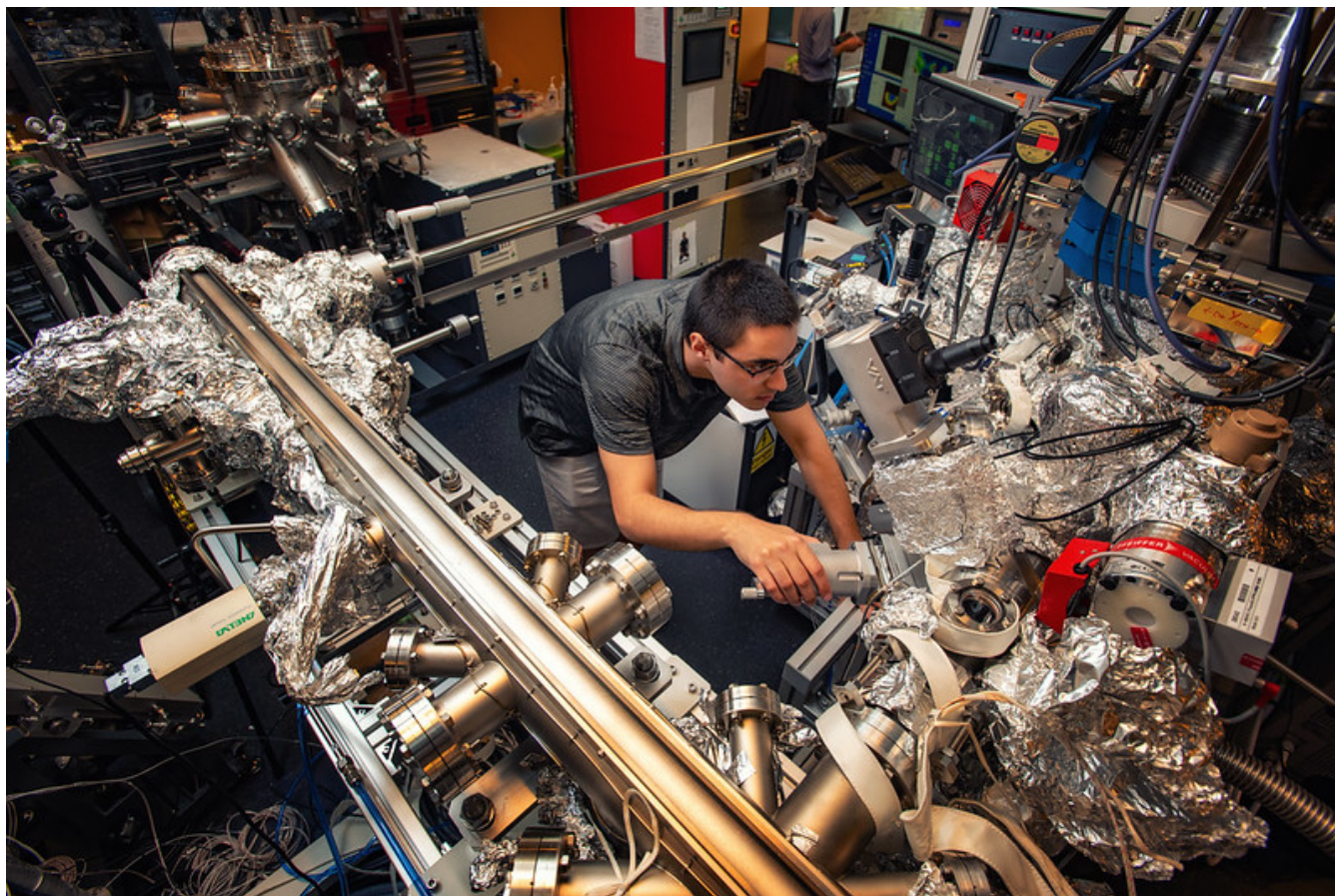


Quantum Materials Science Unit (Yoshinori Okada)

FY2020 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. The main activity in FY2020 was growth of magnetic quantum materials and their characterization. We succeeded to find several new systems with interesting magnetism. In parallel, we kept developing design of massive ultra-high vacuum (UHV) cluster system, which was finally installed in our new lab space in lab-4. Using this cluster system, we are now accelerating spectroscopic visualization of novel quantum states realized in our crystals and heterostructures.

