tohoku Univ.⁷, Dept. of Phys., Hokkaido Univ.⁸, IAS⁹, APS¹⁰

$\text{Sr}_{14-x}\text{Ca}_x\text{Cu}_{24}\text{O}_{41}$ is the first discovered superconducting cuprate without CuO_2 planes, composed of two-leg ladders and edge-sharing chains. By substituting Sr with Ca, holes are transferred from the chains to the ladders [1]. Static charge order in $x = 0$ and $x \sim 11$ with fivefold and threefold periodicity, respectively, was found by A. Ruydy et al. using resonant soft x-ray diffraction [2]. On the other hand, a charge-density wave (CDW) state was reported to occur at $x \sim 9$ by T. Vuletić et al. based on a microwave conductivity experiment [3]. There is not a perfect consensus about two experimental results and also it is unclear whether there is any connections between the static charge orders at $x = 0$ and $x \sim 11$.

Resonant inelastic x-ray scattering (RIXS) experiment has been developed with the emergence of third-generation synchrotron radiation x-ray sources. RIXS at the Cu- K edge has been shown to be well suited to the study of the electronic excitations related to the Cu orbitals with momentum resolution. In order to understand the dynamics of doped holes at ambient pressure in the ladders, we have attempted to observe the charge excitations associated with the static charge order and/or CDW state in $\text{Sr}_{14-x}\text{Ca}_x\text{Cu}_{24}\text{O}_{41}$ using RIXS. We carried out this experiment at the BL11XU beamline at SPring-8 and at the Sector30 of the APS. Five samples with different compositions ($x = 0, 3, 6, 9, 11.5$) were used.

We measured both momentum and temperature dependence of the intraband excitations which is associated with the dynamics of doped holes in the Zhang-Rice singlet band in the ladder. Our results show that both dependences are different between $x \sim 6$ and $x \sim 9$. In $x \sim 6$, the intensity of the intraband excitations decreases with decreasing temperature and an additional peak structure appears only at $q = (q_{\text{rung}}, q_{\text{leg}}) = (0, 2\pi/5)$, which corresponds to the periodicity of the static charge order in $x = 0$. Therefore, we suppose that the charge fluctuations accompanied by the static charge order at $x = 0$ remain at $x \sim 6$ which is consistent with the existence of CDW state. Meanwhile, the intensity remains unchanged upon temperature variation at $x \sim 9$. An additional structure appears, showing a clear dispersion oriented from the zone center to the zone boundary. This is similar to the dispersive mode in the intraband excitations in electron-doped systems, $\text{Nd}_{1.85}\text{Ce}_{0.15}\text{CuO}_4$ [4]. It is the first time that the dispersion of the dynamics of doped holes is observed in hole-doped systems.

In this presentation, we will discuss the relation between the observed excitations and the charge dynamics in the ladder in detail.

<References> [1] M. Kato et al., *Physica C* **258**, 284, (1996) [2] A. Ruydy et al., *Phys. Rev. Lett.* **97**, 016403, (2006) [3] T. Vultić et al., *Phys. Rev. Lett.* **90**, 257002, (2003) [4] K. Ishii et al., *Phys. Rev. Lett.* **94**, 207003, (2005)