# 3 Condensed Matter Research Center

The Condensed Matter Research Center (CMRC) was established on April 1, 2009, in the Institute of Materials Structure Science (IMSS). The objective of the CMRC is to pursue cutting-edge research on condensed matter science through the comprehensive use of multi-probes supplied by the IMSS, such as synchrotron light, neutrons, muons, and slow positrons. The CMRC is expected to be a center of excellence in the field of materials structure science through its close collaboration with researchers at universities and other institutes around the world. The center consists of 26 in-house members including 9 professors, 6 associate professors, 2 vice associate professors, 5 assistant professors, and 4 postdoctoral fellows. These members also collaborate on research with about 50 researchers at universities and other institutes. The in-house members also hold positions in the synchrotron radiation science division, neutron science division, and muon science division, providing user support in these facilities.

The organizational chart for the CMRC, directed by Prof. Y. Murakami, is shown in Fig. 1. The advisory committee, which consists of five academic experts, provides scientific advice. The CMRC has four research groups: the correlated electron matter group (group leader [GL]: R. Kadono), the surface/interface group (GL: K. Amemiya), the matter under extreme conditions group (GL: T. Kondo of Osaka Univ.), and the soft matter group (GL: H. Seto). The research subjects of these groups are matched with the areas of excellence on which the IMSS focuses attention. The groups in the CMRC promote six projects, which include interdisciplinary research among the groups. The correlated electron matter group oversees three projects (1–3) and each other group oversees one project (4–6); brief overviews of the projects are provided below.

**1. Hybridized orbital ordering project (Project Leader (PL): Associate Professor H. Nakao):**

In this project, not only the localized electrons, d-electron in transition metal and f-electron in rare earth metal, but also the itinerant electrons, O2*p*, P3*p*, and so on, are investigated by complementary use of photons, neutrons, and muons. In particular, resonant X-ray scattering utilizing the hard and soft X-ray regions is a useful technique to clarify these electronic states and the orbital hybridized states between localized and itinerant electrons. The external field effect on orbital hybridized states is also an important subject in this project.

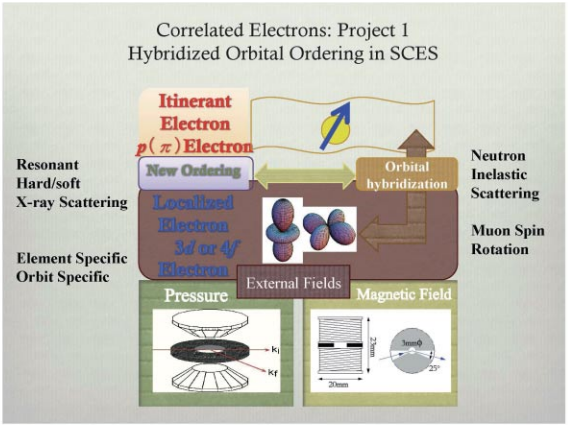


Figure 2
Charge, spin, and orbital orderings can be controlled by pressure and magnetic field.

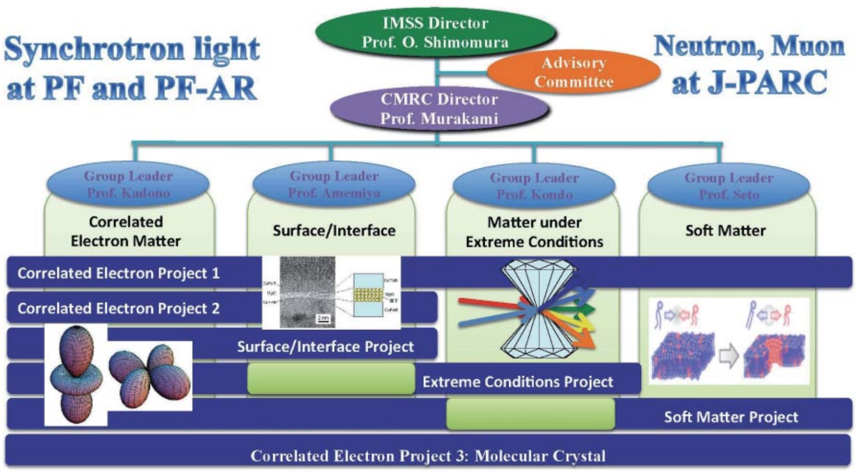


Figure 1
Organizational chart for the Condensed Matter Research Center.