1. Staff

1.1 Researchers

- Dr. Yuita Fujisawa (PD)
- Dr. Kohei Yamagami (PD)
- Dr. Ryutaro Okuma (PD)
- Dr. David Lloyd (PD)

1.2 Graduate Students

- Mr. Mohmed Atwa
- Mr. Barnaby Smith
- Mr. Markel Pardo Almanza
- Ms. Anjana Krishnadas
- Mr. Hiroki Sawada (Rotation Student: Jan.-Apr.2021)
- Mr. Mathieu Couillard (Rotation Student: Dec.2020-Apr.2021)

1.3 Visiting Scientists

- Dr. Chia-Hsiu, Hsu (National Sun Yet-sen University / National Center for Theoretical Science, Taiwan)
- Dr. Tessui Nakagawa (Ryukyu University)

1.4 Intern Student

- Mr. Hiroki Sawada (Keio University, Japan)

2. Collaborations

2.1 First Principle Calculations

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

2.2 Device Fabrication

- Prof. Yasuhiro Niimi (Osaka University, Japan)

2.3 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)

2.4 Magnetic Imaging

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

2.5 Thermal Management Project (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 Searching novel quantum materials and their heterostructure

We are interested in searching novel electric, magnetic and thermal related physical properties in quantum materials and their heterostructures. For this purpose, we have been focusing on growing layered quantum materials, in which interplay between charge, spin, orbital and lattice degree of freedoms can be eventually designed in low dimensional heterostructures. In this FY2020, by focusing on 4f electron and 3d electron based chalcogen compounds, we have found intriguing interplay between magnetism and itinerant electrons in low dimension.

3.2 Cluster system for designing/imaging quantum materials heterostructures

In FY2020, we started to move our lab space to the lowest floor of new building (called lab-4 at OIST). There, we have constructed UHV cluster system, which includes epitaxial thin film growth setups (for growing, for example, oxides, chalcogenides, and intermetallic compounds) and single particle spectroscopies, such as angle resolved photoemission (ARPES) and spectroscopic scanning tunneling microscope (S-STM). More than half of planned infrastructures are functional now. Using this cluster system, we are aiming to synthesize, fabricate, and visualize in artificially quantum materials hetero structures.

