The 17th Korea-Taiwan- Japan Workshop on Strongly Correlated Electron Systems

February 19 ~ February 20, 2017
Yongpyong resort (Dragon Valley Hotel), KOREA

(Photo: Kyujanggak Institute for Korean Studies, Seoul National University)

Organized by Center for Correlated Electron Systems, Institute for Basic Science

ibs CCES
Center for Correlated Electron Systems

Dear friends,

It has been our immense pleasure to organize this 17th Korea-Taiwan-Japan Workshop on Strongly Correlated Electron System. When it started back in 2000, we did not know how long it would last, let alone how successful it would be. Here we are, and we are now preparing for the 17th meeting. Someone, none other than Niels Bohr, famously said that 'science is tradition'. True to this spirit, we have been building a tradition in East Asia for the past 17 years.

And we are very proud of having contributed to and being part of this tradition for all those years. This time, we are organizing this meeting together with APCTP-Quantum Materials Symposium 2017. We hope that you will enjoy not only the 17th KTJ workshop but also the full program of QMS 2017.

Let us end this welcome remark by quoting the ancient poem of Confucius "有朋自遠方來 不亦樂乎".

All the best,

Je-Geun Park

Jaejun Yu

Organizing Committee

- **International Committee**
  Ying-Hao Chu (National Chiao Tung University, Taiwan)
  Atsushi Fujimori (The University of Tokyo, Japan)
  Di-Jing Huang (NSRRC, Taiwan)
  Tsuyoshi Kimura (Osaka University, Japan)
  Je-Geun Park (Seoul National University, Korea)
  Shik Shin (The University of Tokyo, Japan)
  Hidenori Takagi (Max Planck Institute and University of Tokyo)
  Jaejun Yu (Seoul National University, Korea)

- **Local Committee**
  Je-Geun Park (Seoul National University, Korea)
  Jaejun Yu (Seoul National University, Korea)

Invited Speakers

Ashish Chainani (NSRRC, Taiwan)
Cheng Maw Cheng (NSRRC, Taiwan)
S. Y. Cho (Sungkyunkwan University, Korea)
Ming Wen Chu (National Taiwan University, Taiwan)
Ying Hao Chu (National Chiao Tung University, Taiwan)
Atsushi Fujimori (The University of Tokyo, Japan)
Guan-Yu Guo (National Taiwan University, Taiwan)
A Heinrich (Ewha Womans University, Korea)
Takuro Katsufuji (Waseda University, Japan)
DJ Huang (NSRRC, Taiwan)
J. H. Kim (Yonsei University, Korea)
T. H. Kim (Ulsan University, Korea)
Tsuyoshi Kimura (Osaka University, Japan)
Yukitoshi Motome (The University of Tokyo, Japan)
Kenya Ohgushi (Tohoku Universtiy, Japan)
J. H. Park (POSTECH, Korea)
Shik Shin (The University of Tokyo, Japan)
Hide Takagi (Max Planck Institute and University of Tokyo)
Jan-Chi Yang (NCKU, Taiwan)
J. Yu (Seoul National University, Korea)

Registration

Registration desk will be open at 8 AM in front of Grand Ballroom, Dragon Valley Hotel 1F. See Appendix for the local map.

Restaurants

There are several restaurants at the resort. See Appendix for more information.

Accommodation: check-in & Check-out

Please Check-in & Check-out at the front desk with your reservation number.

Hotel Front desk contact: +(82)-33-330-7111 or house phone 667

Tower Condominium Front desk contact: +(82)-33-330-7511

Wifi

Free wi-fi is available at the lecture hall and in all hotel rooms.

Meeting Points at Incheon and Gimpo Airports: see Appendix for Airport map.

Incheon Airport: 1F Gate 1.

Gimpo Airport: 1F Gate 1.

SNU: Seoul National University Main gate.

*The bus that we rented can't stay at the bus stop for long because it will cause a traffic jam. So please be at the meeting point on time. Because of the differences in arrival times, we're sorry for making you to wait at the airports.

Poster Session

There will be poster boards of A0 size with number tag for each poster outside the lecture hall. Each poster presenter will be asked to give one-minute presentation before the poster session.

