Overview

Head of CMRC: Youichi Murakami

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), 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.

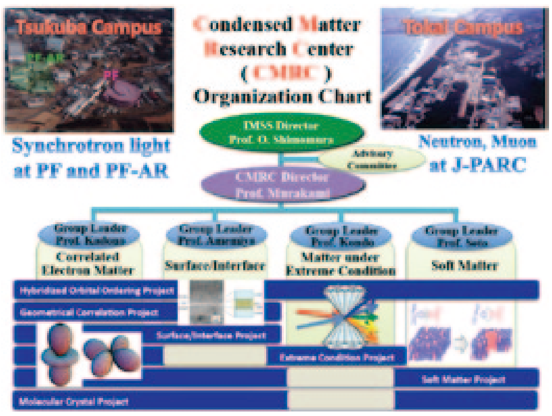

Fig. 1 Organizational chart for the Condensed Matter Research Center.

1. Hybridized orbital ordering project (Project Leader (PL): Associate Professor H. Nakao): The ordered states of the electronic degrees of freedom (charge, spin, and orbital) play very important roles in strongly correlated electron systems. In particular, the hybridization effect of the electronic orbitals has been a central issue in this field for a long time. In this project, both the hybridized orbital ordering between localized and itinerant electrons and the charge/spin/orbital orderings will be studied under high pressure or a strong magnetic field. Resonant hard/soft X-ray scattering and inelastic neutron scattering techniques are used complementarily.

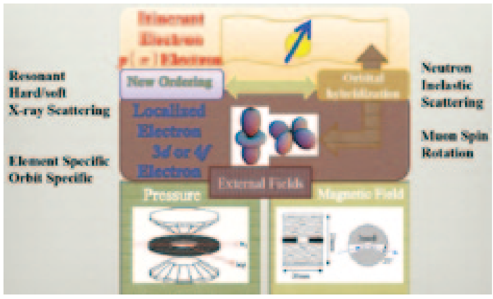

Fig. 2 Charge, spin, and orbital orderings can be controlled by pressure and magnetic field.

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. The objective of this project is to determine a characteristic correlation time for fluctuation in itinerant systems with strong electron correlation under the influence of geometrical frustration using muons, neutrons, and synchrotron X-rays, which have different probing-time scales.

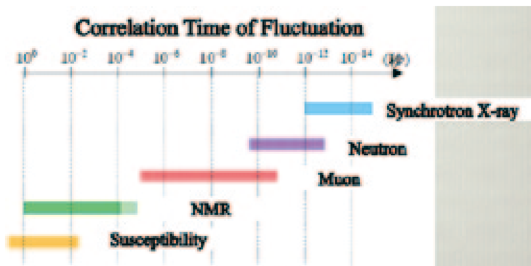

Fig. 3 Complementary use of synchrotron X-rays, neutrons, and muons allows measurement of the correlation time of a wide range of fluctuations in the systems.

3. Molecular crystal project (PL: Professor 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.

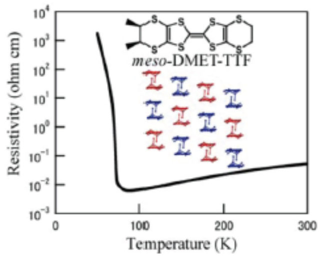

Fig. 4 Resistivity of a molecular crystal suggests charge ordering; its pattern is illustrated in the inset.

4. Surface/interface project (PL: Associate Professor K. Amemiya): Crystal structures and electronic structures at the surface and interface of magnetic thin films and multilayers are studied through depth-resolved magnetic circular dichroism (MCD)/X-ray absorption spectroscopy (XAS), resonant X-ray scattering (RXS), and neutron reflectivity. This research is important for developing materials for new electronics, called "spintronics," as well as for basic surface and interface science.

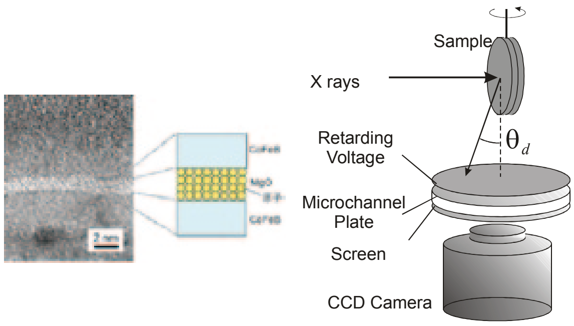

Fig. 5 Illustration of a "spintronics" multilayer material and depth-resolved MCD apparatus.

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.

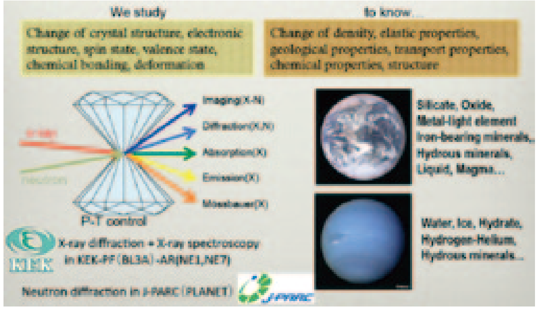

Fig. 6 Outline of the extreme conditions project.

6. Soft matter project (PL: H. Seto): This project has three research objectives: spontaneous motion under non-equilibrium conditions, hierarchical structure of a soft matter complex resulting from self-organization, and functional soft matter interfaces for industrial applications. We are conducting basic studies of these three fields by complementary use of synchrotron X-rays, neutrons, and muons.

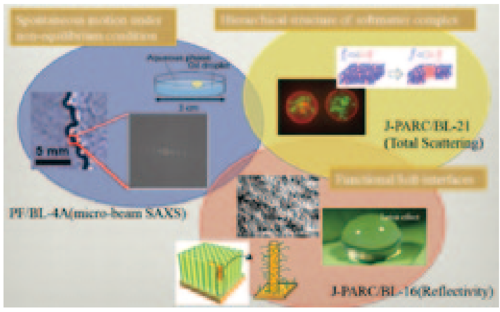

Fig. 7 Illustration of the three targets of the soft matter group.

We are carrying out these studies 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 the J-PARC at the Tokai campus. BL-8A and 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 4C of the PF are frequently used to examine the orders of electronic degrees of freedom, such as charge, spin, and orbital orders 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 was installed in 2009. Experiments on high pressure are carried out at the PF-AR beamlines, namely, BL-NE1 for the diamond anvil cell with laser heating and BL-NE3 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.