Synchrotron Radiation Spectroscopy on Strongly Correlated Electron Systems

UVSOR Facility
Division of Advanced Solid State Physics

KIMURA, Shin-ichi	Associate Professor
MATSUNAMI, Masaharu	Assistant Professor
MIYAZAKI, Hidetoshi	IMS Fellow*
MORI, Tatsuya	Post-Doctoral Fellow[†]
IMURA, Keiichiro	Post-Doctoral Fellow
OZKENDIR, Osman Murat	Research Fellow[‡]
NISHI, Tatsuhiko	Research Fellow[§]
IIZUKA, Takuya	Graduate Student
HAJIRI, Tetsuya	Graduate Student[‖]
NIWA, Ryosuke	Graduate Student[‖]

Solids with strong electron–electron interaction, namely strongly correlated electron systems (SCES), have various physical properties, such as non-BCS superconducting, colossal magneto-resistance, heavy fermion and so on, which cannot be predicted by first-principle band structure calculation. Due to the physical properties, the materials are the candidates of the next generation functional materials. We investigate the mechanism of the physical properties as well as the electronic structure of SCES, especially rare-earth compounds, organic superconductors and transition-metal compounds, by infrared/THz spectroscopy and angle-resolved photoemission spectroscopy based on synchrotron radiation. Since experimental techniques using synchrotron radiation are evolved rapidly, the development of the synchrotron radiation instruments is also one of our research subjects.

1. Electronic-Structure-Driven Magnetic Ordering in a Kondo Semiconductor $CeOs_2Al_{10}$[1,2)]

Cerium-based compounds CeM_2Al_{10} (M = Ru, Os) are new-type of Kondo semiconductors/insulators because they show antiferromagnetic transition at higher temperature than that expected by the Ruderman-Kittel-Kasuya-Yoshida (RKKY) interaction. We reported the anisotropic changes in the electronic structure of a Kondo semiconductor $CeOs_2Al_{10}$ across an anomalous antiferromagnetic ordering temperature (T_0) of 29 K, using optical conductivity spectra as shown in Figsures 1 (a)-(c). The spectra along the *a* and *c* axes indicate that an energy gap due to the hybridization between conduction bands and nearly local 4f states, namely the c–f hybridization gap, emerges from a higher temperature continuously across T_0. Along the *b* axis, on the other hand, another energy gap with a peak at 20 meV becomes visible at 39 K (> T_0) and fully opens at T_0 (Figure 1d) because of a charge instability. This result implies that the appearance of the energy gap, as well as the change in the electronic structure along the *b* axis, induces the antiferromagnetic ordering below T_0.

In the reference material $CeFe_2Al_{10}$, which does not have the anomalous antiferromagnetic ordering, the temperature

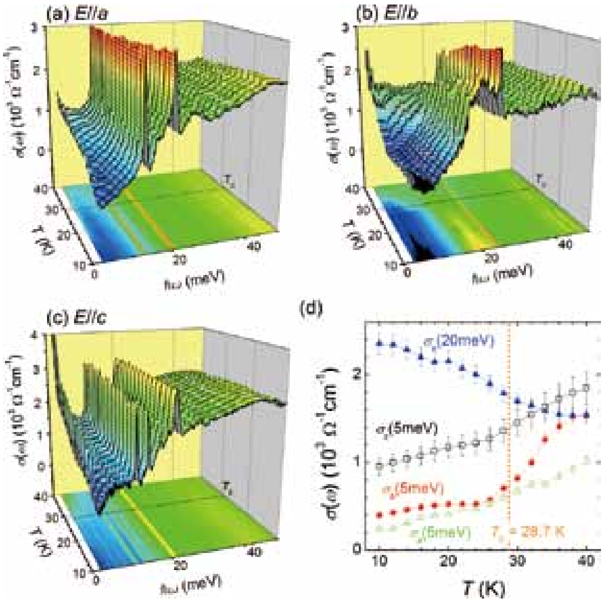

Figure 1. Temperature-dependent optical conductivity [$\sigma(\omega)$] spectra in *E* // *a* (a), *E* // *b* (b), and *E* // *c* (c) at temperatures from 10 to 40 K. (d) Temperature dependence of representatives of spectral change. σ_x(5 meV) [x = *a*, *b*, *c* (x is axis name)] and σ_b(20 meV) are the intensities of the $\sigma(\omega)$ spectra at 5 and 20 meV, respectively.

dependence of the polarized optical conductivity [σ(ω)] spectra were also reported. The σ(ω) spectrum along the *b*-axis differs greatly from that in the *ac*-plane, indicating that this material has an anisotropic electronic structure. At low temperatures, in all axes, a shoulder structure due to the optical transition across the hybridization gap between the conduction band and the localized 4f states, namely c–f hybridization, appears at 55 meV. However, the gap opening temperature and the temperature of appearance of the quasiparticle Drude weight are strongly anisotropic indicating the anisotropic Kondo effect. The strong anisotropic nature in both electronic structure and Kondo effect is considered to be relevant to the anomalous magnetic phase transition in $CeRu_2Al_{10}$ and $CeOs_2Al_{10}$.

