Synchrotron Radiation Spectroscopy on Strongly Correlated Electron Systems

UVSOR Facility
Division of Advanced Solid State Physics

KIMURA, Shin-ichi	Associate Professor
ITO, Takahiro	Assistant Professor
SAKURAI, Yoko	IMS Fellow*
IM, Hojun	Post-Doctoral Fellow†
SUMII, Ryohei	Post-Doctoral Fellow‡
MIZUNO, Takafumi	Graduate Student
MIYAZAKI, Hidetoshi	Graduate Student§
OTA, Syunji	Graduate Student§,‖
MIZUNUMA, Takuro	Graduate Student¶,**
IIZUKA, Takuya	Graduate Student††

Solids with strong electron–electron interaction, so-called strongly correlated electron systems (SCES), have various physical properties such as non-BCS superconducting, colossal magneto-resistance, heavy fermion and so on. The materials are one of candidates of the next generation functional materials. We are investigating the mechanism of the physical properties of SCES, especially rare-earth compounds, organic superconductors and transition-metal compounds, by infrared and angle-resolved photoemission spectroscopies using synchrotron radiation. Since experimental techniques using synchrotron radiation are evolved rapidly, the development is also one of our research subjects.

1. Optical Observation of Non-Fermi-Liquid Behavior in the Heavy Fermion State of $YbRh_2Si_2$[1)]

The crossover between the localized and itinerant properties of rare-earth compounds is one of the main topics of recent solid state physics. We investigate the change of the electronic structure from the localized to itinerant states *via* the quantum critical point. The control from the localized to itinerant properties is usually done by applying pressure or changing the concentration of ligand atoms. $YbRh_2Si_2$ is a recently developed non-Fermi liquid material and is located near the quantum critical point. At the quantum critical point, the electrical resistivity is proportional to the temperature ($\rho \propto T$) below 10 K that is different from the Femi liquid property ($\rho \propto T^2$). Then we measured far-infrared optical properties of $YbRh_2Si_2$ for photon energies down to 2 meV and temperatures 0.4–300 K. In the coherent heavy quasiparticle state, a linear dependence of the low-energy scattering rate on both temperature and photon energy was found (Figure 1). We relate this distinct dynamical behavior different from that of Fermi-liquid materials to the non-Fermi-liquid nature, *i.e.*, the electrodynamic property of $YbRh_2Si_2$ also indicates the non-Fermi liquid nature.

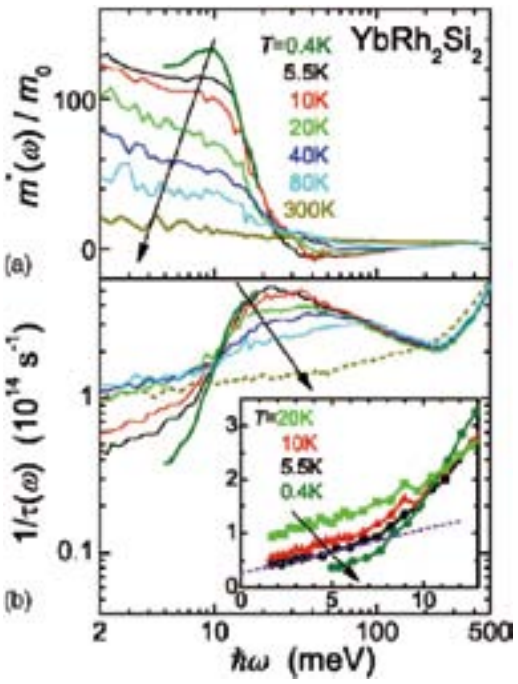

Figure 1. Temperature dependence of (a) the effective mass relative to the free-electron mass, $m^*(\omega)/m_0$, and (b) the scattering rate $1/\tau(\omega)$ as a function of photon energy. The inset of (b) is the low-energy part of $1/\tau(\omega)$. The dashed line emphasizes a $1/\tau(\omega) \propto \omega$ behavior.

2. Magnetic-Field-Induced Superconductor–Insulator–Metal Transition in an Organic Conductor: An Infrared Magneto-Optical Imaging Spectroscopic Study[2)]

The magnetic-field-induced superconductor–insulator–metal transition (SIMT) in partially deuterated κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Br, which is just on the Mott boundary, has

been observed using the infrared magneto-optical imaging spectroscopy. The infrared reflectivity image on the sample surface revealed that the metallic (or superconducting) and insulating phases coexist and they have different magnetic-field dependences as shown in Figure 2. One of the magnetic-field dependence is SIMT that appeared on part of the sample surface. The SIMT was concluded to originate from the balance of the inhomogeneity in the sample itself and the disorder of the ethylene end groups resulting from fast cooling.