17th Korea-Taiwan-Japan Workshop on Strongly Correlated Electron System

February 19(Sun)~20(Mon), 2017. Yong-Pyong Resort, Dragon Valley Hotel, 1F Grand Ballroom

Sunday 19, February

Registration	8:00-9:00		Grand Valley Hotel, 1F Grand Ballroom
Opening	9:00-9:10		Opening address
Session 1	***Chair: Prof. Je-Geun Park***		
	9:10-9:40	Talk #1	Andreas Heinrich (Ewha Womans Univ.) Electron Spin Resonance of single atoms on a surface
	9:40-10:10	Talk#2	Shik Shin (Tokyo Univ.) Laser-PEEM study on the photo-induced ferromagnetism in SrTiO3 surface
	10:10-10:40	Talk#3	Di-Jing Huang (NSRRC) Spin crossover of cobaltates revealed by resonant inelastic X-ray scattering
	10:40-11:00		*Break*
Session 2	***Chair: Prof. Atsushi Fujimori***		
	11:00-11:30	Talk#4	Ying-Hao Chu (NSRRC) Flexible Oxide Heteroepitaxy: A New Playground for Exploring Intriguing Properties of Functional Oxides
	11:30-12:00	Talk#5	Tae Heon Kim (Ulsan Univ.) Polar metals by geometric design
	12:00-12:30	Talk#6	Ming-Wen Chu (National Taiwan Univ.) Emergent Charge Condensations at Two-Dimensional Oxide Interfaces
	12:30-14:00		*Lunch*
Session 3	***Chair: Prof. Di-Jing Huang***		
	14:00-14:30	Talk#7	Jan-Chi Yang (National Cheng Kung Univ.) Tuning the ferroic orders in multiferroic thin films - Role of bottom electrodes
	14:30-15:00	Talk#8	Tsuyoshi Kimura (Osaka Univ.) Multiple order parameters and their domain control in some magnetoelectric multiferroics
	15:00-15:30	Talk#9	Cheng-Maw Cheng (NSRRC) The Topologically Protected Surface State in Sb2Te3-xSex Single Crystals with varied Se content studied by Angle-resolved Photoemission Spectroscopy
	15:30-16:00		*Break*
Session 4	***Chair: Prof. Je-Geun Park***		
	16:00-17:00	Poster session Ⅰ	One minute presentation
	17:00-19:00	Poster session Ⅱ	Poster Presentation

Monday 20, February

Session 5	***Chair: Prof. Jaejun Yu***		
	9:00-9:30	Talk#10	Hidenori Takagi (Tokyo Univ. / RIKEN) Quantum Liquid state of Jeff=1/2 isospins
	9:30-10:00	Talk#11	Jae Hoon Kim (Yonsei Univ.) Terahertz pump-probe spectroscopy of coherent spin precession in YMnxFe1-xO3
	10:00-10:30	Talk#12	Kenya Ohgushi (Tohoku Univ.) Ferroic Order of Magnetic Quadrupoles in BaMn2As2
	10:30-11:00		*Break*
Session 6	***Chair: Prof. Shik Shin***		
	11:00-11:30	Talk#13	Takuro Katsufuji (Waseda Univ.) Photoinduced phase transitions over three phases in AV13O18
	11:30-12:00	Talk#14	Suyeon Cho (Sungkyunkwan Univ.) Te vacancy-driven superconducting state in Weyl semimetal MoTe2
	12:00-12:30	Talk#15	Guang-Yu Guo (National Taiwan Univ.) Quantum Anomalous Hall Effect in Layered Magnetic Oxides
	12:30-14:00		*Lunch*
Session 7	***Chair: Prof. Ying-Hao Chu***		
	14:00-14:30	Talk#16	Atsushi Fujimori (Tokyo Univ.) Electronic structure of the new electron-doped cuprate superconductors in bulk and thin film forms
	14:30-15:00	Talk#17	Jae Hoon Park (Pohang Univ. of Science & Technology) Majorana Ferimons in Kitaev Quantum Spin Lattice α-RuCl3
	15:00-15:30	Talk#18	Ashish Atma Chainani (NSRRC) Evidence for weakly correlated oxygen holes in the highest-Tc cuprate superconductor HgBa2Ca2Cu3O8+d
	15:30-16:00		*Break*
Session 8	***Chair: Prof. Hidenori Takagi***		
	16:00-16:30	Talk#19	Yukitoshi Motome (Tokyo Univ.) Evincing Majorana fermions in Kitaev magnets
	16:30-17:00	Talk#20	Jaejun Yu (Seoul National Univ.) Possible oxygen-ordering induced ferroelectric polarization and magnetic interactions in oxygen deficient SrCoO2.5+x
	17:00-17:00		Closing Ceremony (incl. awarding the poster prize)
	18:00-21:00		Banquet organized together with QMS

