OIST OKINAWA INSTITUTE OF SCIENCE AND TECHNOLOGY GRADUATE UNIVERSITY

Quantum Materials Science Unit (Yoshinori Okada)

FY2021 Annual Report

Quantum Materials Science Unit
Assistant Professor Yoshinori Okada

Abstract

We are interested in searching/designing novel physics and exotic physical properties in low dimensional materials and their heterostructures. Our philosophy is developing understanding by accelerating day by day feedback between materials synthesis, electronic state imaging (angle-resolved photoemission spectroscopy and scanning tunneling spectroscopy), and transport measurements. In Fy2021, we have investigated exotic topological and superconducting materials.

1. Member

1.1 Staff

- Dr. Yoshinori Okada (PI)
- Dr. Yuita Fujisawa (PD)
- Dr. Kohei Yamagami (PD)

- Dr. Sheng Liu (PD)

1.2 Graduate Students

- Mr. Mohmed Atwa
- Mr. Barnaby Smith
- Mr. Markel Pardo Almanza
- Ms. Anjana Krishnadas
- Mr. Takatsugu Onishi (Rotation Student)

1.3 Visiting Scientist/student

- Dr. Tessui Nakagawa (Ryukyu University, Japan)
- Dr. Takahito Takeda (The University of Tokyo, Japan)

1.4 Intern Student

- Mr. Tomoki Kawada (The University of Tokyo, Japan)
- Mr. Kenta Harada (Tohoku University, Japan)
- Mr. Daimo Yoshikawa (The University of Tokyo, Japan)

2. Collaborations

2.1 Oxide electronics

- Dr. Takayuki Harada (NIMS, Japan)

2.2 Magnetic Imaging

- Dr. Anjan Soumyanarayanan (A-Star, Singapore)

2.3 Device Fabrication

- Prof. Yasuhiro Niimi (Osaka University, Japan)

2.4 Photoemission Experiments

- Prof. Takeshi Kondo (The University of Tokyo, Japan)
- Prof. Masaki Kobayashi (The University of Tokyo, Japan)
- Prof. Kenta Kuroda (The University of Tokyo, Japan)

2.5 First Principle Calculations

- Prof. Feng-Chuan Chuang (National Sun Yet-sen University, Taiwan)
- Dr. Hsin Lin (Academia Sinica, Taiwan)
- Dr. Khoong Hong Khoo (A-Star, Singapore)

2.6 Scanning Probe Microscopy Experiments

- Prof. Yasuyuki Yoshida (Kanazawa University, Japan)

2.7 Thermal Management Project (JST-CREST)

- Prof. Tsunehiro Takeuchi (Toyota Technological Institute, Japan)
- Prof. Katsumi Tanigaki (Tohoku University, Japan)
- Prof. Fuyuki Shimojo (Kumamoto University, Japan)
- Prof. Kazunori Sato (Osaka University, Japan)

3. Activities and Findings

3.1 vdW coupled Weyl semimetals

A Weyl semimetal (WSM) is a topological, gapless system which hosts three-dimensional Weyl cones in the bulk and Fermi arc states on the surface. It occurs in a system breaking either time-reversal or inversion symmetry, where nondegenerate conduction and valence bands intersect at arbitrary points in momentum space, forming pairs of the so-called ‘Weyl nodes’ with opposite spin chirality. Near these nodes, the low-energy excitations can be described as linearly dispersing Weyl-Fermions. Using spectroscopic imaging scanning tunneling microscope, we investigated two Weyl semimetals Mo(Se,Te)2 and NbIrTe4.

In Mo(Te,Se)2, we identify the existence of low temperature Td phase with broken inversion symmetry where superconductivity globally coexists. Our findings of robust superconductivity arising from a Weyl semimetal normal phase in MoTe1.85Se0.15, makes it a promising candidate for realizing topological superconductivity. In NbIrTe4, we observe a sharp peak in the density of states near the EF. Based on quasiparticle interference measurements and ab initio calculations, we ascribe this peak to a van Hove singularity (vHs) associated with a Lifshitz transition of the topological Fermi arc states. Furthermore, inelastic spectroscopy measurements show a surprisingly large signature of electron–boson coupling, which presumably represents anomalously enhanced electron–phonon coupling through the enhanced charge susceptibility. Our observation indicates the intriguing interplay between the formation of the near-EF topological vHs and enhanced electron–phonon coupling, which paves the way for the manipulation of topologically nontrivial states in Weyl semimetals via phonon engineering.

3.2 magnetic frustration in vdW coupled materials

An essential component to accelerate the development of the field is to increase the number of materials that host states whose properties are described by multiple coupled degrees of freedom, such as charge, spin, orbital, and lattice. Among these, a particularly interesting playground for discovering such emergent phenomena has been identified in systems which manifest an interplay between itinerant electrons and magnetism, and intensive studies have been pursued and reported. However, a promising area of this playground which simultaneously remains relatively unexplored is that of vdW materials, where itinerant electrons coexist with low-dimensional and potentially frustrated magnetism. Magnetic frustration can result in non-collinear spin textures and field-induced transitions to exotic quantum phases. This includes emergent topologically non-trivial spin textures which lead to exotic couplings between the magnetism and the motion of itinerant electrons. Furthermore, non-collinear spin textures can couple to lattice degrees of freedom to produce phenomena like multiferroicity.