2. Nodeless Superconducting Gap in $A_xFe_2Se_2$ (A = K, Cs) Revealed by Angle-Resolved Photoemission Spectroscopy[3)]

Pairing symmetry is a fundamental property that characterizes a superconductor. For the iron-based high-temperature superconductors, an $s_\pm$-wave pairing symmetry has received increasing experimental and theoretical support. More specifically, the superconducting order parameter is an isotropic s-wave type around a particular Fermi surface, but it has opposite signs between the hole Fermi surfaces at the zone center and the electron Fermi surfaces at the zone corners. Here we report the low-energy electronic structure of the newly discovered superconductors, $A_xFe_2Se_2$ (A = K, Cs) with a superconducting transition temperature (T_c) of about 30 K. We found $A_xFe_2Se_2$ (A = K, Cs) is the most heavily electron-doped among all iron-based superconductors. Large electron Fermi surfaces are observed around the zone corners as shown in Figure 2, with an almost isotropic superconducting gap of ~10.3 meV, whereas there is no hole Fermi surface near the zone center, which demonstrates that interband scattering or Fermi surface nesting is not a necessary ingredient for the unconventional superconductivity in iron-based superconductors. Thus, the sign change in the $s_\pm$ pairing symmetry driven by the interband scattering as suggested in many weak coupling theories becomes conceptually irrelevant in describing the superconducting state here. A more conventional s-wave pairing is probably a better description.

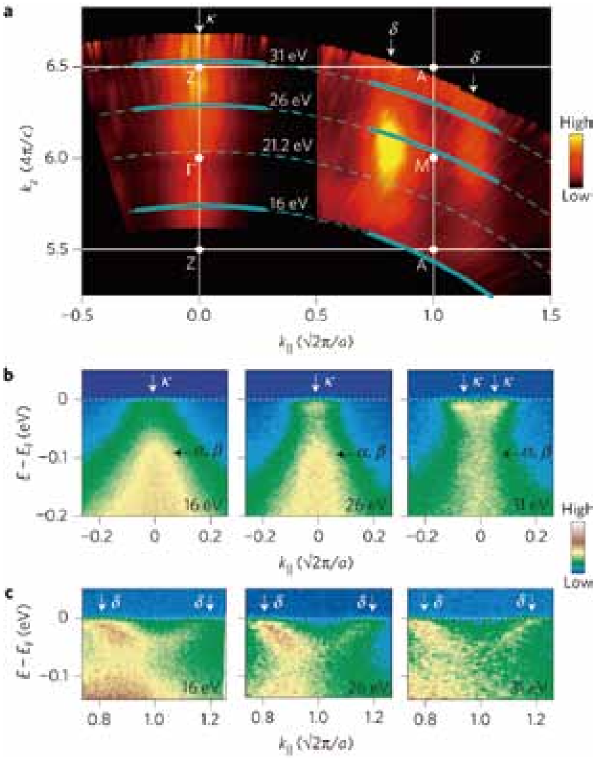

Figure 2. The photoemission intensity of $K_{0.8}Fe_2Se_2$ in the ΓZAM plane. The intensity was integrated over a window of (E_F–15 meV, E_F+15 meV). Different k_z's were accessed by varying the photon energy at Beamline 7U of UVSOR, as indicated by the dashed lines, where an inner potential of 11 eV is used to obtain k_z. **b**, **c**, Photoemission intensity along the three momentum cuts across Γ–Z, and the other three momentum cuts across M–A respectively as marked by thick solid lines in **a**. The data were taken with horizontally polarized 16, 26 and 31 eV photons.

References

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* Present Address; Center for Fostering Young and Innovative Researchers, Nagoya Institute of Technology

† Present Address; Graduate School of Pure and Applied Sciences, University of Tsukuba

‡ from Mersin University, Turkey

§ from Chiba University

|| carrying out graduate research on Cooperative Education Program of IMS with Nagoya University