2nd International Meeting on Thin Film Interfaces, Surfaces and Composite Crystals

(online meeting)

November 08-10, 2021

ABSTRACT BOOK

東京工業大学 Tokyo Institute of Technology　WRHI　岡山大学 OKAYAMA UNIVERSITY　RIIS　東京大学 THE UNIVERSITY OF TOKYO

INVITED SPEAKERS

Artyukhin, Sergey	Italian Institute of Technology, Italy
Biermann, Silke	École Polytechnique, France
Cren, Tristan	Sorbonne Université, France
Ichinokura, Satoru	Tokyo Institute of Technology, Japan
Ishizaka, Kyoko	The University of Tokyo, Japan
Kalisky, Beena	Bar-Ilan University, Israel
Kohsaka, Yuhki	RIKEN, Japan
Li, Wei	Tsinghua University, China
Liu, Canhua	Shanghai Jiao Tong University, China
Nakano, Masaki	The University of Tokyo, Japan
Nguyen, Hoa Hong	Masaryk University Brno, Czech Republic
Nomura, Yusuke	RIKEN, Japan
Rata, Diana	Martin Luther University Halle-Wittenberg, Germany
Rösner, Malte	Radboud University Nijmegen, The Netherlands
Stemmer, Susanne	University of California, Santa Barbara, USA
Taniguchi, Kouji	Tohoku University, Japan
Togawa, Yoshihiko	Osaka Prefecture University, Japan
Vasiliev, Alexander	National Research Centre Kurchatov Institute, Russia
Yasuda, Kenji	Massachusetts Institute of Technology, USA

SHORT PRESENTATIONS

Haze, Masahiro	The University of Tokyo, Japan
Ma, Xiaonan	Shanghai University, China
Medvedeva, Daria	Czech Academy of Science, Czech Republic
Sato, Yudai	The University of Tokyo, Japan
Wang, Xutao	Shanghai Jiao Tong University, China
Weitz Sobelman, Sapir	Bar Ilan University, Israel
Wu, Wanghzou	University of California, Santa Barbara, USA
Zhang, Yanting	Okayama University, Japan

Monday
08-11-2021
14.00 – 14.30

Intercalation-induced superconductivity in graphene

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Funding

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Graphene is known as the most promising nanomaterial for the post-silicon electrical industry. Its flexibility and transparency due to the monatomic thickness make it suitable for optoelectronic applications. Its high carrier mobility is attributed to graphene's linear and steep band dispersion. Although the beautiful Dirac cone nature is based on single-particle approximation, there have been many attempts to induce many-body effects (e.g., superconductivity and magnetism). It is represented by twistronics [1], the cutting edge of two-dimensional material research. In this talk, I would like to show another route to achieve that: the intercalation of guest metals into epitaxial graphene on SiC substrates.

Ca-intercalated graphite is a superconductor with T_c = 11 K. We aim to create a novel transparent superconductor by reducing its dimensionality using graphene. We firstly reported Ca-intercalated bilayer graphene (Ca-BLG) as a superconductor with T_c = 2 K [2]. It was confirmed as phonon-origin superconductivity by a simple Ca-BLG model [3]. Surprisingly, we found that monolayer graphene becomes superconducting as well by the same procedure. We clarified the trick as follows; as shown in Fig. 1a, monolayer graphene has a buffer layer at the interface with the SiC. Ca intercalation to both sides of the buffer layer results in the formation of Ca-BLG / Ca-terminated SiC (Fig. 1b). The overall band structure is roughly consistent with the Ca-BLG model without a substrate [3] except for a larger carrier density. This indicates charge transfer from the Ca-terminated SiC. The optimized transition temperature T_c = 5.4 K is higher than twisted bilayer graphene (T_c = 1.4 K).

Intercalation achieves flat band occupation in a different way than twisting. Pristine graphene has a flat band as an unoccupied state. Many-body effects are expected to be enhanced when the flat band is occupied by huge electron doping [4]. To explore the phase diagram around this region, it is necessary to tune the Fermi level finely in the vicinity of flatband. We found that Li-intercalation makes graphene into this condition, and the Fermi level can be controlled by increasing thickness [5].

Li also intercalates below the buffer layer, creating a sizable Schottky barrier in SiC. This opens up a way to directly apply SiC as the backgate. These properties suggest that the present system is ideal to the field-effect-transistor-device using the many-body interaction.

Literature:

[1] Y. Cao *et al.,* Nature 556, 43 (2018)
[2] S. Ichinokura *et al.,* ACS Nano 10, 2761 (2016)
[3] E. R. Margine *et al.,* Sci. Rep. 6, 21414 (2016)
[4] R. Nandkishore *et al.,* Nat. Phys. 8, 158 (2012)
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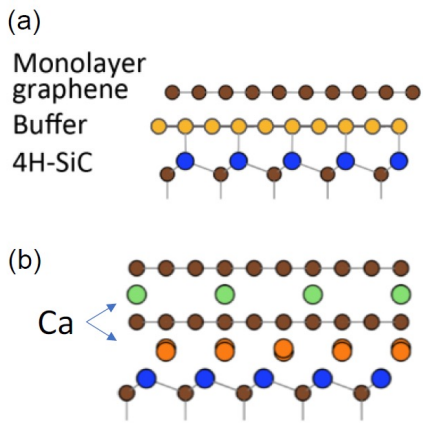

Figure 1. Schematic structure of **(a)** as-grown and **(b)** Ca-intercalated epitaxial graphene on SiC.

Monday
08-11-2021
14.30 – 15.00

Phase ordering dominated superconductivity in FeSe ultrathin films on $SrTiO_3$

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Fermi electrons undergo the superconducting transition via two processes, one is pair formation and the other is phase coherence. In conventional superconductors the two processes occur concurrently, but in unconventional superconductors beyond the framework of BCS theory, the two processes occur concurrently or not is a fundamental question still to be answered with unambiguous experimental evidence. Most of the previous experimental studies on this issue only focuses on the correlation of transition temperature with energy gap characterizing the energy scale of the pair formation [1,2], or with superfluid density characterizing the energy scale of the phase coherence [3,4]. Recently, we developed a multi-functional STM (named STM+), which enables in situ four-point-probe electrical transport and two-coil mutual inductance measurements besides STM/STS [5,6]. With the STM+, we can simultaneously collect information of critical temperature, energy gap and superfluid density from ultrathin superconducting films such as bilayer In films on Si(111) [7,8]. Very recently, our STM+ experiments performed on single-layer FeSe films and K-doped bilayer FeSe films [9] grown on $SrTiO_3$(001) have revealed that the transition temperature is lower than the opening temperature of the energy gap, and it shows a remarkable linear dependence followed by a square-root dependence on the phase stiffness. The results imply that the superconducting transition is dominated by the process of the phase ordering but not by pairing potential. Moreover, the preformed pairs are manifested by the absence of vortex on the homogeneously gaped single-layer FeSe surface above the transition temperature.

Literature:

[1] S. Hüfner, M. A. Hossain, A. Damascelli, G. A. Sawatzky, Rep. Prog. Phys. 71, 062501 (2008)
[2] Y. Kohsaka *et al.*, Nature 454, 1072 (2008)
[3] I. Bozovic, X. He, J. Wu, A. T. Bollinger, Nature 536, 309 (2016)
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[6] J. F. Ge, Z. L. Liu, C. L. Gao, D. Qian, C. Liu, J. F. Jia, Rev. Sci. Instrum. 86, 053903 (2015)
[7] Y. Wu *et al.*, Appl. Phys. Lett. 117, 172601 (2020)
[8] Y. Wu *et al.*, Phys. Rev. B 99 (2019)
[9] G. Yao *et al.*, Phys. Rev. Lett. 123, 257001 (2019)

Monday
08-11-2021
15.00 – 15.30

Imaging the magnetic landscape in a superconductor-correlated insulator alternate stacking 4Hb-TaS_2

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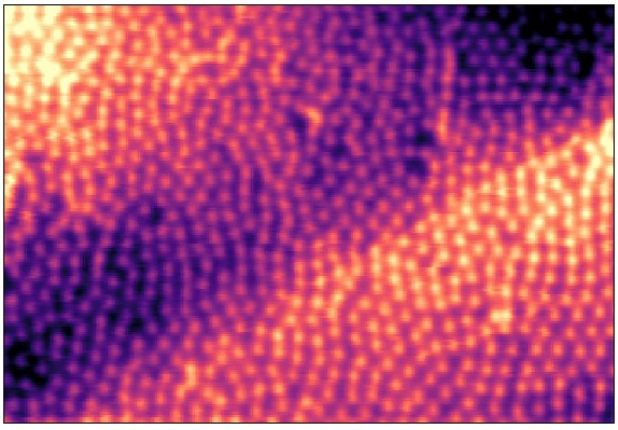
Van der Waals heterostructures provide a unique opportunity to examine proximity effects between materials with vastly different ground states. 4Hb-TaS_2 naturally realizes this opportunity as its structure is an alternate stacking of two lattice structures, 1T and 1H, a candidate chiral spin liquid and a superconductor.