Poster Session

1	Hasung Sim (Seoul National Univ.)
	Doping effects on 2D triangular multiferroic Y(Mn,Al,Ga)O3
2	Joosung Oh (Seoul National Univ.)
	Magnon phonon hybridization in multiferroic RMnO3
3	Hwanbeom Cho (Seoul National Univ.)
	Properties of highly frustrated antiferromagnets: CuRE2Ge2O8 RE=Pr,Nd,Sm~Tm)
4	Kisoo Park (Seoul National Univ.)
	Low energy spin dynamics of rare-earth orthoferrites YFeO3 and LaFeO3
5	Sungmin Lee (Seoul National Univ.)
	Transport study on antiferromagnetic van der Waals MnPS3 using conductive atomic force microscopy
6	Taehun Kim (Seoul National Univ.)
	Strong thermal hysteresis of Verwey transition Fe3O4 Nanoparticles
7	Seokhwan Yun (Seoul National Univ.)
	Breakdown of dimerized valence bonds in Li2Ru1-xMnxO3
8	Suhan Son (Seoul National Univ.)
	Spin glass behavior in ultrathin magnetic van der Waals materials
9	Jonathan Leiner (Seoul National Univ.)
	Spin dynamics in the spin chain compound Sr3CuPtO6
10	Arvind Yogi (Seoul National Univ.)
	Evidence of electron-phonon interaction in single crystal of (Ru3+/Ru4+) mixed-valence Na2.7Ru4O9 and NaRu2O4
11	Howon Lee (Yonsei Univ.)
	Spin Precession Pumped by Pulsed Terahertz Magnetic Field in YMnxFe1-xO3
12	Young Chan Jo (Yonsei Univ.)
	Metallic Terahertz Metamaterials Research
13	Donghwan Kim (POSTECH)
	Effect of strong spin-orbit coupling of anion p orbitals on superexchange interaction
14	Junho Park (POSTECH)
	Magnetic properties of epitaxially grown high quality LaCrO3 films by pulsed laser deposition
15	Wen-Bin Wu (NSRRC)
	High-Resolution Soft X-ray RIXS Using Active Gratings and Energy Compensation
16	Hsiao-Yu Huang (NSRRC)
	Jahn-Teller distortion driven magnetic polarons in magnetite
17	Amol Singh (NSRRC)
	Electronic structure of Ce3Co4Sn13 using hard X-ray photoelectron spectroscopy & x-ray absorption spectroscopy
18	Yi-De Liou (National Cheng Kung Univ.)
	Raman Study on Photostrictive Perovskite SrIrO3 Thin Films
19	Ping-Chun Wu (National Chiao Tung Univ.)
	Heteroepitaxy of Fe3O4/Muscovite: A New Perspective for Flexible Spintronics
20	Yen-Pei Lin (National Chiao Tung Univ.)
	Van der Waals Epitaxy of Flexible and Transparent VO2 Film on Muscovite
21	Min Yen (National Chiao Tung Univ.)
	High Mobility Transparent Heteroepitaxy (Ba, La)SnO3/Muscovite for Flexible Optoelectronics
22	Ying-Hui Hsieh (National Chiao Tung Univ.)
	Creating Flexoelectrity via Composition gradient
23	Yosuke Nonaka (Tokyo Univ.)
	Search for complex orbital order in magnetite Fe3O4 by magnetic-field-direction dependent XAS and XMCD measurements
24	Minu Kim (Max-Planck-Institute fuer Festkoerperforschung)
	High-Pressure Synthesis of a Third-Family Perovskite Bismuthate
25	Kazuhiro Kowa (Osaka Univ.)
	Structure analysis of LaNiO 3 /LaAlO 3 interface by surface X-ray diffraction
26	Yusuke Yoshimori (Osaka Univ.)
	The pressure effect on magnetoelectricity in Cr2O3
27	Tomomasa Kajita (Waseda Univ.)
	Novel relaxation behaviors in the orbital-ordered vanadates

