Evaluation of self-energy in overdoped Bi2201 by Angle-Resolved Photoemission Spectroscopy

Y. Miyai[a], Shiv Kumar[b], T. Kurosawa[c], M. Oda[d], S. Ideta[b], K. Shimada[b]

[a]*Graduate School of Science, Hiroshima University, Kagamiyama 1-3-1, Higashi-Hiroshima 739-8526, Japan*
[b] *Hiroshima Synchrotron Radiation Center, Hiroshima University, Kagamiyama 1-3-1, Higashi-Hiroshima 739-8526, Japan*
[c] *Fuculty of Science and Engineearing, Muroran Institute of Technology, 27-1 Mizumoto-cho, Muroran, Hokkaido, 050-8585, Japan*
[d] *Department of Physics, Hokkaido University, Sapporo 060-0809, Japan*

Keywords: High-T_C Superconductor, ARPES, Many-body interactions

High transition-temperature (T_C) cuprate superconductors have attracted much interest since their discovery in 1986 for their high superconducting transition temperature as well as unusual physical properties such as bad metal state and formation of density waves [1,2]. To understand these physical properties, it is necessary to quantitatively evaluate the electron-electron interaction and the electron-boson interaction and to experimentally clarify a quasiparticle state near the Fermi level. Angle-Resolved Photoemission Spectroscopy (ARPES) is an effective and direct way to investigate electronic states in solids. The ARPES spectrum is associated with the imaginary part of one-particle Green's function and gives the quasiparticle excitation spectrum of the quasiparticle. By analyzing ARPES spectral lineshape quantitatively, it is possible to extract the self-energy that includes information of the electron-electron and the electron-boson interactions. Most of the previous ARPES studies of cuprates have focused on the investigation of the electron-boson interaction at the vicinity of the Fermi level. As the self-energy contains the contributions from the electron-electron interaction, it was subtracted based on the empirical assumptions. On the other hand, the water-fall-like spectral feature which is peculiar to the strong correlation system has been observed in the valence band of cuprates in the wide energy range [3]. To understand the mechanism of the high Tc superconductivity in cuprates, it is important to clarify the electron-boson interaction as well as electron-electron interaction. For this purpose, it is necessary to analyze the electronic states from small energy scale near the Fermi level to large energy scale throughout the entire valance band, but this kind of study has not been sufficiently done so far.

To quantitatively evaluate the electron-boson interaction and the electron-electron interaction, we have focused on the Bi-based high-T_C cuprate, $(Bi,Pb)_2Sr_2CuO_{6+\delta}$ (Pb-Bi2201) and performed high-resolution ARPES. Bi2201 having a single CuO_2 plane in the unit cell is expected to eliminate complexity derived from plural CuO_2 planes, and using the overdoped sample that is expected to behave like metals enable us to extract normal self-energy. Figures 1(a) and (b) show the experimentally extracted real part and imaginary part of the self-energy. The solid lines show fitting to a model self-energy. One can see that the real part of the self-energy crosses the zero line and the imaginary part of self-energy has the maximum at $\omega \sim -0.5$ eV. Figure 1(c) shows the simulation of the ARPES spectrum using the model self-energy. Because the imaginary part of the self-energy gives the spectral width, the water-fall-like structure is caused by the suppression of the spectral intensity due to the significant linewidth broadening at $\omega \sim -0.5$ eV due to the electron-electron interaction.

In addition, we extracted the self-energy due to the electron-boson interaction near the Fermi level using the laser-based μARPES system by subtracting the contribution from the electron-electron interaction estimated above. The coupling parameter of the electron-boson interaction is $\lambda_{EB} \sim 1.5$ at low temperature and decreases with increasing temperature (Figure 1(d)). This behavior is similar to the temperature dependence of the coupling parameter of the electron-phonon interaction [4]. It should be also noted that the total coupling parameter of the electron-electron interaction and the electron boson interaction is $\lambda \sim 2.8$

(strong coupling) at low temperature, and the electron-electron interaction is also significant near the Fermi level.

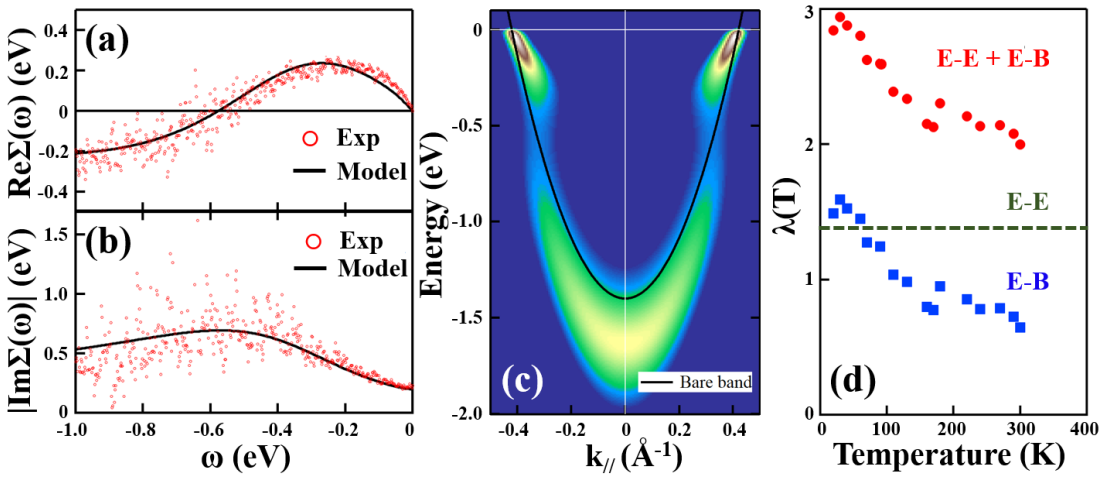

FIGURE 1. (a)(b) Circles indicate experimentally evaluated real and imaginary parts of the self-energy. Solid lines indicate fits to the model self-energy. (c) ARPES simulation using the model self-energy. (d) The temperature dependence of the coupling parameter.

REFERENCES

1. P. Choubey *et al.*, Proceedings of National Academy of Sciences, 117, 14805 (2020).
2. Y.Y. Peng *et al.*, Nature Materials 17, 697 (2018).
3. D.S.Inosov, et al, Phys. Rev. Lett **99**, 237002, (2007).
4. J.Jiang, et al., Phys. Rev. B **84**, 155124, (2011).