In my talk, I will show scanning superconducting quantum interference device (SQUID) data, mapping the magnetic landscape of this compound. The data reveal magnetic history that affects the superconducting state and survives in the normal state. Our results indicate that the coupling between the two constituent layers generates a new unconventional ground state.



Monday
08-11-2021
15.45 – 16.15

Stripe phase in interfacial high-T_c superconductor FeSe/$SrTiO_3$

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We systematically carried out thickness-dependent study on FeSe/$SrTiO_3$ (FeSe/STO) by molecular beam epitaxy and scanning tunneling microscopy. A novel electronic stripe phase is discovered in multilayer FeSe films [1,2]. The stripe phase manifests as unidirectional stripe-like patterns in STM topographic images. The stripes are absent in FeSe single crystal. While tensile strain, as FeSe film is grown on STO, is introduced, giving rise to enhanced electronic anisotropy (*nematicity*). The electrons therefore tend to form unidirectional ordering in multilayer FeSe/STO, i.e., the discovered stripe phase. Long-range stripe order solely appears in bilayer FeSe films, since they are closer to STO substrate and have larger lattice expansion [2]. The stripes still locally exist in the vicinity of defects and gradually fade away with increasing film thickness [1], while it suddenly vanishes in monolayer FeSe due to the heavy electron doping from STO. Surface alkali-metal doping can suppress the stripe phase and induce high-T_c superconductivity in bilayer FeSe [2]. Our finding demonstrates that the monolayer FeSe is in close proximity to the stripe phase, and its superconductivity is likely enhanced by this electronic instability.

Literature:

[1] W. Li *et al.*, Nature Physics 13, 957 (2013)
[2] Y. Yuan *et al.*, Nat. Commun. 12, 2196 (2021)

Monday
08-11-2021
16.15 – 16.45

Huge doping and unconventional superconductivity in the misfit compound $(LaSe)_{1.14}(NbSe_2)_2$

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In the current quest of innovative materials which combine two-dimensionality, strong spin-orbit, valley physics, superconductivity, charge density wave, quantum-spin Hall effect, the transition metal dichalcogenides (TMD) misfit materials appear as extremely promising. They are constituted by sandwiching rocksalt layers, such as LaSe, and TMD layers such as $NbSe_2$. A very large combination of materials is achievable by playing on the stacking. We will show that TMD misfits are a new platform that allows to achieving unprecedented high doping levels in TMD materials. This permits to explore physical properties such as charge density wave or superconductivity in extreme regimes of doping that cannot be achieved by gating.

In this work we investigate $(LaSe)_{1.14}(NbSe_2)_2$ which is a stacking of $NbSe_2$ and LaSe layers. The bulk misfit layer compound has van der Waals bonding in between $NbSe_2$ layers and can thus be easily cleaved; its surface hosts a single layer $NbSe_2$ on top of a LaSe layer. By performing ARPES, STM, quasiparticle interference measurements, and first principles calculations we demonstrate that the charge transfer of LaSe valence electrons to NbSe2 is practically complete and the surface of the cleaved LaSe/$NbSe_2$ heterostructure behaves like a single layer $NbSe_2$ at the extreme high-doping of 0.6 electrons per Nb, almost an order of magnitude larger than what can be obtained in field effect doping [1,2].

Superconductivity in this compound exhibits a huge in-plane critical field which is much higher than the paramagnetic limit. We attribute this enhancement to the fact that LaSe layers behave like insulating barriers. Then the bulk material behaves like a stack of weakly coupled $NbSe_2$ layers in which the Ising spin-orbit coupling, as observed in $NbSe_2$ monolayers, strongly enhance the critical field. The Ising coupling can also induced non-conventional pairing such as f-wave pairing. We have explored this possibility by measuring the gap by tunnelling in different directions and we find some hint of non-conventional pairing.

Literature:

[1] R. T. Leriche *et al.*, Adv. Funct. Mater. 31, 2007706 (2021)
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Monday
08-11-2021
17.30 – 18.00

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How to tailor magnetic properties of ferrite nanoparticles and thin films

Nanotechnology and nanoscience are considered to be the rapid emerging fields for the last two decades. Nano-sized particles and nano-sized thin films have unique, unusual, unexpected, unimaginable, and superior properties compared to their bulk counterparts. Due to their uniqueness, the physical and chemical properties of nanomaterials were extensively investigated. At nanoscale, the quantum size effects are strongly influenced by core and surface area. Knowing that, one can manipulate to fabricate artificial materials with the controlled properties using different chemical compositions.

The unexpected magnetism in few materials is due to their nano-size. When the dimension of the material is reduced, it results in the reduction of co-ordination number of atoms, which in turn, may reduce the electrons hopping from one site to another site. Therefore, the bandwidth reduces and increases the Coulomb interaction. This leads to the appearance of magnetism at nanoscale. Moreover, defects due to additives may create vacancies in the magnetic material which also plays important role in inducing collective magnetic properties in nano-sized materials.

I will talk about three cases: $ZnFe_2O_4$, $BiFeO_3$, and $BaFeO_3$. We have achieved to manipulate those ferrites to tune their magnetic properties up to our applications' expectation. In general, there are appropriate ways to suppress the spiral magnetic ordering by applying a very high magnetic field, by creating epitaxial constrains, or reducing the dimensions of the sample, or by chemical substitution of Bi^{3+} or Fe^{3+} by other ions of comparable ionic sizes. Reduction in dimension is certainly shown to enhance the magnetization in thin films and in nanoparticles

Monday
08-11-2021
18.00 – 18.30

Electron microscopy study of interfaces in functional oxides

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Functional oxides are widely used materials in many applications like superconductivity, nanoelectronics, gas-turbine engine production and many others. The interfaces between oxide layers and supporting materials or between different oxide layers play key role in electro-physical and mechanical properties of these materials. The interface structure can be characterized by using a number of techniques, including transmission or scanning electron microscopy (TEM and STEM, respectively) together with energy dispersive X-ray microanalysis (EDX) and electron energy loss spectroscopy (EELS). Electron microscopy and microanalysis performed using modern equipment allows obtaining structural and analytical information at the atomic level.

Several examples of interface studies by TEM, STEM and EDX will be considered: MgO tunneling barriers, epitaxial thin film of cobalt-doped hexagonal $LuFeO_3$ on Y stabilized zirconia, GdBCO high-T_c films on $SrTiO_3$ substrate with Gd_2O_3 intermediate layer. MgO layers are used as a spin filters and diffusion barrier for deposition of ferromagnetic films on GaAs (001) surfaces. The relatively large lattice mismatch of the MgO, and GaAs substrate and probable formation of interface states at the metal layer side require a careful barrier design. The dependence of morphology of MgO layers on their thickness and stress at the MgO/GaAs interface was determined.

Epitaxial thin films of hexagonal $LuFeO_3$, where Co was partially substituted for Fe, are a new class of ferroelectric materials. The use of atomic-resolution EDX mapping (ChemiSTEM) to probe the distribution of the chemical elements in the $Lu(Fe,Co)O_3$ thin films showed the Co substitution for Fe $LuFeO_3$ thin films. The Co doping is responsible for the ubiquitous appearance of double layers of (Fe/Co)–O, which can be termed 'reconstructed stacking faults' and represent structural fragments of $LuFe_{2-x}Co_xO_4$ compound.

Good lattice match between GdBCO film and substrate provides favorable conditions for the growth of undesirable (100)-oriented grains in RBCO films. It was found that the orientation of RBCO film is influenced not only by the mismatch, but also by substrates crystal structure. Few nanometer thick Gd_2O_3 substrate effectively suppresses the formation of (100)-oriented grains in GdBCO films, and that could be explained by a simple model based on the nucleus formation mechanism.