Invited Talk #1

Electron Spin Resonance of single atoms on a surface

Andreas Heinrich[12]

[1] *Center for Quantum Nanoscience, Institute of Basic Science, Seoul, South Korea*

[2] *Physics Department, Ewha Womans University, Seoul, South Korea*

The scanning tunneling microscope is an amazing experimental tool because of its atomic-scale spatial resolution. This can be combined with the use of low temperatures, culminating in precise atom manipulation and spectroscopy with microvolt energy resolution. In this talk I will apply these techniques to the investigation of the quantum spin properties of transition metal atoms on surfaces. We will conclude with our recent measurements of electron spin resonance in an STM on individual Fe atoms supported on an insulating thin film, offering unprecedented energy resolution on the atomic scale. This tool can be used as an ESR sensor to measure the magnetic field (dipolar interaction) from neighboring atoms, enabling the high-precision measurement of the magnetic moment of individual atoms on surfaces.

Invited Talk #2

Laser-PEEM study on the photo-induced ferromagnetism in $SrTiO_3$ surface

Shik Shin

The Institute for Solid State Physics, The University of Tokyo, Kashiwa, Chiba 277-8581, Japan

We report the first experiments carried out on a new chemical and magnetic imaging system, which combines the high spatial resolution of a photoemission electron microscopy (PEEM) with a continuous wave (CW) deep ultraviolet laser. We achieved the spatial resolution of 2.6 nm [1]. This is the highest resolution of the world as the PEEM.

We would like to report the ferromagnetic domain structures of two-dimensional-electron-gas on $SrTiO_3$ perovskite oxide surfaces [2]. We will also report the photo-induced ferromagnetism on Sc-doped $SrTiO_3$.

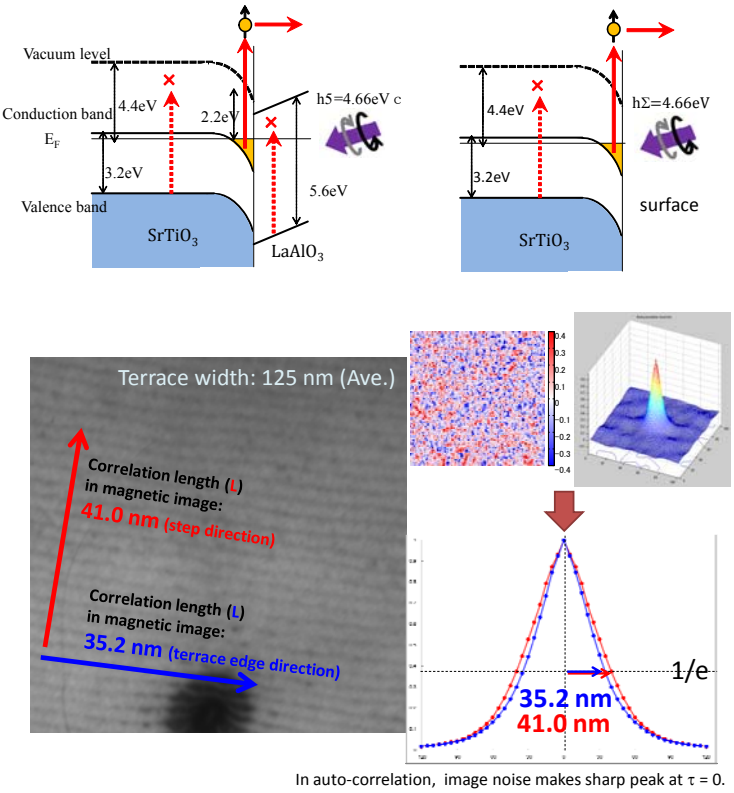

Fig.1 Feromagnetic domain structures of $SrTiO_3$ surface[2]

Reference

[1] T.Taniuchi, Y.Kotani, S.Shin, Rev. Sci. Instrum.**86**, 023701 (2015)

[2] T.Taniuchi, Y.Motoyui, K.Morozumi, T.C.Rödel, F.Fortuna, A.F.Santander-Syro, S. Shin, Nature Commun.7, 11781(2016)