**2. Geometrical correlation project (PL: Professor R. Kadono):**

Geometrical frustration often produces novel phenomena in strongly correlated electron systems, such as the heavy fermion state in which anomalous mass enhancement occurs. This research project aims to clarify the microscopic origin of the heavy fermion behavior in d-electron metals including $LiV_2O_4$ and $Y(Sc)Mn_2$. To this end, we are focusing on a class of transition metal oxides having the so-called pyrochlore structure.

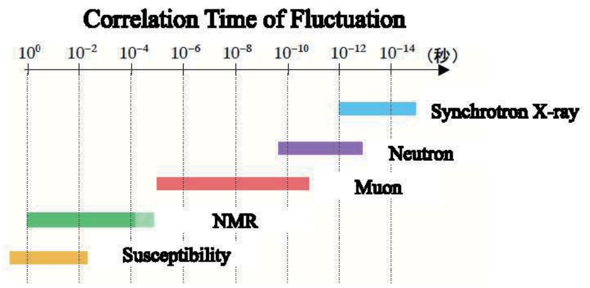


Figure 3
Complementary use of synchrotron X-rays, neutrons, and muons allows measurement of the correlation time of a wide range of fluctuations in the systems.

**3. Molecular crystal project (PL: Dr. R. Kumai):**

In this project, electronic correlation in molecular crystal systems will be investigated to elucidate novel phenomena such as superconductivity, magnetism, ferroelectricity and charge ordering. We will analyze the crystal structure under high pressure using a pressure cell developed specifically for molecular crystals to elucidate the mechanism of superconductivity. The charge ordering state of molecular crystal systems is sometimes destroyed under an electric field. The transient behavior from charge ordered to disordered state will be investigated using structural analysis by synchrotron X-rays.

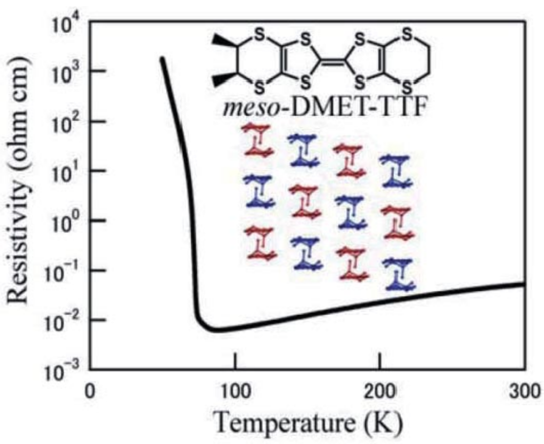


Figure 4
Resistivity of a molecular crystal suggests charge ordering; its pattern is illustrated in the inset.

**4. Surface/interface project (PL: Associate Professor K. Amemiya):**

The surface and interface of magnetic thin films play essential roles in the appearance of extraordinary magnetic properties such as perpendicular magnetic anisotropy and the giant magnetoresistance effect. We are investigating the crystalline, magnetic and electronic structures of the surface and interface of magnetic thin films and multilayers in order to reveal the origins of the magnetic properties, which do not appear in bulk materials.

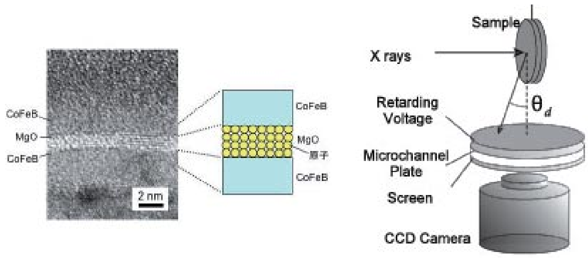


Figure 5
Illustration of a "spintronics" multilayer material and depth-resolved MCD apparatus.