Monday
08-11-2021
18.30 – 19.00

Growth-sequence-dependent interface magnetism of $SrIrO_3$ – $La_{0.7}Sr_{0.3}MnO_3$ bilayers

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Designing artificial heterostructures of iridates with other well-studied transition metal oxides in order to explore the interfacial coupling between 5*d* and 3*d* electrons in oxides is important, both fundamentally and for future applications. Broken inversion symmetry due to the interface and large spin-orbit coupling result in the occurrence of the Dzyaloshinskii-Moriya (DM) interaction at the interfaces. This can have a strong impact on fundamental properties of magnetic materials like, e.g., magnetic anisotropy. Especially the perpendicular magnetic anisotropy is essential for new spintronic devices [1].

Bilayers consisting of 3*d* ferromagnet $La_{0.7}Sr_{0.3}MnO_3$ and the 5*d* paramagnet $SrIrO_3$ with large spin-orbit coupling (SOC) were investigated in order to study the impact of interfacial SOC on the magnetic order. $La_{0.7}Sr_{0.3}MnO_3$ and $SrIrO_3$ layers were grown fully strained on TiO_2-terminated $SrTiO_3$(100) substrates by pulsed laser deposition with both growth sequence. The bilayers have similar interface composition and were coherently grown on the substrate.

Measurements of magnetization and field-dependent Mn $L_{2,3}$ edge x-ray magnetic circular dichroism reveal strong changes of $La_{0.7}Sr_{0.3}MnO_3$ magnetic order. The soft ferromagnetism of $La_{0.7}Sr_{0.3}MnO_3$ changes towards more hard-magnetic behavior with a canted perpendicular magnetic moment and reduced saturated magnetization. These changes are much stronger in $La_{0.7}Sr_{0.3}MnO_3$ grown on top of $SrIrO_3$ compared to the other growth sequence [2].

We attribute the impact of the growth sequence on the magnetic order of $La_{0.7}Sr_{0.3}MnO_3$ to the interfacial lattice structure, which is known to influence the interfacial magnetic coupling governed by MnO_6 octahedral rotations and/or distortions. Our results demonstrate the importance of the growth sequence for the magnetism of the $La_{0.7}Sr_{0.3}MnO_3$ – $SrIrO_3$ interface with large spin orbit coupling.

Literature:

[1] D. Yi, C. L. Flint, P. P. Balakrishnan, K. Mahalingam, B. Urwin, A. Vailionis, Y. Suzuki, *et al.,* Phys. Rev. Lett. 119, 077201 (2017)
[2] L. Bergmann, Pia Duering, S. Agrestini, K. Doerr, A. D. Rata *et al.*, AIP Advances 10, 035132 (2020)

Tuesday
09-11-2021
14.00 – 14.30

An aperiodic electronic superstructure in a misfit layered chalcogenide

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Funding

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We show the electronic state of misfit layered chalcogenides, $(PbSe)_{1.16}(TiSe_2)_2$ and $(SnSe)_{1.18}(TiSe_2)_2$, using spectroscopic-imaging scanning tunneling microscopy. The misfit layered chalcogenide is a member of composite crystals and consists of sublayers distinct in symmetry and periodicity, i.e., rock-salt metal monochalcogenide (PbSe or SnSe) and octahedral transition-metal dichalcogenide ($TiSe_2$) (Fig. 1). The lattice constants match in one in-plane direction (the commensurate direction) but do not in the other in-plane direction. Because of this unique structure, in-place Bragg peaks of the misfit layered chalcogenides are indexed by three integers.

We have observed three kinds of termination layers for each material. On the PbSe/SnSe terminations, topographic images show rectangular lattices. When two $TiSe_2$ sublayers lie on the surface, a 3Q-2a_0 (2×2) charge density wave found in 1*T*-$TiSe_2$ appears together with triangular lattices of the lattice constant a_0. When a single $TiSe_2$ sublayer is left on the surface, a 1Q-2a_0 charge density wave appears in the commensurate direction of $(SnSe)_{1.18}(TiSe_2)_2$ while new electronic superstructure emerges in $(PbSe)_{1.16}(TiSe_2)_2$. The new electronic superstructure requires three indices, inheriting the aperiodic characteristic of the misfit lattice. The detailed analysis of spectroscopic measurements reveals that the aperiodic electronic superstructure appears when interlayer bonding between the PbSe sublayer to the $TiSe_2$ sublayer is strong enough. Our finding demonstrates that the unique stacking consisting of sublayers distinct in symmetry and periodicity can induce a novel electronic order with symmetry different from those of individual sublayers.

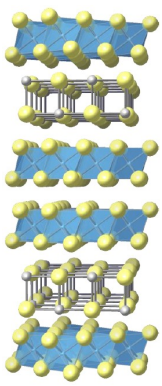

Figure 1. Crystal structure of $(PbSe)_{1.16}(TiSe_2)_2$ and $(SnSe)_{1.18}(TiSe_2)_2$

Tuesday
09-11-2021
14.30 – 15.00

ARPES study on composite layered transition-metal dichalcogenides

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There has been increasing interest in Moiré superlattice structures appearing in heterostructure and/or twisted van der Waals materials. There the electronic structures are modulated reflecting the super-periodic potentials, in some cases appearing as band replicas, strongly modified band widths, *etc*. In this presentation, I will introduce our recent works on misfit and artificially-stacked transition-metal dichalcogenides, investigated by angular resolved photoelectron spectroscopy (ARPES). In the misfit transition metal dichalcogenide superconductor $(PbSe)_{1.16}(TiSe_2)_n$, the square lattice PbSe and the triangular lattice $TiSe_2$ layers are alternatively stacked, thus offering a nature made bulk example of heterostructure composite material with constituents of different symmetries. By performing ARPES, we found an evidence of charge transfer between PbSe and $TiSe_2$ layers, with the characteristic band and Fermi surface appearing at the edge of the misfit composite Brillouin zone. The detailed band structures and the behavior of inherent charge density waves will be discussed in comparison with $TiSe_2$. In the latter half, I will introduce our laser-based micro-ARPES result on artificially stacked atomically thin WTe_2 and $MoTe_2$. Peculiar layer number dependent electronic structures and possible effect of twisted stacking will be discussed.

Tuesday
09-11-2021
15.45 – 16.15

Realistic modelling and correlation effects in monolayer NbS_2 and $NbSe_2$

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Layered transition metal dichalcogenides constitute a unique class of materials offering an exceptionally rich phase diagram and serving as a testbed for investigating various quantum phenomena. The competition between charge density waves and superconductivity has been reported in monolayer dichalcogenides $NbSe_2$ and NbS_2. While it is popularly believed that the two states tend to suppress each other, the origin of their coexistence remains unclear.

Many theoretical works studying the coexisting charge density wave and superconducting states in NbS_2 and $NbSe_2$ have mostly focused on the phonon spectra, where the appearance of imaginary modes is attributed to the charge-density-wave instability and the superconductivity is described by the conventional electron-phonon coupling calculations. However, electron correlations that play an important role in transition metal compounds are widely neglected. In our study, we investigate the effect of long-range electronic correlations in monolayer NbS_2 and $NbSe_2$ by constructing the low-energy electronic models entirely from first principles and simulating their properties by means of extended dynamical mean-field theory.

Tuesday
09-11-2021
16.15 – 16.45

Materials design of cuprate-analog nickelates and magnetic exchange coupling

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Acknowledgments

This work is done in collaboration with Motoaki Hirayama, Terumasa Tadano, Takuya Nomoto, Kazuma Nakamura, Yoshihide Yoshimoto, and Ryotaro Arita.

The recent discovery of superconductivity in the doped infinite-layer nickelate $R_{1-x}Sr_xNiO_2$ (R = Nd, Pr) offers a great opportunity to unravel the mystery of superconductivity in correlated materials [1,2]. While the electronic structure of the nickelates is similar to that of the cuprates in the sense that the strongly-correlated x^2-y^2 band is present, $RNiO_2$ is not a Mott insulator due to the carrier doping from the rare-earth layer (self-doping) [2,3]. In the present study, we answer two fundamental questions: (i) Is it possible to design nickelates whose electronic structure is more similar to cuprates? (ii) Is it possible to achieve large magnetic exchange coupling J in cuprate-analog nickelates?

For (i), we find dynamically stable cuprate-analog nickelates by a systematic material design of layered nickelates [4]. In such d^9 nickelates, the self-doping is absent and the x^2-y^2 band becomes half-filled, which enables us to compare the nickelates (Mott-Hubbard-type material) and cuprates (charge-transfer-type material) on an equal footing. (ii) Then, it is interesting to investigate whether the d^9 nickelates can have a sizeable J because a large value of J of about 130 meV is a characteristic feature of the cuprates. We study the J value in theoretically-designed $RbCa_2NiO_3$ and $A_2NiO_2Br_2$ (A: a cation with the valence of +2.5). We show that these nickelates have a significant magnetic exchange coupling as large as about 80 – 100 meV, which is not far smaller than that of the cuprates [5].