Invited Talk #3

Spin crossover of cobaltates revealed by resonant inelastic X-ray scattering

Di-Jing Huang

National Synchrotron Radiation Research Center, Hsinchu 30076, TAIWAN,
djhuang@nsrrc.org.tw

Spin-state transitions or crossovers between low-spin and high-spin states occur in diverse materials. While the preferred model of thermal evolution is based on changes in the crystal-field excitations of transition-metal ions, the associated changes in Coulomb energies across spin-state transitions are not known from experiment. Here we demonstrate that resonant inelastic X-ray scattering (RIXS) effectively characterizes the evolutions of the high and low spin states in LaCoO3, respectively, when the temperature is changed across the spin crossover temperature. Markedly the results indicate that one can use a high-energy (~1.3 eV) excitation method to unravel a spin-state transition which is triggered by a temperature change equivalent to an energy change less than 10 meV. The RIXS approach establishes a new window to understanding the spin sate
transition of transition metal compounds, particularly those containing transition metal ions with a $3d^6$ electronic configuration.

This work was done in collaboration with K. Tomiyasu, J. Okamoto, H. Y. Huang, Z. Y. Chen, E. P. Sinaga, W. B. Wu, Y. Y. Chu, A. Singh, R.-P. Wang, F. M. F. de Groot, C. T. Chen, A. Chainani, and S. Ishihara.

Invited Talk #4

Flexible Oxide Heteroepitaxy: A New Playground for Exploring Intriguing Properties of Functional Oxides

Ying-Hao Chu[1,2,3,4]

[1] Department of Materials Science & Engineering, National Chiao Tung University, Hsinchu 30010, Taiwan
[2] Department of Electrophysics, National Chiao Tung University, Hsinchu 30010, Taiwan
[3] Institute of Physics, Academia Sinica, Taipei 11529, Taiwan
[4] Material and Chemical Research Laboratories, Industrial Technology Research Institute, Hsinchu 31040, Taiwan

In the diligent pursuit of low-power consumption, multifunctional, and environmentally friendly electronics, more sophisticated requirements on functional materials are on demand. For example, flexible electronics represents a fast-developing field and has a great potential to impact our daily life. In building up flexible electronics, the materials with controllable conduction, transparency, and good flexibility are required. Recently, the discovery of free-standing 2D materials has created a revolution to this field. Pioneered by graphene, these new 2D materials exhibit aboundant unusual physical phenomena that is undiscovered in bulk forms. In the meantime, it also possesses very high transparency to the visible light. However, the extensively studied pristine graphene naturally has no bandgap and become restricted in many field-effect based applications. Hence, looking for various types of new 2D materials has been a focal research direction nowadays. In this talk, we intend to take the same concept, but to integrate a family of functional materials in order to open new avenue to flexible electronics. Due to the interplay of lattice, charge, orbital, and spin degrees of freedom, correlated electrons in oxides generate a rich spectrum of competing phases and physical properties. However, a generic approach to build up flexible electronics based on functional oxides is yet to be developed. In this study, we use a 2D material as the substrate. And we take several functional oxides as a models system to demonstrate a pathway to build up functional oxides for transparent and flexible electronics.

Invited Talk #5

Polar metals by geometric design

Tae Heon Kim[1,2]

[1] Department of Physics, University of Ulsan, Ulsan 44610, Korea
[2] Department of Materials Science and Engineering, University of Wisconsin-Madison, Madison 53706, USA

In general, metallic conductivity and polar displacements are not compatible each other, because free electrons in a metal effectively screen electric dipoles. Despite the incompatibility, 'polar metals', where itinerant electrons and electric dipole moments coexist, have been discovered in various material systems for several decades, offering the potential for novel device applications [1,2]. In contrast with these exciting findings of exotic polar metallic states, a feasible approach for realization of the polar metals has never been provided, yet.