**5. Extreme conditions project (PL: Professor T. Kondo):**

The targets of this project are compounds in the Earth's core/mantle as well as light element minerals. We are studying changes in the crystal structures, electronic structures, spin states, valence states, and chemical bonding of these compounds to understand changes in density and in elastic, geological, transport, and chemical properties. We will use diffraction and spectroscopy techniques employing synchrotron X-rays and neutrons. In this project we are also developing a new in-situ technique to investigate the physical and chemical properties of Earth and planetary materials.

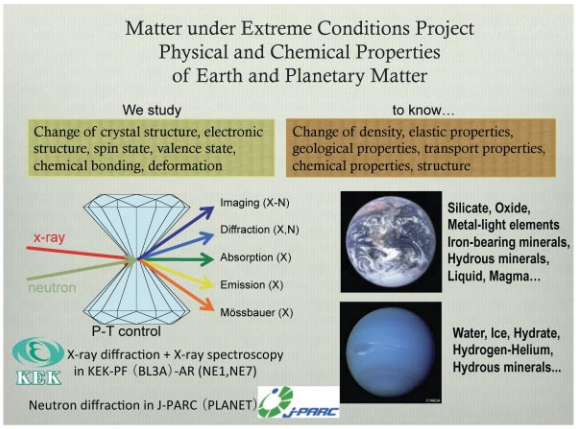


Figure 6
Outline of the extreme conditions project.

**6. Soft matter project (PL: Professor H. Seto):**

We are investigating the structural properties of soft matter such as liquids and amphiphilic molecules. Especially, the contributions of electrostatic interactions due to the existence of ions, which are much stronger than the other interactions, are distinct and not well understood. Additionally, structures formed under far-from -equilibrium conditions are interesting. These investigations will yield basic knowledge that will help to solve the mystery of life.

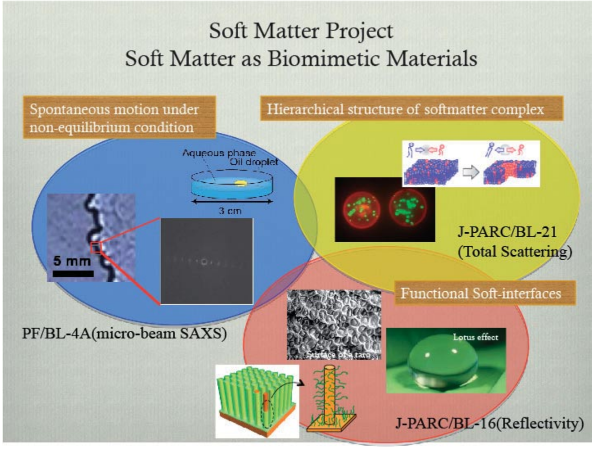


Figure 7
Illustration of the targets of the soft-matter group.

These studies are being carried out using the synchrotron beamlines (BL) of the Photon Factory (PF) and the Photon Factory Advanced Ring (PF-AR) at the Tsukuba campus and the neutron and muon BL of J-PARC at the Tokai campus. BL-8A and BL-8B of the PF are used to analyze the crystal structure. Additionally, the super-high-resolution powder diffractometer (super-HRPD) at J-PARC is useful for crystal and magnetic structure analyses. BL-3A and BL-4C of the PF are used to examine the orders of electronic degrees of freedom under high pressure and a strong magnetic field. BL-16A of the PF is used for measuring MCD, RXS, and XAS, and a resonant soft X-ray scattering diffractometer is installed. Experiments on high pressure are carried out at the AR-NE1A for the diamond anvil cell with laser heating and AR-NE5C for the large press. The chopper spectrometer (HRC) of J-PARC makes it possible to conduct high-resolution experiments of inelastic neutron scattering, while experiments using the muon BL of J-PARC provide information about local magnetization.