Literature:
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[2] Y. Nomura, R. Arita, *arXiv*:2107.12923
[3] Y. Nomura *et al.*, Phys. Rev. B 100, 205138 (2019)
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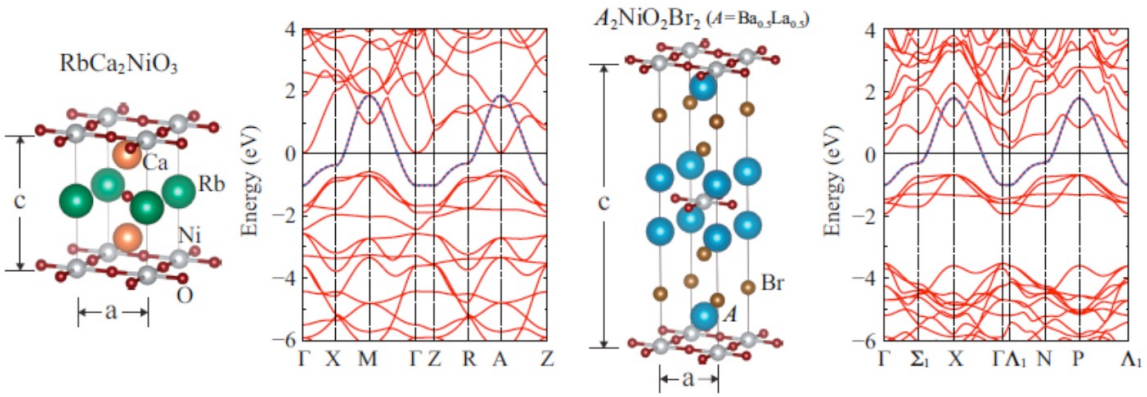
[5] Y. Nomura *et al.*, Phys. Rev. Research 2, 043144 (2020)



Tuesday
09-11-2021
16.45 – 17.15

Anisotropic superconductivity induced at a hybrid superconducting-semiconducting interface

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Epitaxial semiconductor-superconductor heterostructures are promising as a platform for gate-tunable superconducting electronics. Thus far, the superconducting properties in such hybrid systems have been predicted based on simplified hybridization models which neglect the electronic structure that can arise at the interface. Here, we demonstrate that the hybrid electronic structure derived at the interface between semiconducting black phosphorus and atomically thin films of lead can drastically modify the superconducting properties of the thin metallic film. Using ultra-low temperature scanning tunneling microscopy and spectroscopy, we ascertain the moiré structure driven by the interface, and observe a strongly anisotropic renormalization of the superconducting gap and vortex structure of the lead film. Based on density functional theory, we attribute the renormalization of the superconductivity to weak hybridization at the interface where the anisotropic characteristics of the semiconductor band structure is imprinted on the Fermi surface of the superconductor. Based on a hybrid two-band model, we link this hybridization-driven renormalization to a weighting of the superconducting order parameter that quantitatively reproduces the measured spectra. These results illustrate the effect of interfacial hybridization at superconductor-semiconductor heterostructures, and pathways for engineering quantum technologies based on gate-tunable superconducting electronics.

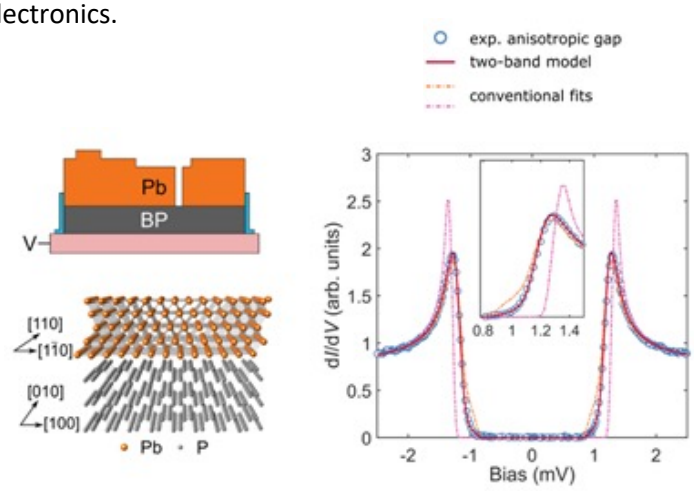

Figure 1. (left) Sketch of the sample geometry showing the cross section of the ultra-thin Pb(111) film and the BP crystal; **(right)** d*I*/d*V* spectrum (open blue circles) measured at T = 30 mK on a 7 ML film together with the fit employing a two-band model (red curve). The fit uses an anisotropic gap and an anisotropic density of states represented by a weight function $w(\vartheta)$. The magenta and orange curves represent simulated spectra with an isotropic gap and an anisotropic gap without incorporating the weight function, respectively.

Tuesday
09-11-2021
17.30 – 18.00

Crystals inside crystals: modelling valence bond solid states in $IrTe_2$

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$IrTe_2$ combines the most expensive (and strongly spin-orbit coupled) cations and anions in a MoS_2 structure with triple layers formed by a triangular layer of Ir ions sandwiched between two layers of Te. As temperature is lowered below 280 K, some of the Ir-Ir bonds shrink by about 20% resulting in Ir-Ir dimers, which are arranged into various patterns at different temperatures. The mechanism that stabilizes these states is still debated.

Here we combine first-principles calculations and a simplified analytical model to rationalize these phenomena. The ab-initio calculations suggest that the total energy for the experimentally observed phases first decreases linearly with the number of dimers and then grows, thus giving an optimal dimer density at zero temperature.

With the dimer formation the phonon density of states is shifted to higher frequencies, into the dimer-localized phonon bands. This interplay between dimer formation energy and phonon entropy is captured with a simplified model, that suggests a phase diagram in the form of a Devil's staircase. We further extract the interactions between dimers from first-principles force constant matrix. The interactions through the lattice strain drive striped orders in a way, analogous to that in orthorhombic manganites. The patterns are compared to those observed experimentally in the bulk and in scanning probe experiments on $IrTe_2$ films.

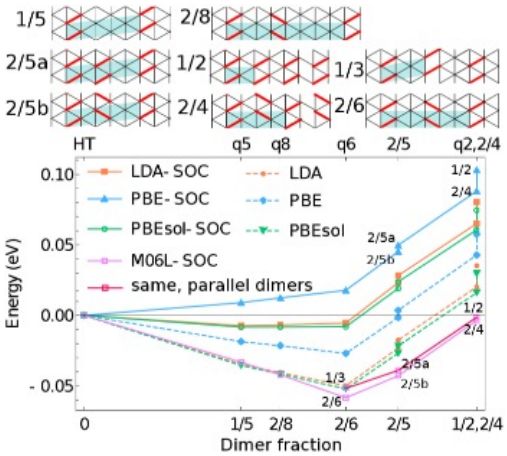

Figure 1. (top) Valence bonds (in red) that may be formed in a triangular lattice of Ir ions in $IrTe_2$. The shaded area indicates the resulting supercell. The patterns are captioned according to the dimer density; **(bottom)** despite the complexity of dimer arrangements, the DFT total energy dependence on the dimer density for all states and XC functionals has a rather simple form.

Tuesday
09-11-2021
18.00 – 19.00

LECTURE: Spectral properties of correlated electron materials from a dynamical mean field theory perspective and beyond

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Dynamical mean field techniques (DMFT), in conjunction with electronic structure methods, have led to tremendous progress in the description of spectral properties of materials with strong electronic Coulomb correlations. We will provide an overview and review some highlights.

The basic assumption of DMFT is that electronic correlations can be captured by a local (i.e., momentum-independent) many-body self-energy. In the second part of this talk, we present examples of materials where one needs to go beyond this paradigm: the description of spectral properties of Sr_2IrO_4 for example is significantly improved when including interatomic self-energies, reflecting strong antiferromagnetic fluctuations between Ir atoms present in this compound.

Wednesday
10-11-2021
10.00 – 10.30

Stacking-engineered two-dimensional ferroelectrics

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Acknowledgments

This work is performed in collaboration with Xirui Wang, Yang Zhang, Song Liu, Kenji Watanabe, Takashi Taniguchi, James Hone, Liang Fu, and Pablo Jarillo-Herrero.