We demonstrated that CeSiI hosts itinerant electrons coexisting with exotic magnetism. In CeSiI, the magnetic cerium atoms form a triangular bilayer structure sandwiched by van der Waals stacked iodine layers. From resistivity and magnetometry measurements, we confirm the coexistence of itinerant electrons with magnetism with dominant antiferromagnetic exchange between the strongly Ising-like Ce moments

below 7 K. Neutron diffraction directly confirms magnetic order with an incommensurate propagation vector k ~ (0.28, 0, 0.19) at 1.6 K, which points to the importance of further neighbor magnetic interactions in this system. The presence of a two-step magnetic-field-induced phase transition along c axis further suggests magnetic frustration in the ground state. Our findings provide a novel material platform hosting a coexistence of itinerant electron and frustrated magnetism in a vdW system, where exotic phenomena arising from rich interplay between spin, charge and lattice in low dimension can be explored.

4. Publications

4.1 Journals

1. Z. Wang, C.Y. Huang, C.H. Hsu, H. Namiki, T.R. Chang, F.C. Chuang, H. Lin, T. Sasagawa, V. Madhavan and Y. Okada, *Observation of near EF Fermi-arc van Hove singularity with prominent coupling to phonon in a van der Waals coupled Weyl semimetal*, Phys. Rev. B, 105, 075110 (2022)
2. R. Okuma, C. Ritter, G.J. Nilsen and Y. Okada, *Magnetic frustration in a van der Waals metal CeSil*, Phys. Rev. Materials (L)5, L121401 (2021)
3. Z. Wang, J. Olivares, H. Namiki, V. Pareek, K. Dani, T. Sasagawa, V. Madhavan and Y. Okada, *Visualizing superconductivity in a doped Weyl semimetal with broken inversion symmetry*, Phys. Rev. B, 104, 115102 (2021)
4. H. Oka, K. Katoh, Y. Okada, D. Oka, T. Hitosugi, M. Yamashita and T. Fukumura, *Single Molecular Adsorption of Terbium (lll) Bis-phthalocyaninato (TbPc2) Governed by Two Surface Reconstructions of Perovskite Type SrVO3 Epitaxial Ultrathin Film*, Chem. Lett., 50, 1489 (2021)
5. H. Yoshino, K. Yamagami, H. Wadati, H. Yamagishi, H. Setoyama, S. Shimoda, A. Mishima, B.L. Ouay, R. Ohtani and M. Ohba, *Coordination Geometry Changes in Amorphous Cyanide-Bridged Metal-Organic Frameworks upon Water Adsorption*, Inorg. Chem., 60, 5, 3338-3344 (2021)
6. Y. Fukuda, N. Yoshinari, K. Yamagami and T. Konno, *Transformations of empty Cu core to CuCuo and CuS cores via oxide and sulfide insertions*, Chemical Communications, 57, 44, 5386-5389 (2021)

4.2 Books and other one-time publications

Nothing to report

4.3 Oral and Poster Presentations

1. M. Atwa, M. Colliard, Y. Fujisawa, M. Pardo-Almanza, Y. Okada, *Magneto-Thermo-Transport of Cr1+δTe2 Epitaxial films*, The Physical Society of Japan, Autumn Meeting(online), 14-23 September (2021)
2. M. Pardo-Almanza, Y. Fujisawa, K. Yamagami, C. H. Hsu, F. C. Chuang, Y. Okada, *Evolution of Band Structure Associated with Sign Change of Anomalous Hall Conductivity in Cr1+δTe2 Epitaxial films*, The Physical Society of Japan, Autumn Meeting(online), 14-23 September (2021)
3. A. Krishnadas, Y. Fujisawa, M. Pardo-Almanza, K. Yamagami, Y. Okada, *In-situ ARPES visualization of electronic states on epitaxial YBCO thin film surface*, The Physical Society of Japan, Autumn Meeting(online), 14-23 September (2021)
4. Y. Fujisawa, T. Onishi, M. Paro-Almanza, Y. Okada, *Observation of scalar spin chirality in Cr1+δTe2 films by magneto-transport measurements*, The Physical Society of Japan, 77th Annual Meeting(online), 15-19 March (2022)
5. Y. Fujisawa, M/ Pardo-Almanza, K. Yamagami, C. H. Hsu, F. C. Chuang, Y. Okada,*Tunable Cr1+δTe2 films hosting skyrmion from frustrated ferrimagnetic background*, The Japan Society of Applied

5. Intellectual Property Rights and Other Specific Achievements

Nothing to report

6. Meetings and Events

Nothing to report

7. Other

Nothing to report.