A key to design polar metal is that electronic conduction is structurally decoupled from polar displacements. In ternary perovskite ABO_3 oxides, the multiple A and B cations provide two sublattices, which allow one to contribute partially-occupied delocalized states for conduction, while the other is able to undergo polar distortion in response to changes in the BO_6 octahedra. For this aim, we selected strongly-correlated rare-nickelates $RNiO_3$, which undergo a thermally-driven metal-to-insulator transition depending on the crystallographic tolerance factor [3]. Among them, $NdNiO_3$ is a suitable candidate, which is electronically conductive at room temperature and structurally orthorhombic (*Pnma*) due to the tilting of NiO_6 octahedra. Note that A-site polar displacements with respect to oxygen atoms can be attained in perovskite oxides, when the tilting of BO_6 octahedra is suppressed [4]. Thus, by achieving a non-equilibrium tilt pattern of NiO_6 octahedra, we could realize a polar metallic state in $NdNiO_3$, where finite band occupancy of Ni 3*d* orbitals for metallicity and an acentric Nd-oxygen displacement coexist.

[1] D. Puggioni and J. M. Rondinelli, Nat. Commun. 5, 3432 (2013).

[2] Y. Shi et al., Nature Mater. 12, 1024 (2013).

[3] J. B. Torrance, P. Lacorre, A. I. Nazzal, E. J. Ansaldo, and C. Niedermayer, Phys. Rev. B 45, 8209 (1992).

[4] N. A. Benedek and C. J. Fennie, J. Phys. Chem. C 117, 13339 (2013).

Invited Talk #6

Emergent Charge Condensations at Two-Dimensional Oxide Interfaces

Ming-Wen Chu
Center for Condensed Matter Sciences, National Taiwan University, Taipei 106, Taiwan

With the assistance of modern thin-film growth techniques, perovskite oxides with a three-dimensional crystal structure can now be grown in a layer-by-layer manner at atomic-level precision on heterostructural substrates, opening up vast opportunities for unprecedented phenomena at the two-dimensional (2D) oxide interfaces. The emergence of a conductive interface between the two band insulators, $LaAlO_3$ (LAO) and $SrTiO_3$ (STO), represents the most celebrated exemplification in this context. Up to the date, a plethora of unexpected properties have been established at oxide heterointerfaces, ranging from 2D electron gas, 2D superconductivity, 2D orbital reconstruction to 2D magnetic ordering. However, why can be the oxide interfaces so surprising? This remains an outstanding unresolved problem. This speaker intends to elucidate on how to tackle the puzzle using atomic-plane-by-atomic-plane and unit-cell-by-unit-cell scrutiny of charge, lattice, and electronic-structure degrees of freedom in interfacial unit cells by atomically-resolved electron spectroscopy. Several intriguing phenomena were readily resolved, including the presence of localized 2D electron density at the insulating (Nd,Sr)MnO_3/STO interface [C.-P. Chang *et al.*, Phys. Rev. B **87**, 075129 (2013)], the condensation of the 2D interfacial charges in (Nd,Sr)MnO_3/STO into one-dimensional electron chains by the misfit-dislocation strain field [C.-P. Chang *et al.*, Nat. Commun. **5**, 3522 (2014)], and the hidden lattice instabilities as the origin of the conductive LAO/STO interface [P. W. Lee *et al.*, Nat. Commun. **7**, 12773 (2016)]. Perspectives on 2D oxide-interfacial phenomena will also be discussed.

Invited Talk #7

Tuning the ferroic orders in multiferroic thin films - Role of bottom electrodes

Jan-Chi Yang[1]

[1] *Department of Physics, National Cheng Kung University, Tainan 70101, Taiwan*

The strong coupling between (anti)ferromagnetism and ferroelectricity found in multiferroics has triggered high expectations for the development and design of technological devices with multifunctionalities. Researchers have been enthusiastically devoted to the development of effective modulation on these intriguing coupling and phenomena among multiferroics via external stimuli. Due to the correlations between intrinsic degrees of freedom, the electrical and magnetic field are usually the most conventional ways to reach external control on the correlated phenomena. In order to enrich the tunability, the exploration of additional factors or controlling parameters to modulate the lattice, charge, orbital, and spin degrees of freedom in multiferroics has received more and more demand to cooperate with the existing approaches.