Recent advances in van der Waals stacking techniques made it possible to fabricate heterostructures with emergent physical properties. For example, in twisted bilayer graphene, it has been shown that flat bands induce strongly correlated physics such as superconductivity and ferromagnetism unlike monolayer graphene. In this talk, I will demonstrate the design principle of creating ferroelectrics out of paramagnetic parent materials by controlling the crystal symmetry using van der Waals stacking.

Bulk hexagonal boron nitride (BN) has spatial inversion symmetry because adjacent layers are rotated by 180° (AA' stacking, Fig. 1a). On the other hand, when two BNs are stacked without rotation, the crystal becomes ferroelectric [1]. Parallel-stacked BNs are AB or BA stacking, which results in out-of-plane polarization switching due to interlayer sliding (Figs. 1b,c). In this study, we fabricated parallel-stacked bilayer BN by cut-and-stack method and measured the polarization using piezoresponse force microscopy and graphene as a probe [2-4]. Furthermore, by twisting the two BNs at a small angle, moiré ferroelectricity is formed with adjacent domains having opposite polarizations (Fig. 1d). This design principle applies to a wide range of two-dimensional materials and has the potential to significantly expand the variety of two-dimensional ferroelectrics. By applying the same idea to transition metal dichalcogenides (TMDs), we have also achieved ferroelectricity in four semiconductors TMDs, namely MoS_2, $MoSe_2$, WS_2, and WSe_2 [5].

Literature:

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[2] K. Yasuda *et al.*, Science 372, 1458 (2021)
[3] M. V. Stern *et al.*, Science 372, 1462 (2021)
[4] C. R. Woods *et al.*, Nat. Commun. 12, 347 (2021)
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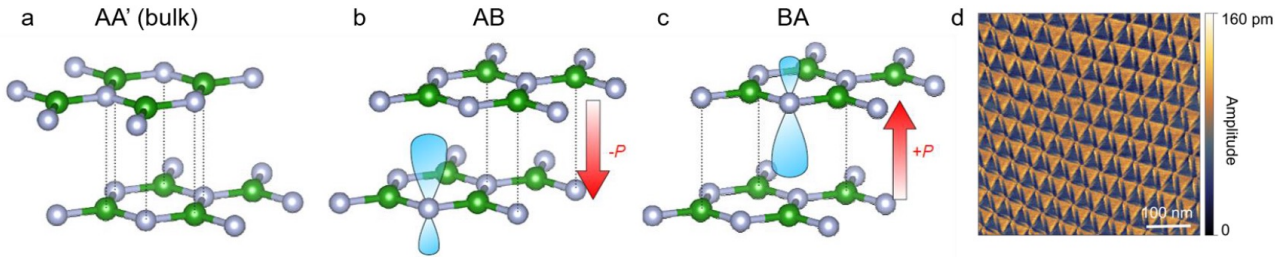

Figure 1. (a) Crystal structure of bulk hexagonal boron nitride and **(b, c)** parallel-stacked boron nitride. **(d)** Ferroelectric moiré lattice observed with piezoresponse force microscopy. Adapted from [2].

Wednesday
10-11-2021
10.30 – 11.00

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Inversion symmetry breaking and superconductivity of $SrTiO_3$

During the previous "International Meeting on Thin Film Interfaces, Surfaces and Composite Crystals" we discussed ferroelectricity and superconductivity in strained thin films of doped strontium titanate ($SrTiO_3$). For example, we showed that the superconducting transition temperature is enhanced by a factor of two in such films. In this talk, we will discuss more recent insights into what causes the enhanced transition temperature. One new finding is that the superconducting critical temperature correlates with the length scale of polar order. In particular, the transition temperature is enhanced when polar nanodomains are sufficiently large or, in the extreme limit, films are globally ferroelectric prior to becoming superconducting. Another new set of experiments concerns the film thickness dependence of the superconductivity. In particular, we show that the superconducting transition is suppressed below 20 nm and we correlate this observation with the ferroelectric transition. Moreover, we will discuss the pronounced insensitivity of the superconductivity to large amounts of rare earth impurities. All our findings point to spin-orbit coupling as an important parameter in controlling the superconductivity of $SrTiO_3$.

Wednesday
10-11-2021
11.30 – 11.40

Molecular beam epitaxy of phase-pure antiperovskite Sr_3SnO thin films

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The antiperovskite Sr_3SnO is of substantial interest because it is a Dirac material that has six Dirac nodes along the six Γ–X directions [1]. Moreover, Sr-deficient $Sr_{3-x}SnO$ can become superconducting [2-4]. This unusual combination of a topological band structure and superconductivity makes $Sr_{3-x}SnO$ a potential platform for an intrinsic topological superconductor [5]. So far, superconductivity has only been observed in highly Sr-deficient $Sr_{3-x}SnO$ polycrystalline samples that also contain secondary phases [2-4]. The impact of these impurity phases on superconductivity remains poorly understood. Recently, molecular beam epitaxy (MBE) of Sr_3SnO and Sr_3PbO films has been reported [6-8]. X-ray diffraction (XRD) was used in these studies to ascertain the phase purity of the films. Impurity phases in thin films can, however, be hard to detect in XRD, especially if they have random orientations or poor crystallinity.

In this work, oxide MBE was used to grow Sr_3SnO thin films, by co-evaporation of high-purity elemental Sr and SnO_2. The films' stoichiometry was controlled by varying the flux from the SnO_2 cell while keeping the Sr flux constant. Film growth was monitored in-situ by reflection high-energy electron diffraction. The films were then characterized by XRD, scanning electron microscopy (SEM) in a focused ion beam, and electrical measurements. We demonstrate that phase-pure $Sr_{3-x}SnO$ films can be grown. Sn-rich growth conditions can lead to large amounts of a Sn-rich impurity phase which is difficult to detect in XRD but can be seen in SEM images. Carrier densities and the amount of impurity phase change systematically with the growth conditions, suggesting that MBE allows for excellent control of the films' stoichiometry. Electrical properties are discussed, including quantum interference phenomena, which support the topological nature of the films.

Literature:

[1] T. H. Hsieh, J. W. Liu, L. Fu, Phys. Rev. B 90, 081112 (2014)
[2] M. Oudah *et al.*, Nat. Commun. 7, 13617 (2016)
[3] M. Oudah *et al.*, Sci. Rep. 9, 1831 (2019)
[4] A. Ikeda *et al.*, Phys. Rev. B 101, 174503 (2020)
[5] T. Kawakami, T. Okamura, S. Kobayashi, M. Sato, Phys. Rev. X 8, 041026 (2018)
[6] D. Samal, H. Nakamura, H. Takagi, APL Mater. 4, 076101 (2016)
[7] Y. J. Ma *et al.*, Adv. Mater. 32, 2000809 (2020)
[8] H. Nakamura *et al.*, Nat. Commun. 11, 1161 (2020)

Wednesday
10-11-2021
11.40 – 11.50

Superconductivity of Ca-intercalated bilayer graphene on silicon carbide

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Graphite intercalation compounds [1,2] have been attracting continuous interest as it can introduce superconductivity into graphene/graphite which has many remarkable properties except superconductivity. Though the bulk CaC_6 and YbC_6, with T_c of 11.5 and 5.5 K, respectively, have been reported, T_c of C_6CaC_6 film (4K) [3] sharply decreases when the material is close to quasi-two-dimensional. In addition, previous results of STM and STS show that charge density wave was observed on C_6CaC_6 film grown on Silicon Carbide at 5K [4], which may compete with superconductivity.

In our work, we directly intercalated Ca into top two-layer graphene of a three-layer graphene film on SiC (0001) substrate by controlling the deposition condition instead of Li pre-intercalate. Here, we found that this Ca-intercalated bilayer graphene produces a Bardeen-Cooper-Schrieffer (BCS)-type (s-wave) superconductivity with a higher T_c (8.83 K) by detecting the diamagnetic response with STM/STS, measured by a self-developed multifunctional scanning tunneling microscope (named STM+). This work shows the highest Tc in two-dimensional carbon system which ensures an abroad application prospect.

