論文の内容の要旨

Transition from Dirac-node semimetal to magnetic insulator in perovskite-related iridium oxides

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氏名　根岸　真通

Dirac nodes in energy band dispersion of electrons in condensed matter are one of hot topics in research of solid state physics due to their exotic properties including topological protection of the nodes by symmetry. Since the concept of Dirac nodes stands on band theory, i.e., basically single electron picture, electron correlation effects on Dirac materials are one of the interesting problems and have attracted researchers' attention in these years. To tackle this problem, we focused on iridium oxides, where interplays of spin-orbit coupling, correlation and variety of crystal structures provide mines for exotic quantum phases. Among iridates, orthorhombic perovskite $A\mathrm{IrO_3}$ (A = Sr, Ca) is known as Dirac line node semimetal with correlation. Especially, effective strength of correlation in perovskite iridate can be controlled by changing Sr or Ca in *A* site. Recently, it is discovered that partial substitution of Ir sites by Sn ions in perovskite $SrIrO_3$ enhances correlation and triggers a transition from the Dirac semimetal to a magnetic insulator. On the other hand, Sn substitution on perovskite $CaIrO_3$ which initially has stronger correlation than $SrIrO_3$ will be a curious problem, but had not been investigated before our work. Therefore, we introduced correlation and disorders by Sn doping in both $SrIrO_3$ and $CaIrO_3$, and compared their responses. By doing that, we tried to investigate effects of underlying correlation in the initial Dirac nodal semimetallic states.

In order to realize the orthorhombic perovskite $SrIrO_3$ and $CaIrO_3$, both metastable at ambient condition, we grew epitaxial thin films of them on perovskite $SrTiO_3$(001) substrates.

Evaluation of crystal structures using X-ray diffraction and transmission electron microscope confirmed successful realization of epitaxial thin films of the perovskite phases for both $SrIrO_3$ and $CaIrO_3$, and both undoped and Sn doped systems. Especially for $SrIrO_3$ films, technique using step-terrace structures on substrate was used to control crystalline orientations in film and to suppress twining.

Then, we performed electric transport measurements for undoped systems in order to check their semimetallic states. Both $SrIrO_3$ and $CaIrO_3$ showed almost temperature-independent resistivity, which is consistent with semimetallic electronic states. Perovskite $SrIrO_3$ film showed negative Hall effect reflecting existence of Dirac electrons as already reported in bulk and films. Our orientation-controlled film helped us to find a characteristic anisotropy of magnetoresistance, though interpretation for it has not been established. Perovskite $CaIrO_3$ film showed positive Hall effect different from Dirac electron carriers in bulk, which suggests epitaxial strain effect making upper shift of the Dirac node across the Fermi energy.

Next, we compared Sn doped effects on two Dirac semimetals, perovskite $SrIrO_3$ with weaker correlation and $CaIrO_3$ with stronger correlation. We found that they both reach magnetic insulator phases but driving forces of these transitions are contrasting. Sn-doped $SrIrO_3$ remains semimetallic resistivity against introduction of disorders, and the weak ferromagnetism triggers a transition from semimetal to insulator, similarly to the previous studies on bulk. On the other hand, we discovered that Sn-doped $CaIrO_3$ develops insulating behavior independently from magnetism. This insulating behavior is probably assisted by both correlation and disorders, suggesting an interplay of correlation and disorders. This discovery of contrasting Sn substitution effects on $Sr/CaIrO_3$ is the first example to show that different strengths of correlation result in a variety of quantum phases in 5*d* Dirac electron systems.

We also performed detailed characterization of the weak ferromagnetism in Sn-doped perovskite $SrIrO_3$. By performing magnetic diffraction using resonant X-ray diffraction, we confirmed that the weak ferromagnetism comes from canting of antiferromagnetic order of Ir moments. We investigated anisotropy of the weak ferromagnetism using the orientation-controlled sample, and discussed the magnetic ordering patterns consistent with the experimental results.

In conclusion, we revealed that perovskite $SrIrO_3$ and $CaIrO_3$, Dirac line node semimetals with different scales of correlation, roach magnetic insulators with different origins under Sn doping, due to interplays of correlation and disorders. This contrast clearly demonstrates different effects of underlying correlation in two Dirac semimetals $SrIrO_3$ and $CaIrO_3$. On the other hand, how topological properties of the symmetry-protected Dirac line nodes appear in these materials remains a future problem.