【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Mathematical and Physical Sciences)

Title of Project : Molecular quantum liquids in strongly correlated electron systems

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Research Project Number : 16H06346 Researcher Number : 80169531
Research Area : Mathematical and Physical Sciences
Keyword : Molecular solid/Organic conductor, Strongly correlated electron system, Superconductivity

【Purpose and Background of the Research】

Materials where the electrons are strongly correlated form one of highly important research fields of this century in terms of both basic science and application. In the strongly correlated electron systems, several degrees of freedom including charge, spin, lattice, and orbital are simultaneously active and competing with each other. This causes plenty of uncharted electronic states that are waiting our investigation. Among them, "quantum liquids" that exhibit neither long-range order (as solid) nor complete uniformity (as gas), characterize essential behavior of the strongly correlated electron system.

The molecular π electron system is suitable for the study of quantum liquids, thanks to "simple and clear electronic structures", "soft crystal lattice", "low carrier density", and "controllability by chemical modifications".

In this project, we will quest for three types of quantum liquids in molecular π electron systems, 1) Quantum spin liquid, 2) Fractional Hall liquid in multi-layer Dirac electron system, 3) Non-Fermi liquid in the vicinity of the field-induced Mott transition.

【Research Methods】

1) Quantum spin liquid (QSL)

Based on NMR, ESR, low-temperature X-ray diffraction, vibrational spectroscopy, and theoretical studies on the molecular QSL with a triangular lattice, $EtMe_3Sb[Pd(dmit)_2]_2$, and related materials, we figure out the QSL phase with neighboring unconventional electronic phases.

2) Fractional Hall liquid in multi-layer Dirac electron system

We aim to observe an unconventional fractional Hall effect in a hole-doped organic conductor α-$(BEDT\text{-}TTF)_2I_3$. Another goal is development of new Dirac electron systems based on single-component molecular conductors.

3) Non-Fermi liquid in the vicinity of the field-induced Mott transition

By studying the filling-controlled Mott transition in the field-effect transistor (FET) with a thin single crystal, we will reveal non-Fermi liquid and superconducting phases in a universal phase diagram around the Mott insulator.

【Expected Research Achievements and Scientific Significance】

This comprehensive and interdisciplinary research project is expected to provide basic understanding of the strongly correlated electron system and to open new field of materials science that constructs basis of molecular electronics and devices.

【Publications Relevant to the Project】

- "Development of π-Electron Systems Based on $[M(dmit)_2]$ (M= Ni and Pd; dmit: 1,3-dithiole-2-thione-4,5-dithiolate) Anion Radicals", R. Kato, *Bull. Chem. Soc. Jpn.*, **87**, 355-374 (2014).
- "Quantum Hall Effect in Multilayered Massless Dirac Fermion Systems with Tilted Cones", N. Tajima, T. Yamauchi, T. Yamaguchi, M. Suda, Y. Kawasugi, H. M. Yamamoto, R. Kato, Y. Nishio, and K. Kajita, *Phys. Rev. B*, **88**, 075315/1-6 (2013).
- "A Strained Organic Field-Effect Transistor with a Gate-Tunable Superconducting Channel", H. M. Yamamoto, M. Nakano, M. Suda, Y. Iwasa, M. Kawasaki, and R. Kato, *Nature Commun.*, **4**, 2379/1-7 (2013).

【Term of Project】 FY2016-2020

【Budget Allocation】 142,600 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.riken.go.jp/lab-www/molecule/index-e.html