Literature:

[1] N. Emery *et al.*, Phys. Rev. Lett. 95, 087003 (2005)
[2] T. Weller *et al.*, Nature Phys. 1, 39 (2005)
[3] S. Ichinokura *et al.*, ACS Nano, 10, 2761 (2016)
[4] R. Shimizu *et al.*, Phys. Rev. Lett. 114, 146103 (2015)

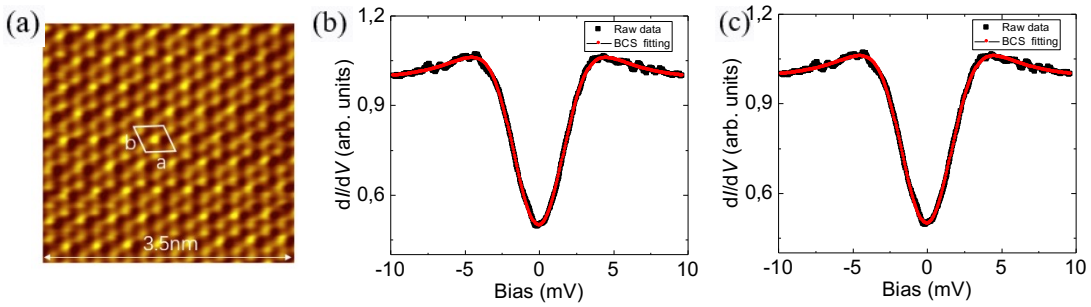

Figure 1. (a) Atomic-scale STM image of the C_6CaC_6 taken at 4.2 K with V_s = –110 mV, I = –80 pA. **(b)** Averaged tunneling spectrum taken at 4.2 K with V_s = 10 mV, I = 100 pA, Δ = 1.92 meV. The red line is the fitting result to the Dynes function. **(c)** Temperature dependence of real part mutual inductance V_P^{Re} collected at various magnetic fields.

Wednesday
10-11-2021
11.50 – 12.00

Role of steps on superconductor-insulator transition of mono-atomic-layer metal films formed on semiconducting substrates

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Two-dimensional (2D) superconductors undergo superconductor-insulator transition (SIT), which is one of the quantum phase transitions, with the application of magnetic field. The behavior has been explained by bosonic scenario [1]; the Cooper pairs are condensed and magnetic vortices are localized in the superconducting phase, and in the insulating phase, the Cooper pairs are localized and the vortices are condensed. It has been known that the critical temperature and the critical magnetic field depend on the strength of disorder. Since 2D superconductors are extremely sensitive to disorder, it is expected that the behavior of SIT are also significantly modified by introduction of impurities or defects.

Recent studies using highly crystalline 2D superconductors revealed anomalous metallic state around the transition [2,3] and have attracted a plenty of attentions. The anomalous metallic state is observed as the temperature-independent residual resistance near zero temperature under small magnetic fields, and thus believed to be related to the motion of vortices by quantum phase fluctuation. Microscopic understandings on these curious phases: the localized Cooper pairs and anomalous metallic phases, are, however, still missing. One of the problems is that most of the experiments on SIT are performed by macroscopic methods such as electron and heat transport measurements. Several SIT studies [4,5] have been performed using scanning tunneling microscopy and spectroscopy (STM/S), which is a powerful microscopic tool for superconductivity. All of them, however, focused on strongly disordered systems and there is no report on SIT by STM/S on highly crystalline systems, in which the anomalous metallic state is observed.

In this presentation, we will report the magnetic-field-driven SIT evaluated by electrical conductance measurements and STM/S performed on mono-atomic-layer Pb thin films formed on the Si(111) substrates with various step densities. From electrical conductance measurements, we found that the critical temperature T_c is reduced but the orbital critical magnetic field B_{c2}^{orb} is enhanced with the increase in the step density. In addition, the behavior of the anomalous metallic state depends on the step density. From STM/S measurements, the shape of vortices is circular but not clear. These features indicate that the

atomic step works as disorder, disrupting the superconducting coupling across the terraces [6,7]. Interestingly, in the case of the sample with large step density, the superconducting gap still remains under the magnetic field above B_{c2}^{orb}. We expect that it implies that large step density induces Bose insulating phase, in which the Cooper pairs are still remaining but localized.

Literature:

[1] M. P. A. Fisher *et al*., Phys. Rev. B 40, 546 (1989)
[2] K. Ienaga *et al*., Phys. Rev. Lett. 125, 257001 (2020)
[3] S. Ichinokura *et al*., Phys. Rev. B 99, 220501(R) (2019)
[4] Y. Noat *et al*., Phys. Rev. B 88, 014503 (2013)
[5] M. Žemlička *et al*., Phys. Rev. B 88, 180508(R) (2020)
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Wednesday
10-11-2021
12.00 – 12.10

Compressed sensing for efficient measurement of quasiparticle interference with the use of scanning tunneling microscopy/spectroscopy

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Scanning tunneling microscopy and spectroscopy (STM/S) enables us to detect quasi-particle interference (QPI) patterns, which is based on electron interference phenomena on surfaces. By taking the Fourier transformation of such patterns at various energies, we obtain the energy dispersion of quasi-particles, which is related to the band structure of the system. This technique is widely used in condensed matter physics such as unconventional superconductors and topological insulators. However, those measurements are time-consuming because tunneling spectroscopy measurement has to be performed both in high spatial and energy resolutions to obtain sufficient momentum-space (q-space) information. In order to improve the time-efficiency of the measurement, we study the use of compressed sensing (CS) for STS. CS is a signal-processing technique for the recovery of signals from a small number of data points. Our application of CS is based on the sparseness of QPI patterns in q space. We applied least absolute shrinkage and selection operator (LASSO), a CS technique, to analyze an STM image of the Ag(111) surface whose q-space image of QPI shows a circular pattern. We revealed that LASSO performs well in reconstructing the circular pattern from reduced data points [1].

Literature:
[1] Y. Nakanishi-Ohno, M. Haze *et al.*, J. Phys. Soc. Jpn. 85, 093702 (2016)

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Wednesday
10-11-2021
12.10 – 12.20

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Temperature-dependent FET properties of dibenzo[n]phenacenes (n = 5 – 7)

The extended phenacene molecules, [n]phenacenes (n = 5 – 11), that consist of fused benzene rings taking a W-shaped structure, have been synthesized, and the field-effect transistors (FETs) using their molecules were successfully fabricated, demonstrating excellent performance with the high field-effect mobility [1-4]. The [n]phenacene and phenacene derivatives show high air-stability, compared with acene type molecules like pentacene. Therefore, the synthesis of new types of phenacene derivatives is of significance to realize high-performance FETs without degradation under atmospheric condition.

A new type of phenacene-based polycyclic aromatic molecules, dibenzo[n]phenacenes (**DBnP**s) were successfully synthesized, which are recognised as acene-phenacene hybrid molecules. The values of effective field-effect mobility, m_{eff}, of single crystal FETs of **DBnPs** were evaluated to demonstrate that the FET performance of **DB6P** is superior to that of **DB5P** and **DB7P** [5]. The low value of field-effect mobility, m, of organic FETs not only originates from the insufficient extension of p-conduction network over the channel region but also the extrinsic trap states formed between highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO). To quantitatively estimate the trap states generated at the interface between gate dielectrics and single crystals of **DBnP**s, the temperature-dependent FET properties were investigated using the multiple trap and release (MTR) model.

The intrinsic mobility, m_0, of **DB6P**, which refers to the maximum m value without any extrinsic trap states, was higher than those of **DB5P** and **DB7P**, consistent with the fact that the value of μ_{eff} of **DB6P** was higher than those of **DB5P** and **DB7P**. These results indicate that **DB6P** is a good material from view of the channel transport, implying the formation of superior p-conduction network, which is recognized as an intrinsic factor ascribable to the molecule itself. Also, the ratio of the number of total trap states, N_t, with respect to that of valence states, N_v, of **DB6P** was much smaller than those of **DB5P** and **DB7P**, suggestive of lower trap states in **DB6P**, which is recognized as an extrinsic factor.

Literature:

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Wednesday
10-11-2021
14.00 – 14.30

Proximity-induced ferromagnetism in 2D $NbSe_2$

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Fabrication of a van der Waals (vdW) heterostructure by stacking dissimilar quantum materials should provide a simple but versatile approach for creation of an emergent quantum phase that is not accessible by individual materials. Proximity-induced ferromagnetism in a non-magnetic *metallic* 2D quantum material is one of such examples essentially important for 2D spintronics applications, but not yet realized so far mainly because of difficulties that such metallic 2D materials are hard to exfoliate and chemically unstable in most cases. We have overcome those difficulties by employing the bottom-up molecular-beam epitaxy technique [1] and succeeded in fabrication of high-quality magnetic vdW heterostructures based on a representative metallic 2D material $NbSe_2$ and a newly-developed 2D ferromagnet V_5Se_8 with precise layer-number control [2].

