Emergent topological and magnetic phases of pyrochlore iridate thin films and heterostructures

Electron correlation (U) in strongly correlated materials reorganizes the electronic structure and engender various interaction driven phenomena such as metal-insulator transition, magnetism, unconventional superconductivity etc. Besides electron correlation, a lot of interest has piqued in the recent days to study systems that show relatively high spin-orbit interaction as well. For systems having 5*d* transition metal ions, the energy scale of spin-orbit coupling is of the order of ~ eV and is comparable with those of the bandwidth *W* and the Coulomb *U*. The delicate competition and/or interplay of spin-orbit coupling with others may alter the landscape of electronic structure completely. Indeed, the study on complex Ir-based oxides (iridates) has emerged as a new paradigm for correlated electron physics. It is proposed that these iridates may exhibit various intriguing electronic and magnetic phases. Epitaxial thin films of iridates stabilised under suitable growth condition can pave the way for exploring the exciting electronic properties subject to lattice strain/symmetry, dimensionalty, doping, and superlattice design. In particular, pyrochlore iridate ($RE_2Ir_2O_7$ with RE=Pr, Nd, Sm, Eu, Y...) is an actively discussed series of materials in context of possible novel correlated topological phases and magnetism due to the comparable energy scales of U, W, and the associated geometrical frustration with pyrochlore lattice. In pyrochlore iridates, to stabilise a correlated Weyl semimetal state, the microscopic magnetic order has to preserve inversion symmetry. Weyl semimetals require broken inversion crystal symmetry or time-reversal symmetry (via magnetic order or an applied magnetic field). So far intrinsic magnetic Weyl semimetals are rare! To realize this possibility, we aim to search for quasi two-dimensional magnetic materials with topological band structures in the form of epitaxial thin film and heterostruture design involving pyrochlore iridates and investigate their related transport (magneto resistance and Hall resistance) and magnetic properties.

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Interfacial magnetic skyrmions in the designer thin film heterostructures

Non-collinear spin configurations in magnets are the focus of recent intensive researches, which include the nontrivial ground states such as the helical/spiral magnetic state. Skyrmions, a type of localized spin texture, discovered in chiral magnets show unique physical properties due to their nontrivial topology such as the stability against the annihilation and the motion driven by the ultralow current density, which can be advantageous for the device applications such as magnetic memories. More importantly, the magnetic skyrmions generate a so-called topological contribution to the Hall effect, and are very easily moved by the flow of spin-polarized electrons, signifying the opportunity towards ultra-low power skyrmion-based spintronic devices. However, the grand challenge is the formation and stabilization of skyrmions, and it has been predicted that ultrathin magnetic films interfaces with strong spin-orbit heavy metals can give rise to interfacial magnetic skyrmions. The goal of this project is to increase our understanding of the formation and stabilization skyrmions and engineer them at the interfaces in thin films based heterostructures.

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