4. Publications

4.1 Journals

1. K. Yamagami, Y. Fujisawa, B. Driesen, C.H. Hsu, K. Kawaguchi, H. Tanaka, T. Kondo, Y. Zhang, H. Wadati, K. Araki, T. Takeda, Y. Takeda, T. Muro, F.C. Chuang, Y. Niimi, K. Kuroda, M. Kobayashi and Y. Okada, *Itinerant ferromagnetism mediated by giant spin polarization of metallic ligand band in van der Waals magnet Fe₅GeTe₂*, Phys.Rev. B (Lett) 103, L060403 (2021)
2. T. Ohta, M. Tokuda, S. Iwakiri, K. Sakai, B. Driesen, Y. Okada, K. Kobayashi and Y. Niimi, *Butterfly-shaped magnetoresistance in van der Waals ferromagnet Fe₅GeTe₂*, AIP Advances 11, 025014 (2021)
3. M. Watanabe, R. Nakamura, S. Lee, T. Asano, T. Ibe, M. Tokuda, H. Taniguchi, D. Ueta, Y. Okada, K. Kobayashi and Y. Niimi, *Shubnikov-de-Haas oscillation and possible modification of effective mass in CeTe₃ thin films*, AIP Advances 11, 015005 (2021)
4. Y. Fujisawa, M. Pardo-Almanza, J. Garland, K. Yamagami, X. Zhu, X. Chen, K. Araki, T. Takeda, M. Kobayashi, Y. Takeda, C.H. Hsu, F.C. Chuang, R. Laskowski, K.H. Khoo, A. Soumyanarayanan and Y. Okada, *Tailoring Magnetism in Self-intercalated Cr_{1+δ}Te₂ Epitaxial Films*, Physical Review Materials (2020)
5. R. Okuma, D. Ueta, S. Kuniyoshi, Y. Fujisawa, B. Smith, C.H. Hsu, Y. Inagaki, W. Si, T. Kawae, H. Lin, F.C. Chuang, T. Masuda, R. Kobayashi and Y. Okada, *Fermionic Order by Disorder in a van der Waals Antiferromagnet*, Scientific Reports 10, 15311 (2020)
6. M. Watanabe, S. Lee, T. Asano, T. Ibe, M. Tokuda, H. Taniguchi, D. Ueta, Y. Okada, K. Kobayashi and Y. Niimi, *Quantum oscillations with magnetic hysteresis observed in CeTe₃ thin films*, Appl. Phys. Lett. 117, 072403 (2020)
7. M. Atwa, T. Nakagawa, A. Yonamine, D.C. Lloyd, M. Schreiber, K. Miyazaki, T. Takeuchi and Y. Okada, *Top-down Approach using Supercritical Carbon Dioxide Ball Milling for Producing Sub-10 nm scaled Bi₂Te₃ Powders*, Applied Physics Express 13 067002 (2020)
8. H. Oka, Y. Okada, K. Kaminaga, D. Oka, T. Hitosugi and T. Fukumura, *Width-induced metal-insulator transition in SrVO₃ lateral nanowires spontaneously formed on the ultrathin film*, Applied Physics Letters 117, 051603(2020)