In this presentation, we show our recent results on the transport properties of those heterostructures in the specific regime, where the layer number of V_5Se_8 was decreased to the 2D limit so that the transport properties are dominated by $NbSe_2$ [3]. Very interestingly, we found that the sign of the anomalous Hall effect (AHE) of those samples were positive at the lowest temperature, which is opposite to those of the V_5Se_8 individual films. We also found that the AHE signal of those samples was enhanced with the in-plane magnetic fields, suggesting an additional contribution to the AHE signal except magnetization. We verify by theoretical calculations that those intriguing behavior could be well understood by accepting the idea that $NbSe_2$ is in a ferromagnetic state, where a characteristic Zeeman-type spin-orbit interaction plays an essential role.

Literature:

[1] M. Nakano *et al.*, Nano Lett. 17, 5595 (2017)
[2] H. Matsuoka *et al.*, Nano Lett. 21, 1807 (2021)
[3] H. Matsuoka *et al.*, *submitted*

Wednesday
10-11-2021
14.30 – 15.00

Zero-bias photocurrent generation in chirality-introduced layered organic-inorganic hybrid perovskites

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Organic-inorganic hybrid perovskite (OIHP)-type lead halides are recently attracting worldwide interest as a photoelectric conversion material, such as a light absorber in the solar cell [1]. Herein, we report observation of the zero-bias photocurrent generating phenomena, such as bulk photogalvanic effect (BPVE) [2] and circular photogalvanic effect (CPGE) [3] in the chiral 2D-OIHP lead iodides, which are designed by incorporating organic chiral cations between the inorganic layers of lead iodides (Fig. 1). Among them, the CPGE originates from spin-polarized electronic band structures in non-centrosymmetric systems with strong spin-orbit coupling (SOC) and is expected as a promising opto-electronic effect, which might generate spin-polarized current only by light irradiation without application of a bias voltage. In our study, we have observed light-helicity-dependent steady photocurrents induced by the CPGE and the chirality dependent CPGE in the chiral 2D-OIHP lead iodides (Fig. 2). These results indicate the formation of chirality dependent radial spin texture in the ***k***-space of chiral 2D-OIHPs with strong SOC.

Literature:

[1] A. Kojima, K. Teshima, Y. Shirai, T. Miyasaka, J. Am. Chem. Soc. 131, 6050 (2009)
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[3] P.-J. Huang, K. Taniguchi *et al.*, Adv. Mater. 33, 2008611 (2021)

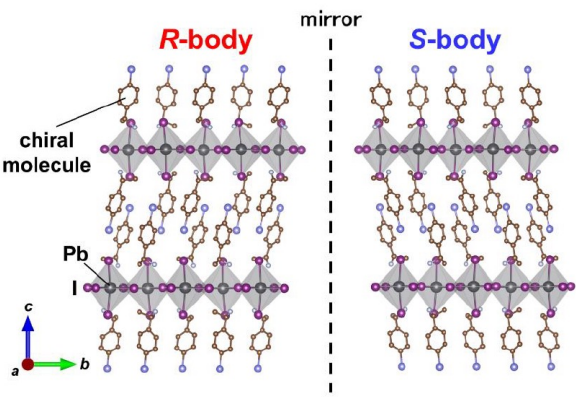

Figure 1. Crystal structures of chiral 2D-OIHPs

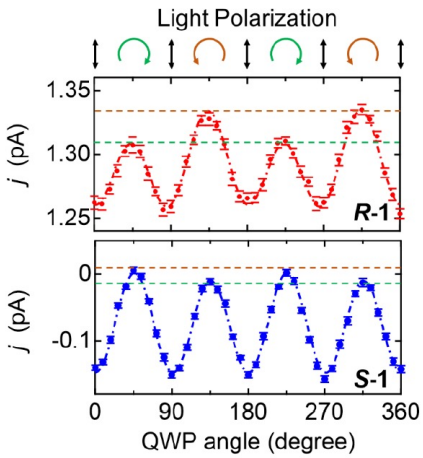

Figure 2. CPGE signals of 2D-OIHPs

Wednesday
10-11-2021
15.00 – 15.30

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Chirality-induced macroscopic spin response

The concept of chirality is widely found in many phenomena in nature and governs the symmetry properties of the chiral system. An interplay between structural and dynamical chirality should play a key role in a mechanism underlying chirality-induced phenomena. In this talk, we will focus on a role of chirality in materials in terms of an emergence of macroscopic spin response, being inspired by recent works on chiral magnetism and chirality-induced spin polarization. These viewpoints may bring us to a new frontier of chiral spin material science.

One of the good examples enlightening the importance of chirality in materials is a chiral magnetic crystal [1,2]. Crystalline and magnetic chirality in such crystals play an important role in inducing a variety of striking physical responses through a coupling with conduction electrons or electromagnetic fields. A microscopic effect, associated with a symmetry breaking of chiral magnetic crystals, spreads over the whole crystal and the physical responses emerge on macroscopic length scales. Indeed, an antisymmetric (Dzyaloshinskii-Moriya) exchange interaction [3,4] works throughout a monoaxial crystal and consequently induces chiral magnetic order with macroscopic coherence such as chiral soliton lattice [5] and nontrivial electrical transport phenomena [6,7] and collective dynamics [8,9] of chiral magnetic orders.

Moreover, it is recently found that a chiral crystal exhibits a spin-polarized state when the charge current is injected into the crystal [10-12]. A spin-polarized transport occurs in a linear regime of the current-voltage characteristics. Importantly, a robust protection of the spin polarization enables a nonlocal spin transport over micrometers. Such a spin polarization has also been demonstrated in chiral molecules via spin-polarized photocurrent emission [13] and tunneling transport experiments [14,15]. The phenomena, where electrons flowing through a chiral material become spin polarized, are frequently called chirality-induced spin selectivity (CISS). Importantly, while the CISS phenomena occur at a nanometer scale in chiral molecules, the same effect happens at macroscopic length scales over micrometers or longer in chiral crystals. A comprehensive understanding of the CISS remains an important issue and may clarify the interplay between structural and dynamical chirality.

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Wednesday
10-11-2021
16.00 – 16.10

Tunable vertical ferroelectricity and domain walls by interlayer sliding in β-ZrI_2

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Layered transition-metal dichalcogenides have gained enormous attention because of their ferroelectric properties caused by in-plane ionic displacements. In this study [1], we predict robust vertical ferroelectricity upon interlayer sliding in β-ZrI_2, a sister material of polar semimetals $MoTe_2$ and WTe_2. Based on extensive first-principles calculations, we elaborate the microscopic origin of electric polarization in ZrI_2 and investigate the variety of ferroelectric domain boundaries, that alongside with the semiconducting behavior and a small switching barrier can hold promise for novel ferroelectric applications.

Literature:

[1] X. Ma, C. Liu, W. Ren, S. A. Nikolaev, *arXiv*:2105.05773 (accepted in npj Computational Materials)

Wednesday
10-11-2021
16.10 – 16.20

Scanning SQUID imaging of ferromagnetic ultra-thin $SrRuO_3/SrTiO_3$

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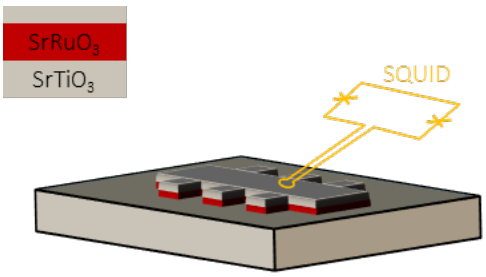
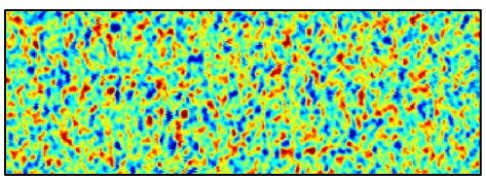
Thin films of $SrRuO_3$ (SRO) display many interesting properties such as quantum anomalous Hall state and spin-orbit coupling. In my poster I will show how we used scanning superconducting quantum interference device (SQUID) to image magnetic flux near the heterostructure. We mapped the spatial distribution of the static magnetic landscape as a function of temperature and field, to capture the magnetic order at different locations on the magnetization loop. The data reveals surprising landscape with more than one coercive field.