In this talk, we will spin on the intriguing role played by functional bottom electrodes, in terms of tuning ferroic orders in room temperature multiferroic $BiFeO_3$. The insertion of bottom electrodes not only could be used to stabilize single domain feature in $BiFeO_3$ thin films, but also enables the thin films being tuned via new controlling factor, light. Through a combination of x-ray diffraction, piezoforce microscopy and x-ray absorption spectroscopy, we found free charges in bottom electrode that have the opposite sign to the surface charges of ferroelectric would like to approach ferroelectric-electrode interface, resulting in a 'built-in electric field' for stabilization single domain multiferroic $BiFeO_3$ films. More importantly, the incorporation of bottom electrode that shows significant photostriction has endowed the ferroic orders in $BiFeO_3$ with new tunabilities driven by light illumination. Such results offer a new pathway to control the intriguing physical properties through the correlations between ferroic orders and external stimuli, which lead to new-generation multifunctional applications.

Invited Talk #8

Multiple order parameters and their domain control in some magnetoelectric multiferroics

Tsuyoshi Kimura[1]

[1] *Division of Materials Physics, Graduate School of Engineering Science, Osaka University, Toyonaka 560-8531, Japan*

One of the most important concepts in condensed matter physics is the spontaneous breakdown of symmetry in a solid, which bears the ordered phase and domains in its consequence. In magnetoelectric multiferroics, multiple order parameters coexist in a system, sometimes couple with each other, and exhibit nontrivial crossed phenomena. In this presentation, we deal with magnetoelectric multiferroics in which a symmetry breaking due to the orderings of various order parameters such as electric dipole, magnetic dipole, and magnetic quadrupole moments as well as chirality originating from these multipole moments. We show our recent research activity on exploration for new magnetoelectrics and manipulations of their multiple order parameters as well as domains.

This work has been done in collaboration with K. Kimura, H. Ueda, M. Sera, T. Honda, T. Aoyama, Y. Wakabayashi, K. Yamauchi, M. Toyoda, K. Shimizu, Y. Tanaka, P. Babkevich, H. M. Rønnow, J. S. White, M. Kenzelmann et al.

Invited Talk #9

The Topologically Protected Surface State in $Sb_2Te_{3-x}Se_x$ Single Crystals with varied Se content studied by Angle-resolved Photoemission Spectroscopy

Cheng-Maw Cheng[1,2*], Shih-Chang Weng[1], Wei-Chuan Chen[1], Je-Wei Lin[1], Ku-Ding Tsuei[1], Chao-Kuei Lee[2,3], Shih-Hsun Yu[4], Mitch Ming-Chi Chou[4], Ching-Wen Chang[2], Li-Wei Tu[2,5], Hung-Duen Yang[2], Chien-Ming Tu[6], Chih-Wei Luo[6], and Marin M. Gospodinov[7]

[1]National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan
[2]Department of Physics, National Sun Yat-sen University, Kaohsiung 80424, Taiwan
[3] Department of Photonics, National Sun Yat-sen University, 7 Kaohsiung 80424, Taiwan
[4]Department of Materials and Optoelectronics Science, National Sun Yat-sen University, Kaohsiung 80424, Taiwan
[5]Department of Medical Laboratory Science and Biotechnology, Kaohsiung Medical University, Kaohsiung 80708, Taiwan
[6]Department of Electrophysics, National ChiaoTung University, Hsinchu 300, Taiwan
[7]Institute of Solid State Physics, Bulgarian Academy of Sciences, 1784 Sofia, Bulgaria

A topological insulator (TI) is a new class of quantum material with attractive properties for physical and technological applications. Regarding topological insulators (TI) in the bismuth family, most work has focused on Bi_2Se_3, Bi_2Te_3 and $Bi_2Se_{3-x}Te_x$ compounds, but experimental work on *p*-type $Sb_2Te_{3-x}Se_x$ ternary topological insulators is lacking. Here we derive the electronic structure of highly crystalline $Sb_2Te_{3-x}Se_x$ single crystals with varied Se content studied with angle-resolved photoemission spectra. The result of band mapping reveals that the $Sb_2Te_{3-x}Se_x$ compounds with x=2.4 still behave as a *p*-type semiconductor and have an isolated Dirac cone of a topological surface state, which are highly favored for spintronic and thermoelectric devices because of the dissipationless surface state and the decreased scattering from bulk bands. More importantly, a Sb bilayer (BL) was successfully grown on Sb_2Te_3 single crystal, we found that the position of the Dirac point almost located at the Fermi level. The band hybridization of Sb/Sb_2Te_3 in band gap engineering makes a potential to fabricate a spintronic devices in the future.