4.2 Books and other one-time publications

Nothing to report

4.3 Oral and Poster Presentations

1. Y. Fujisawa, M. Pardo-Almanza, J. Garland, K. Yamagami, X. Zhu, X. Chen, K. Araki, T. Takeda, M. Kobayashi, Y. Takeda, C.H. Hsu, F.C. Chuang, R. Laskowski, A. Khoo, A. Soumyanarayanan, Y. Okada, *Tailoring magnetism in self-intercalated Cr_{1+δ}Te₂ epitaxial films*, American Physical Society, March Meeting(online), 15-19 March (2021)
2. J. Garland, Y. Fujisawa, M. Pardo-Almanza, Y. Okada, *Tunable Magnetic Anisotropy and Curie Temperature in Cr_{1+δ}Te₂ Thin Films*, American Physical Society, March Meeting(online), 15-19 March (2021)
3. K.H. Khoo, Z.C. Huang, J.F. Kong, Y. Fujisawa, Y. Okada, A. Soumyanarayanan, *First Principles Study of Magnetic Properties of Cr_{1+δ}Te₂*, American Physical Society, March Meeting(online), 15-19 March (2021)
4. K. Yamagami, B. Driesen, Y. Fujisawa, C.H. Hsu, K. Kawaguchi, H. Tanaka, K. Kuroda, T. Kondo, Y. Zhang, H. Wadati, K. Araki, T. Takeda, M. Kobayashi, Y. Takeda, T. Muro, F.C. Chuang, Y. Niimi, Y. Okada, *Itinerant ferromagnetism mediated by giant spin polarization of metallic ligand band in van der Waals magnet Fe₅GeTe₂*, American Physical Society, March Meeting(online), 15-19 March (2021)
5. T. Ohta, K. Fujiwara, K. Ohboshi, K. Yamagami, Y. Okada, K. Kobayashi, Y. Niimi, *原子層強磁性体/超伝導体ヘテロ接合における輸送特性*, The Physical Society of Japan, 76th Annual Meeting(online), 12-15 March (2021)
6. K. Yamagami, Y. Fujisawa, M. Pardo-Almanza, Y. Takeda, Y. Okada, *軟X線磁気円二色性によるファンデルワールスFe系強磁性体の元素別磁気特性の温度/磁場依存性の観測*, The Physical Society of Japan, 76th Annual Meeting(online), 12-15 March (2021)
7. R. Okuma, H. Ishikawa, Z. Yang, K. Kindo, Y. Kohama, Y. Okada, *フラストレート半金属GdGa₂における強磁場下での電荷密度波の融解*, The Physical Society of Japan, 76th Annual Meeting(online), 12-15 March (2021)
8. Y. Fujisawa, M. Pardo-Almanza, K. Yamagami, C.H. Hsu, F.C. Chung, Y. Okada, *Anomalous Hall effect of Cr_{1+δ}Te₂ epitaxial films*, The Physical Society of Japan, 76th Annual Meeting(online), 12-15 March (2021)
9. B.R.M. Smith, Y. Fujisawa, K. Yamagami, C.H. Hsu, F.C. Chuang, Y. Okada, *Real space observation of inhomogeneous atomic structures in Fe₅GeTe₂ using STM*, The Physical Society of Japan, 76th Annual Meeting(online), 12-15 March (2021)
10. M. Pardo-Almanza, Y. Fujisawa, K. Yamagami, C.H. Hsu, F.C. Chuang, Y. Okada, *Direct Visualization of the Band Structure in Cr_(1+δ)Te₂ Epitaxial Films by ARPES*, The Physical Society of Japan, 76th Annual Meeting(online), 12-15 March (2021)
11. K. Yamagami, B. Driesen, Y. Fujisawa, C.H. Hsu, K. Kawaguchi, H. Tanaka, K. Kuroda, T. Kondo, Y. Zhang, H. Wadati, K. Araki, T. Takeda, M. Kobayashi, Y. Takeda, T. Muro, F.C. Chuang, Y. Okada, *軟X線磁気円二色性で観測したファンデルワールス強磁性体Fe₅GeTe₂の混成由来による配位子のスピン偏極状態*, The Physical Society of Japan, Autumn Meeting(online), 8-17 September (2020)
12. K. Kuroda, K. Kawaguchi, K. Yamagami, Y. Fujisawa, R. Noguchi, K. Yaji, A. Harasawa, Y. Okada, T. Kondo, *レーザー ARPES によるファンデルワールス Fe 系強磁性体における準粒子コヒーレンスの温度変化の観測*, The Physical Society of Japan, Autumn Meeting(online), 8-17 September (2020)
13. T. Ohta, K. Sakai, H. Taniguchi, B. Driesen, Y. Okada, K. Kobayashi, Y. Niimi, *ファンデルワールス強磁性金属Fe₅GeTe₂における垂直磁気異方性の評価*, The Physical Society of Japan, Autumn Meeting(online), 8-17 September (2020)
14. H. Tanaka, Y. Fujisawa, K. Kuroda, R. Noguchi, S. Sakuragi, C. Bareille, B.R.M. Smith, C. Cacho, S.W. Jung, T. Muro, Y. Okada, T. Kondo, *Observation of the three-dimensional electronic structure in*

Fe₃Sn₂ with kagome layers by angle-resolved photoemission spectroscopy, The Physical Society of Japan, Autumn Meeting(online), 8-17 September (2020)

15. R. Okuma, G. Nilsen, Y. Okada, ファンデルワールス金属CeSiIにおけるサイクロイド型らせん磁性の観測, The Physical Society of Japan, Autumn Meeting(online), 8-17 September (2020)

16. R. Okuma, Y. Okada, ファンデルワールス半金属GdGaIのフラストレート磁性と磁気輸送特性, The Physical Society of Japan, Autumn Meeting(online), 8-17 September (2020)

5. Intellectual Property Rights and Other Specific Achievements

Nothing to report

6. Meetings and Events

Nothing to report

7. Other

Nothing to report