【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Mathematical and physical sciences)

Title of Project : Strong spin-orbit interaction and novel electronic phases in heavy 5d transition metal oxides

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Research Area : Mathematical and physical sciences
Keyword : Correlated electron systems, Spin-orbit coupling, 5d transition metal oxides

【Purpose and Background of the Research】

Heavy 5d transition metals such as Iridium and Osmium, compared with light 3d transition metals such as Copper and Manganese, have a very distinct physical parameter. Spin-orbit coupling, a relativistic effect, is as large as 0.5 eV, which is more than an order of magnitude larger than that of 3d.

Transition metal oxides have been the playground for the physics of electron correlations, where the interplay between the kinetic energy and Coulomb repulsion gives rise to a rich variety of electronic phases. This project aims to explore the novel correlated electron physics emerging out of spin-orbit coupling by leaving 3d for 5d transition metal oxides. The energy scale of spin-orbit coupling in 5d transition metals oxides is indeed comparable to kinetic energy and Coulomb repulsion, which may alter the effect of electron correlations drastically and possibly produce a novel electronic phases. We recently from this view point focused on a complex iridium oxide Sr_2IrO_4 and experimentally demonstrated that the system changes its face from a metal to a magnetic insulator because of the strong spin-orbit coupling.

【Research Methods】

With the discovery of the novel electronic phase which can be called a spin-orbital Mott insulator, we will investigate for a wider variety of iridium oxides how the electronic states and the excitation of spin, charge and orbitals are modified by the strong spin-orbit interaction. The measurements of optical response, electronic transport and resonant x-ray scattering will be conducted on the series of perovskite oxides $Sr_{n+1}Ir_nO_{3n+1}$ and the pyrochlore oxides $RE_2Ir_2O_7$.

With the strong spin-orbit coupling, the orbital motion will be restored and the wave function of 5d electrons will attain a phase associated with it. The interplay with the topology of lattice may result in the pronounced effect of quantum phase and the emergence of exotic electronic phases may be anticipated. With the aid of solid state chemistry, iridium oxides with a honeycomb lattice and a pyrochlore lattice will be picked up and the possibility of an exotic electronic phase will be explored. The approach using thin film superstructure will be attempted in parallel.

【Expected Research Achievements and Scientific Significance】

We would like to realize an exotic electronic phase in a real material, such as a topological insulator, a Dirac semimetal, a Kitaev spin liquid and an exotic superconductivity. Based on the data on the electronic states and the elementary excitations over a variety of iridium oxides, we hope to construct and deliver a basic physics of spin orbit coupling and electron correlations. The new field for science of a 5d transition metal oxide shall be established.

【Publications Relevant to the Project】

・B. J. Kim, H. Ohsumi, H. Takagi, and T. Arima *et al.*, "Phase-sensitive observation of a spin-orbital Mott state in Sr_2IrO_4", Science 323, 1329-1332 (2009).
・K. Ishii, I. Jarrige, M. Yoshida, K. Ikeuchi, J. Mizuki, K. Ohashi, T. Takayama, J. Matsuno, and H. Takagi, "Momentum-resolved electronic excitations in the Mott insulator Sr_2IrO_4 studied by resonant inelastic x-ray scattering", Phy. Rev. B 83, 115121 (2011).
・S.Fujiyama, H.Ohsumi, T.Komesu, J.Matsuno, B.J.Kim, M.Takata, T.Arima and H.Takagi, "Two-Dimensional Heisenberg Behavior of Jeff=1/2 Isospins in the Paramagnetic State of the Spin-Orbital Mott Insulator Sr_2IrO_4", Phys. Rev. Lett. 108, 271472 (2012).

【Term of Project】 FY2012-2016

【Budget Allocation】 164,200 Thousand Yen

【Homepage Address and Other Contact Information】

http://park.itc.u-tokyo.ac.jp/takagi_lab/