論文の内容の要旨

Three-dimensional Dirac electrons in Sr_3PbO antiperovskite
(Sr_3PbO アンチペロブスカイトにおける三次元ディラック電子)

氏名 末次祥大

Three-dimensional (3D) topological Dirac semimetals (TDSs) with 3D linear dispersion in bulk have been attracting considerable interest. 3D TDS can host topological surface states and can be driven into topologically distinct phases such as a topological insulating or a Weyl semimetallic state by controlling a band gap or breaking symmetry. Because of the possible realization of chiral anomaly, the quantum limit where all carriers reside in the lowest Landau level has been studied with great interest. Nontrivial topology of conduction and valence bands mixing in Dirac semimetals can give rise to giant orbital diamagnetism. To explore such unconventional physics of 3D Dirac electrons, chemically flexible 3D TDS, in which it is easy to break symmetries, to introduce magnetism, and to control band filling and spin-orbit coupling, is highly desirable. Recently, a family of cubic antiperovskite A_3TtO (A = Ca, Sr, Ba; Tt = Sn, Pb) was theoretically proposed as a 3D massive Dirac electron system, free from the contribution from other parabolic bands. The antiperovskite family with chemical flexibility is promising for band engineering of 3D Dirac electrons.

In this thesis, we report the magnetotransport, the bulk magnetic susceptibility and the nuclear magnetic resonance (NMR) experiments on Sr_3PbO, one of the antiperovskite family. The Hall resistivity and Shubnikov-de Haas oscillation measurements indicate a low density of holes $n \sim 10^{18}$ cm^{-3} with an extremely light cyclotron mass of $\sim 0.01m_e$, one percent of free electron. A linear magnetoresistance (MR) with a giant MR ratio $\Delta\rho_{xx}(B) / \rho_{xx}(0) \sim 10$ was observed similar to other 3D TDS. The temperature dependence of NMR spin lattice relaxation rate T_1^{-1} with the deviation from the Korringa behavior at high temperature reflects a V shaped density of states expected for 3D

Dirac electrons. These results are fully consistent with the presence of 3D Dirac electrons in Sr_3PbO. The next step is to explore unconventional physics anticipated for the 3D Dirac electrons.

Chiral anomaly has been experimentally explored and expected negative longitudinal MR has been observed in several 3D TDSs. However, current jetting effects, focusing of a current density, raised ongoing discussion about these experiments. We studied the angular dependences of the longitudinal MR and the planar Hall effect in the Sr_3PbO antiperovskite. The intrinsic contribution associated with the chiral anomaly may be captured by the negative longitudinal MR and the planar Hall effect at low magnetic field $B \sim 0.5$ T. The angular dependences at high field $B > 0.5$ T indicate the predominant effect of the current jetting rather than the chiral anomaly. The detailed experiments will be left for future study to extract clear conclusion.

In Dirac semimetals, the topology of inter-band mixing, represented by inter-band Berry connection, can give rise to a giant orbital diamagnetism which strongly depends on the chemical potential and temperature. The large diamagnetism has been observed, for example, in the bulk magnetic susceptibility of Bi. However, the orbital origin of the large diamagnetism has not been experimentally confirmed owing to the presence of other contributions to the magnetic susceptibility associated with the complicated Fermi surface of Bi. We report the bulk magnetic susceptibility and the ^{207}Pb NMR experiments on Sr_3PbO antiperovskite samples with different carrier density from $\sim 10^{18}$ to $\sim 10^{20}$ cm^{-3}. The magnitude of T_1^{-1} is well scaled by a density of states derived from a band calculation. This enables us to separate spin and orbital contributions of NMR Knight shift by analyzing K, T_1^{-1} and χ with the help of a Korringa relation, which provides the evidence for the presence of the giant orbital diamagnetism in Sr_3PbO.