Wednesday
10-11-2021
16.20 – 16.30

Inelastic electron tunneling through nanomagnetic structures

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Inelastic electron tunneling spectroscopy (IETS) [1,2] is a well-established experimental technique used to explore a variety of application of molecular vibrational spectra [3]. Advantage of the IETS over infrared and Raman spectroscopy is its high sensitivity based on a fact that interaction between electron and molecular vibration is much stronger. The use of scanning tunneling microscope (STM), firstly demonstrated by B. C. Stipe *et. al.* in 1998 [3], lets to analyze the local density of states (LDOS) of the substrate and vibrations of the adsorbate. The main requirements for a successful experiment are extremely low temperatures and mechanical stability, that potentially can lead to the significant measurement error, that highlights the importance of supportive theoretical calculations. Further improvement of this technique by attaching a magnetic molecule to the tip expands the possibilities of the probe [4] and lets to study stable spin-dependent magnetic states in the absence of magnetic field together with long magnetic relaxation times [5]. First presented in 2005 by Repp J. *et. al.* [6] this approach was associated later [7,8] with development of such scientific fields as spintronics [9], quantum computing [10,11], quantum engineering [12], that indicates the need to control the spin states of a surface-supported objects such as molecular nanomagnets [13]. In this work we discuss inelastic tunneling process in magnetic nanosystems. The present concept is based on cotunneling theory [14] and applied to the cluster Hubbard model, each site of which is associated with a magnetic center. Mostly theories, oriented on solution of this problem, work on the simplest structures, for example a dimer reduced to the task of one atom (molecule) in the effective field of the second one. The presented method potentially lets to calculate the structures of any geometry. Obtained results are in great agreement with the experiment and presented in the Fig. 1.

Literature:

[1] B. Verlhac *et al.*, Science 366, 623 (2019)
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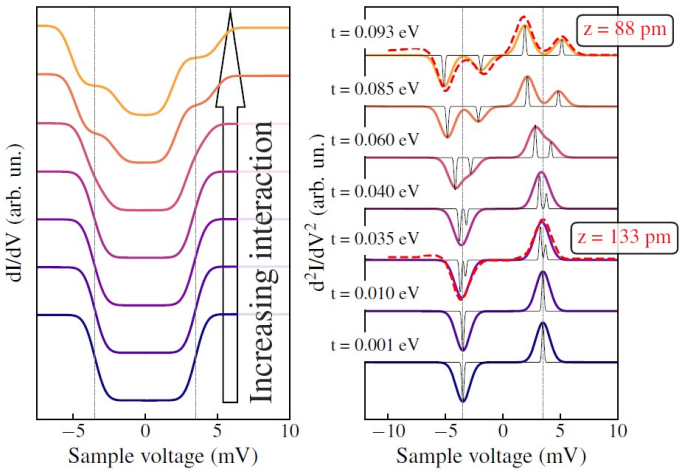

Figure 1. Spin excitation spectra of the system with Nc-terminated tip and Fe adatom. Numerical reproduction of the experiment [1]. The arrow on the left panel shows the increasing of the interaction between Nc and Fe/Cu(100). The red dotted line on the right panel denes the signal obtained from the experiment.

SCHEDULE

JAPANESE STANDARD TIME!

MONDAY, 8.11.2021

Time	Session	Speaker	Title
13:45 – 14:00	**Opening**		
14:00 – 14:30	**Surface analysis & Imaging**	**Satoru Ichinokura** Tokyo Institute of Technology, Japan	Intercalation-induced superconductivity in graphene
14:30 – 15:00		**Canhua Liu** Shanghai Jiao Tong University, China	Phase ordering dominated superconductivity in FeSe ultrathin films on $SrTiO_3$
15:00 – 15:30		**Beena Kalisky** Bar-Ilan University, Israel	Imaging the magnetic landscape in a superconductor-correlated insulator alternate stacking 4Hb-Tas_2
15:30 – 15:45	*Break*		
15:45 – 16:15	**Surface analysis & Imaging**	**Wei Li** Tsinghua University, China	Stripe phase in interfacial high-T_c superconductor FeSe/$SrTiO_3$
16:15 – 16:45		**Tristan Cren** Sorbonne Université & CNRS, France	Huge doping and unconventional superconductivity in the misfit compound $(LaSe)_{1.14}(NbSe_2)_2$
16:45 – 17:15	**Panel Discussion**		
17:15 – 17:30	*Break*		
17:30 – 18:00	**Functional oxide films**	**Nguyen Hoa Hong** Masaryk University, Czech Republic	How to tailor magnetic properties of ferrite nanoparticles and thin films
18:00 – 18:30		**Alexander Vasiliev** National Research Centre, Kurchatov Institute, Russia	Electron microscopy study of interfaces in functional oxides
18:30 – 19:00		**Diana Rata** University of Halle-Wittenberg, Germany	Growth-sequence-dependent interface magnetism of $SrIrO_3$-$La_{0.7}Sr_{0.3}MnO_3$ bilayers
19:00 – 19:30	**Panel Discussion**		

TUESDAY, 9.11.2021

Time	Session	Speaker	Title
14:00 – 14:30	**Misfit heterostructures**	**Yuhki Kohsaka** RIKEN, Japan	An aperiodic electronic superstructure in a misfit layered chalcogenide
14:30 – 15:00		**Kyoko Ishizaka,** The University of Tokyo, Japan	ARPES study on composite layered transition-metal dichalcogenides
15:00 – 15:30	**Panel Discussion**		
15:30 – 15:45	*Break*		
15:45 – 16:15	**Theory & Modelling**	**Sergey Nikolaev** Tokyo Institute of Technology, Japan	Realistic modelling and correlation effects in monolayer NbS_2 and $NbSe_2$
16:15 – 16:45		**Yusuke Nomura** RIKEN, Japan	Materials design of cuprate-analog nickelates and magnetic exchange coupling
16:45 – 17:15		**Malte Rösner** Radboud University, The Netherlands	Anisotropic superconductivity induced at a hybrid superconducting-semiconducting interface
17:15 – 17:30	*Break*		
17:30 – 18:00	**Theory & Modelling**	**Sergey Artyukhin** Italian Institute of Technology, Italy	Crystals inside crystals: modelling valence bond solid states in $IrTe_2$
18:00 – 19:00		**Silke Biermann** École Polytechnique, France	**Lecture:** Spectral properties of correlated electron materials from a dynamical mean field theory perspective and beyond
19:00 – 19:30	**Panel Discussion**		

SCHEDULE

WEDNESDAY, 10.11.2021

Time	Session	Speaker	Title
10:00 – 10:30	**Functional oxides & Misfit heterostructures**	**Kenji Yasuda** Massachusetts Institute of Technology, USA	Stacking-engineered two-dimensional ferroelectrics
10:30 – 11:00		**Susanne Stemmer** University of California, Santa Barbara, USA	Inversion Symmetry Breaking and Superconductivity of $SrTiO_3$
11:00 – 11:30	**Panel Discussion**		
11:30 – 12:20	**Short Presentations I**	**Wangzhou Wu** University of California	Molecular beam epitaxy of phase-pure antiperovskite Sr_3SnO thin films
		Xutao Wang Shanghai Jiao Tong University	Superconductivity of Ca-intercalated Bilayer Graphene on Silicon Carbide
		Yudai Sato The University of Tokyo	Role of steps on superconductor-insulator transition of mono-atomic-layer metal films formed on semiconducting substrates
		Masahiro Haze The University of Tokyo	Compressed sensing for efficient measurement of quasiparticle interference with the use of scanning tunneling microscopy/spectroscopy
		Yanting Zhang Okayama University	Temperature-dependent FET properties of dibenzo[n]phenacenes (n = 5 – 7)
Long break			
14:00 – 14:30	**Interfacial magnetism**	**Masaki Nakano** The University of Tokyo, Japan	Proximity-induced ferromagnetism in 2D $NbSe_2$
14:30 – 15:00		**Kouji Taniguchi** Tohoku University, Japan	Zero-bias photocurrent generation in chirality-introduced layered organic-inorganic hybrid perovskites
15:00 – 15:30		**Yoshihiko Togawa** Osaka Prefecture University, Japan	Chirality-induced macroscopic spin resonance
15:30 – 16:00	**Panel Discussion**		
16:00 – 16:30	**Short Presentations II**	**Xiaonan Ma** Shanghai University, China	Tunable vertical ferroelectricity and domain walls by interlayer sliding in β-ZrI_2
		Sapir Weitz Sobelman Bar-Ilan University, Israel	Scanning SQUID imaging of ferromagnetic ultra-thin $SrRuO_3/SrTiO_3$
		Daria Medvedeva Czech Academy of Science, Czech Republic	Inelastic Electron Tunneling through Nanomagnetic Structures
16:30 – 16:45	**Closing Remarks**		

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OUR STATS

(invited speakers)