Emergent Quantum and Topological Phenomena in Artificial (111)-Oriented Spinels

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The quest to design, discover and manipulate new quantum and topological states of matter has fostered tremendous research focus of condensed matter physicists. With recent advances in the fabrications of epitaxial thin films, it has enabled a plethora of artificial multilayers and heterostructures with the atomic layer precision, where numerous fascinating phenomena have been brought about. In the pursuit for new physics, and to make the full use of these technical advances the current interest is shifted to tailoring the magnetic properties of materials at reduced dimensionality. Specifically, lowering dimensionality can alter several key factors including neighboring coordination, crystal fields, exchange pathways, magnetic anisotropy, quantum confinement, and a universality class. As a result, the magnetic ground state of a material in the crossover towards 2D can be distinctly different from its 3-dimensional counterpart.

To illustrate this paradigm, we demonstrate the case of $CoCr_2O_4$ spinel as a prototypical example. Towards this end, we successfully grew a set of (111)-oriented $CoCr_2O_4$ ultrathin films. As the thickness is reduced to a few unit cells, we found a new magnetic state of $CoCr_2O_4$ which switches from the spiral ferrimagnetic type to a hidden Yafet-Kittel kind. Eventually, in the case of single unit cell $CoCr_2O_4$, no signs of long range ordering is observed down to 30 mK implying the formation of quantum spin liquid with the very large frustration factor of almost 100. Our results highlight the opportunities of achieving novel quantum and topological phases of matter by means of geometrical lattice engineering.