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Role of coherent part and incoherent part in the electron transport properties of the materials characterized by strong electron correlation

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Recent progress in angle resolved photoemission spectroscopy (ARPES) allows us to gain deep insight into the momentum dependent electronic structure of the materials. The self-energy of quasiparticles can be also investigated by ARPES as a function of energy and momentum, in which information about the variety of many body effects including the electron correlations is involved. The real part of the self-energy indicates the energy shift from that of the bare electrons free from the many body effects, while the imaginary part represents the lifetime of the quasiparticles. A large number of groups including us have employed this highly sophisticated experimental technique to investigate the electronic structure and the many body effects of materials, such as the high-*T*c superconductors.

We realized by using ARPES measurements that the electron transport properties could be quantitatively analyzed, because all factors, the number of electrons at a given energy, momentum dependent group velocity, and momentum dependent relaxation time, are obtainable from the ARPES measurements, provided that the lifetime of the quasiparticles is considered as the relaxation time of conducting wave packets. For the high-T_c superconductors, in which almost of all quasiparticles behave as a coherent wave, this method worked well and the electrical resistivity, thermoelectric power, and Hall coefficient were quantitatively reproduced by calculation using the information obtained from the ARPES measurement. [1]

The layered cobalt oxide Na_xCoO_2 is widely known to possess variety of unusual properties, such as superconductivity, the large magnitude of thermoelectric power, the Curie-Weiss magnetic susceptibility behavior coexisting together with the metallic electrical conduction, the charge density wave oriented insulating phase, and the spin density wave behaviors. Those characteristics are presumably caused by the strong electron correlation. Recently, we have intensively investigated the effect of strong electron correlation upon the electronic structure and the electron transport properties of Na_xCoO_2 by using high-resolution ARPES measurements, and found that the incoherent part as well as the coherent part, strongly affects the electron transport properties.

The electronic structure of layered cobalt oxides, including the present material Na_xCoO_2, is characterized by the simultaneous possession of coherent part and incoherent part shown as Fig.1. Generally speaking, the incoherent part is caused by the strong electron correlation, and this strong electron correlation drastically reduces the energy-width of the “coherent band”. Indeed, the observed energy-width of the “coherent band” is reduced to 1/3 of that of the band calculated by the FLAPW-LDA method. Note here that these characteristics in electronic structure cannot be predicted by the first principle calculation using the mean field theory. The use of the high-resolution ARPES, therefore, is of great importance in order to reveal the electronic structure of materials under the strong many body effects.

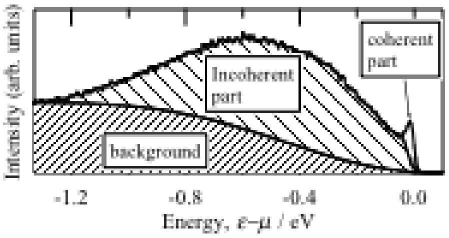

Fig. 1. An energy distribution curve of the $Na_{0.7}CoO_2$ at a Fermi wave vector. The spectrum is definitely characterized by the coherent and incoherent parts.

The temperature dependence of the thermoelectric power and the electrical resistivity was well accounted for with the Boltzmann transport theory provided that the contributions of coherent and incoherent part are properly taken into account. Both properties are dominantly determined by the coherent part at low temperature below 150 K and by the incoherent part at high temperature above 300K, respectively. The measured and calculated thermoelectric power of $Na_{0.7}CoO_2$ is shown in Fig.2 as one of the typical examples.

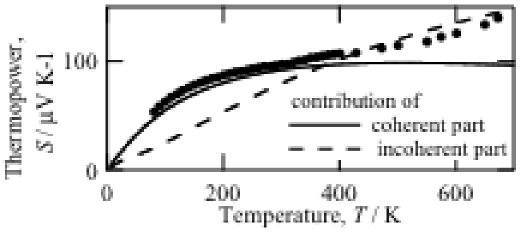

Fig. 2. Measured (markers) and calculated (lines) thermoelectric power of $Na_{0.7}CoO_2$.

[1] T. Kondo *et al.*, Phys. Rev. B **72** (2005) 024533., T. Kondo *et al.*, Phys. Rev. B **74** (2006) 225411. , T. Kondo *et al.*, J. Elec. Spec. Relat. Phenom. **144-147** (2005) 1249-1252., T. Takeuchi *et al.*, J. Elec. Spec. Relat. Phenom. **156-158** (2007) 452-456., H. Komoto and T. Takeuchi, J. Elec. Mater. **38** (2009) 1365-1370.