3 Condensed Matter Research Center

3-1 Overview

The aim of the Condensed Matter Research Center (CMRC) is to pursue cutting-edge research through the comprehensive use of multi-probes supplied by the Institute of Materials Structure Science (IMSS), such as synchrotron radiation, neutrons, muons, and slow positrons in collaboration with researchers at universities and other institutes. The CMRC has four research groups: the correlated electron matter group, the surface/interface group, the matter under extreme conditions group, and the soft matter group. Through collaboration among these four groups, the CMRC has been promoting seven bottom-up projects: the hybridized orbital ordering project, the geometrical correlation project, the molecular crystal project, the oxide hetero-structure project, the surface/interface project, the extreme condition project, and the soft matter project. One more project, the hydrogen project, will soon join the CMRC. This year, the IMSS joined in the cooperative effort of the Element Strategy Initiative of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) to form a Core Research Center. In addition to the abovementioned bottom-up projects, the CMRC is working on this MEXT project involving electronic materials and magnetic materials in collaboration with the Tokyo Institute of Technology and the National Institute of Materials Science, respectively.

(http://cmrc.kek.jp/english/index_eng.html)

3-2 CMRC Projects

The Hybridized Orbital Ordering Project [1, 2]

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.

The Geometrical Correlation Project [3]

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-ray, which have different probing time scales.

The Molecular Crystal Project [4-8]

The electronic correlation in molecular crystal systems is being investigated to elucidate novel phenomena such as superconductivity and charge ordering. We are analyzing the crystal structures of molecular crystals under high pressure and/or at low temperature to elucidate the origins of phase transitions.

The Oxide Hetero-Structure Project [9]

The goal of this project is to design novel physical properties appearing at the hetero-interface of strongly correlated oxides. The physical properties arise from strong mutual coupling among the spin, charge, and orbital degrees of freedom in the interface region between two different oxides. In order to control such properties, it is necessary to clarify the interfacial electronic, magnetic, and orbital structures. We are therefore using synchrotron radiation spectroscopic techniques having elemental selectivity to probe these structures in the nm-scale at the oxide hetero-interface.

The Surface/Interface Project [10]

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 magneto-resistance effect. We are investigating the crystalline, magnetic and electronic structures at the surface and interface of magnetic thin films and multilayers, in order to reveal the origin of fascinating magnetic properties that cannot be realized in bulk materials.

The Extreme Condition Project

Materials under pressure and temperature show many interesting behaviors unlike those under ambient conditions. In this project, we will develop a new in-situ technique to investigate physical and chemical properties of Earth and planetary materials including iron and hydrogen under extreme conditions.

The Soft Matter Project [11]

Soft matter is a subfield of condensed matter comprising a variety of physical states that are easily deformed by thermal stresses or thermal fluctuations. They include liquids, colloids, polymers, liquid crystals, amphiphilic molecules, and a number of biological materials. These materials often self-organize into mesoscopic physical structures that are much larger than the microscopic scale (the arrangement of atoms and molecules), and yet are much smaller than the macroscopic scale of the material. The properties and interactions of these mesoscopic structures may determine the macroscopic behavior of the material. In spite of the various forms of these materials, many of their properties have common physicochemical origins, such as a large number of internal degrees of freedom, weak interactions between structural elements, and a delicate balance between entropic and enthalpic contributions to the free energy. These properties lead to large thermal fluctuations, a wide variety of forms, sensitivity of equilibrium structures to external conditions, macroscopic softness, and metastable states.

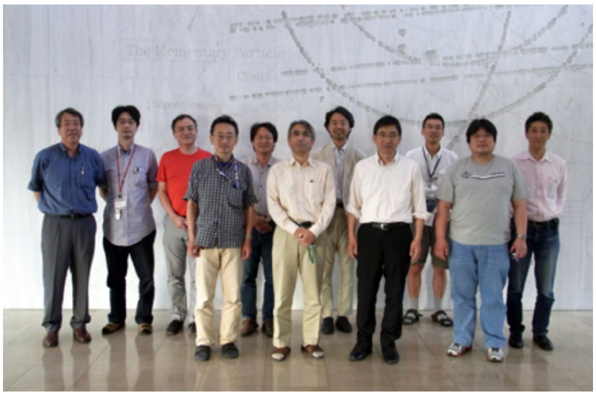

Figure 1: Project leaders of the Condensed Matter Research Center (CMRC).

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