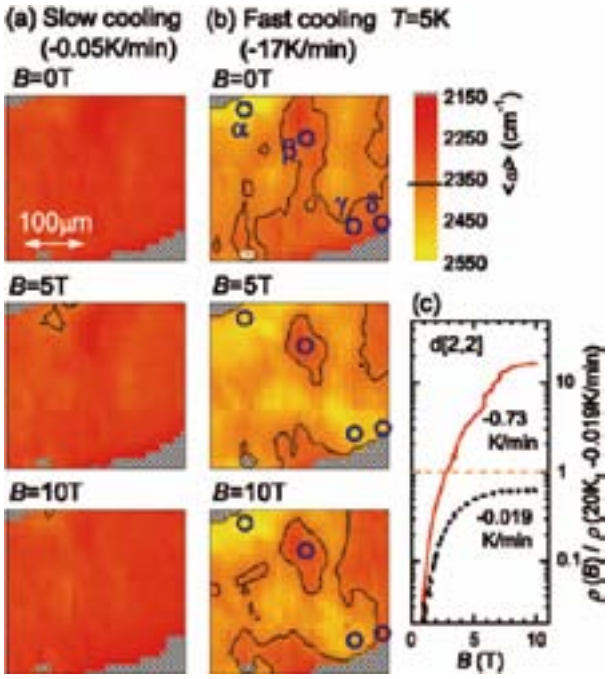

Figure 2. Magnetic-field and cooling-rate [slow cooling in (a) and fast cooling in (b)] dependencies of the spatial image of the center of the spectral weight <ω> of 50% deuterated κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Br (*d*[2,2]) at T = 5 K. The wavenumber of <ω> below (above) 2350 cm^{-1} is metallic (insulating) region. The black lines indicate the rough *M–I* boundary (ω_{MI}) of 2350 cm^{-1} and the lower and higher wave numbers indicate the insulating and metallic (superconducting) reflectivity spectra, respectively. The blue circles in (b) indicate the points of the different magnetic-field dependencies on the sample surface. The hatched area is the outside of the sample. (c) Magnetic-field and cooling-rate dependencies of the normalized resistivity of *d*[2,2] at 5.5 K for the reference. Though the cooling rate of –0.73 K/min is different from that of (b), the physical character is the same.

3. Infrared Reflection-Absorption Spectroscopy of Alq_3 Thin Film on Silver Surface Using Synchrotron Radiation[3)]

Infrared reflection-absorption spectra of Alq_3 film on Ag surface have been measured as a function of thickness in the wave number region from 300 to 500 cm^{-1} using synchrotron radiation, UVSOR-II, to determine which of the geometrical isomers of Alq_3 is dominant. The observed spectra of the Al–N stretching modes of Alq_3 at around 420 cm^{-1} indicate that Alq_3 film predominantly consists of the meridional isomer including the first monolayer adsorbed on the Ag surface as shown in Figure 3. In the spectrum of the monolayer Alq_3, the Al–N stretching mode was observed to be located at wave number slightly lower than that of multilayer Alq_3 probably due to the charge transfer between Alq_3 and the Ag surface.

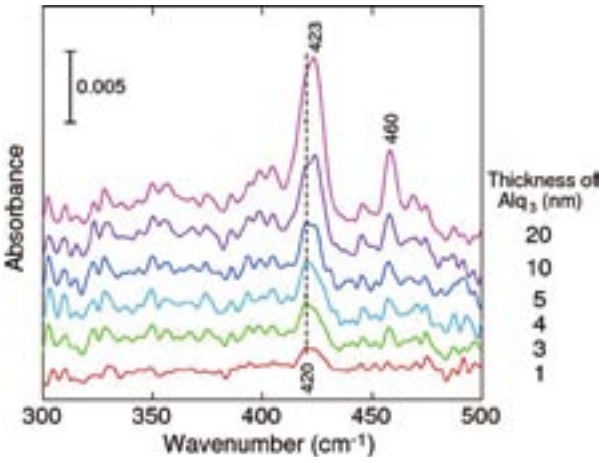

Figure 3. The thickness dependence of the IRAS spectra of an Alq_3 film on Ag surface.

References

1) S. Kimura, J. Sichelschmidt, J. Ferstl, C. Krellner, C. Geibel and F. Steglich, *Phys. Rev. B* **74**, 132408 (4 pages) (2006).
2) T. Nishi, S. Kimura, T. Takahashi, H. J. Im, Y. S. Kwon, T. Ito, K. Miyagawa, H. Taniguchi, A. Kawamoto and K. Kanoda, *Phys. Rev. B* **75**, 014525 (5 pages) (2007).
3) Y. Sakurai, S. Kimura and K. Seki, *Appl. Phys. Lett.* **91**, 061922 (3 pages) (2007).

* Present Address; JAEA/SPring-8, Sayo, Hyogo 679-5148
† from Sungkyunkwan University, Korea
‡ from Nagoya University
§ carrying out graduate research on Cooperative Education Program of IMS with Nagoya University
|| Present Address; INAX Co. Ltd.
¶ carrying out graduate research on Cooperative Education Program of IMS with Meiji University
** Present Address; Department of Physics, Meiji University, Kawasaki 214-8571
†† carrying out graduate research on Cooperative Education Program of IMS with Kobe University