Research Interests – Prof. Dr. Hidenori Takagi

The electric and magnetic properties of solids are governed by the multitude of electrons that reside in the system, as many as 10^{22}-10^{23} in a volume of 1 cm^3. These electrons interact with each other through Coulomb repulsion and are entangled, a phenomenon, which is particularly significant in a class of compounds represented by transition metal oxides. The ensemble of strongly interacting electrons, called “correlated electrons”, on a crystalline lattice forms a rich variety of exotic phases, such as the electron solid, electron liquid crystal, electron superfluid (called superconductivity), and electron spin liquid. As a material physicist, Takagi aims to explore such unusual phases of correlated electrons through the discovery of novel transition metal oxides and unveil the physics of phase formation. His field might be aptly viewed as the sociology of interacting electrons (instead of human beings).

In the early days of Takagi’s career, his main scientific playground was a family of layered copper oxides, which displays superconductivity at high temperature (high-T_c superconductivity). His major contributions to the field include the first identification of the superconducting phase in La-Ba-Cu-O, as well as the discoveries of an electron-doped superconductor $Nd_{2-x}Ce_xCuO_4$ with distinct character of charge carriers, the unusual normal state charge transport properties leading to the concept of a pseudo-gap phase, and an electron crystal (checkerboard) as a hidden ordering in the pseudo-gap phase.

Takagi then extended his explorations to 3d transition metal oxides and related compounds, which led him to the discovery of superconductivity in nickel boron carbides, the verification of a heavy mass Fermi liquid in LiV_2O_4, and the observation of a half-magnetisation plateau state induced by magnetic field in CdV_2O_4. In parallel, he developed functionalities from electronic phase changes, including giant negative thermal expansion in MnN antiperovskites and an electronic ice pack based on VO_2.

The major arena for Takagi’s explorations has recently shifted to 5d transition metal oxides, where he was one of the first to recognise the novel interplay of electron correlations and very strong spin-orbit coupling. He established Sr_2IrO_4 as a spin-orbital Mott insulator (electron solid) produced by such interplay and is now aiming to construct a novel quantum spin liquid state and other exotic phases based on the spin-orbital Mott insulator. Very recently, he discovered a quantum spin liquid in the honeycomb iridate, $H_3LiIr_2O_6$.