Correlated Electron Physics

During the last two decades, an enormous number of strongly interacting electrons in solid materials have been observed exhibiting various novel physical phenomena, such as unconventional superconductivity, quantum critical (non-Fermi liquid) behaviors, and exotic types of magnetism (multipolar orderings/fluctuations), that cannot be understood within the framework of conventional solid state physics. Our group aims to create and observe unprecedented and innovative electronic states in new materials, focusing on multiple-degrees of freedom involved in *d*- and *f*-electron, i.e., spin, orbital, charge, and ion vibration. For this purpose, we explore new compounds, grow world class high-quality single crystals by exploiting different types of furnaces, and perform systematic measurements of transport, magnetic, and thermodynamic properties to improve our fundamental understanding of novel phenomena, in collaboration with many institutions around the world. We are also interested in the application of our findings as novel functional materials.

(Keywords: strongly-correlated electrons, superconductivity, quantum critical phenomena, multipole)

1. Staff Members and HP

Professor : Y. Aoki
Associate Professor: T. Matsuda
Assistant Professor : R. Higashinaka

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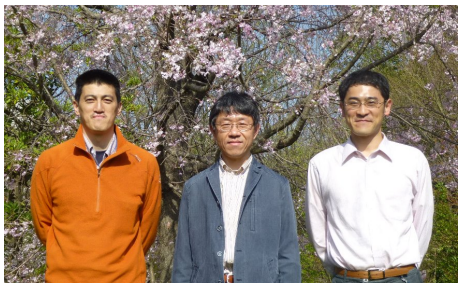
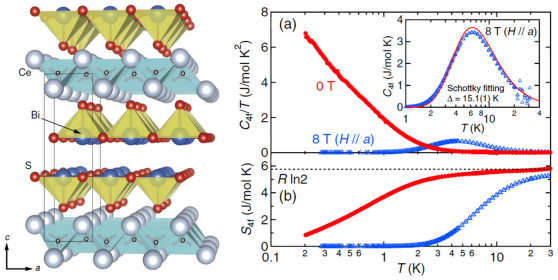


2. Recent Activities

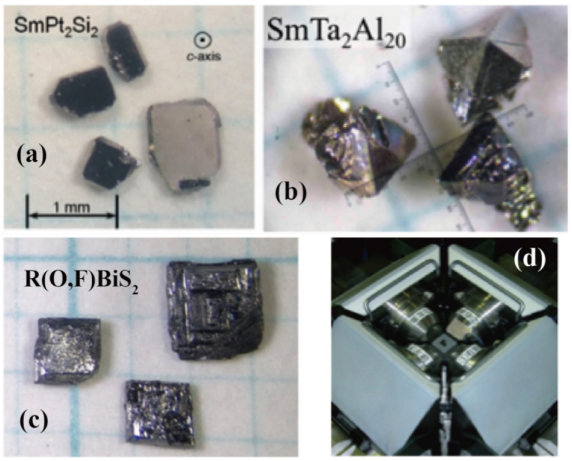
2-1) New class of unconventional superconductors and novel electronic states

Newly found layered superconductors *Ln*(O,F)BiS_2 (*Ln*: rare earth) are found to show not only anomalous superconducting properties but also exotic magnetism of *Ln* ions. In the mother compound, $CeOBiS_2$, we have observed a log*T* divergence of specific heat at low temperatures, indicating that this material is located in the vicinity of a quantum critical point (QCP), where quantum fluctuations of magnetic moments dominate. This is the first realization of *QCP in a nonmetallic system*; therefore, an unconventional mechanism is necessary to account for the QCP in $CeOBiS_2$ (note that all the QCPs reported so far appear in metallic materials and they are caused by the competition between the Kondo and RKKY interactions).



2-2) Extraordinary *f*-electron-based magnetism in Sm and Yb based materials

In Sm based caged materials, we have found remarkable *magnetic-field-insensitive* phenomena. Filled-skutterudite $SmOs_4Sb_{12}$ has a heavy-fermion ground state, in which the effective electron mass does not change in magnetic fields up to 30 T. $SmTa_2Al_{12}$ shows pronounced log*T*-dependent resistivity in the paramagnetic state and an antiferromagnetic ordering with quasiparticle mass enhancement, both of which are robust against applied magnetic fields. In an Ising magnet $SmPt_2Si_2$, we have observed magnetic anomalies that indicate the existence of *partially disordered Sm ions* in an antiferromagnetically ordered state. All of these exotic behaviors are considered to provide clues to clarify the mysterious *f*-electron nature of Sm ions.



(a-c) Pictures of single crystals grown in our laboratory and (d) high pressure furnace.

3. Collaborating Institutions

University of Tokyo ISSP, Kobe University, Tokyo Institute of Technology, JASRI/SPring-8, JAEA, CNRS/Grenoble.

4. Recent Papers

1) R. Higashinaka *et al*., J. Phys. Soc. Jpn. **84**, 023702 (2015).
2) K. Fushiya *et al*., J. Phys. Soc. Jpn. **83**, 113708 (2014).
3) A. Yamada *et al*., J. Phys. Soc. Jpn. **82**, 123710 (2013).
4) Y. Aoki *et al*., J. Phys. Soc. Jpn., **80**, 054704 (2011).
5) S. Kambe *et al*., Nature Phys. **10**, 840 (2014).
6) T. Yamashita *et al*., Nature Phys. **11**, 17 (2014).
7) T. D. Matsuda *et al*., J. Phys. Soc. Jpn. **80**, 114710 (2011).
8) R. Okazaki *et al*., Science **331**, 439 (2011).

5. Awards

The 12th Excellent Paper Award of the Physical Society of Japan (2007).
The 15th Excellent Paper Award of the Physical Society of Japan (2010).
Award of JPSJ Papers of Editors' Choice (2005, 2006, 2011, 2014).