Invited Talk #10

Quantum Liquid state of J_{eff}=1/2 isospins

Hidenori Takagi[1,2], Tomohiro Takayama[2] and Kentaro Kitagawa[1]

[1]Department of Physics, University of Tokyo
[2]Max Planck Institute for Solid State Research

In 5d Iridium oxides, the relativistic spin-orbit coupling for 5d electrons is as large as ~0.5 eV and not small as compared with other relevant electronic parameters, including Coulomb U, transfer t and crystal field splitting D. The large spin-orbit coupling and its interplay with the other parameters gives rise to a variety of exotic magnetic ground states. In the layered perovskite Sr_2IrO_4, spin-orbital Mott state with J_{eff}=1/2 is realized due to the novel interplay of those energy scales [1]. Despite the strong entanglement of spin and orbital degrees of freedom, J_{eff}=1/2 iso-spins in Sr_2IrO_4 was found to be surprisingly isotropic, very likely due to a super-exchange coupling through almost 180° Ir-O-Ir bonds [2]. The temperature dependence of in-plane magnetic correlation length of J_{eff}=1/2 iso-spins, obtained from inelastic x-ray resonant magnetic scattering, was indeed well described by that expected for two-dimensional S=1/2 Heisenberg antiferromagnet [3].

When J_{eff}=1/2 iso-spins interact with each other through 90° Ir-O_2-Ir bonds, an Ising ferromagnetic coupling with an easy axis perpendicular to the bond plane is expected, due to an interference of the two Ir-O-Ir superexchange paths [2]. In α, β,γ-Li_2IrO_3 with honeycomb based structure, J_{eff}=1/2 iso-spin are connected by the three competeting 90° Ir-O_2-Ir bonds, which could be a materialization of Kiatev model [4] with quantum spin liquid state. A long range magnetic ordering, however, was observed at low temperatures in α, β,γ-Li_2IrO_3, which is very likely due to the presence of additional magnetic couplings not included in the original Kitaev model [4]. The exploration of Kitaev state was recently extended to related compounds and pressure effect. We found that a quantum spin liquid state is realized in hydorogenated Ir 2D honeycomb (α-type) and β-Li_2IrO_3 under high pressure [5]. The search for possible fractionalized excitations, expected for Kitaev spin liquid, is now underway.

[1] B. J. Kim *et al.*, *Phys. Rev. Lett.* **101**, 076402 (2008), *Science* **323**, 1329 (2009).
[2] G. Jackeli and G. Khaliullin, *Phys. Rev. Lett.* **102**, 017205 (2009).
[3] S. Fujiyama *et al.*, *Phys. Rev. Lett.* **108**, 247212 (2012).
[4] A.Kitaev, Annals of Physics **312** 2 (2006).
[5] T.Takayama, *et al.*, *Phys. Rev. Lett.*114, 077202 (2015).

Invited Talk #11

Terahertz pump-probe spectroscopy of coherent spin precession in $YMn_xFe_{1-x}O_3$

Jae Hoon Kim and Young Jai Choi

Department of Physics, Yonsei University, 50 Yonsei-Ro, Seodaemun-Gu, Seoul 03722, Republic of Korea

We report on our recent study of coherent spin dynamics in canted antiferromagnetic $YMn_xFe_{1-x}O_3$ (x=0-0.45) based on terahertz-pump terahertz-probe spectroscopy. Both the quasi-ferromagnetic resonance mode (qFMR) and the quasi-antiferromagnetic resonance mode (qAFMR) were detected. We can probe a number of distinct magnetically ordered phases by varying temperature and Mn doping. Spin reorientation transition and new infrared-active resonance modes were also observed.

Invited Talk #12

Ferroic Order of Magnetic Quadrupoles in $BaMn_2As_2$

Kenya OHGUSHI

Department of Physics, Graduate School of Science, Tohoku University, Japan

Kondo effect is one of the most fascinating phenomena in condensed matters. The phenomenon is realized when conduction electrons couple with a localized spin; the spin is an even-parity magnetic dipole moment. A natural extension of this phenomenon is a quantum transport in a system, in which conduction electrons couple with a higher order electric or magnetic multipole. Among higher-order multipoles, we are particularly interested in odd-parity multipoles such as electric octupole and magnetic quadrupole. When odd-parity multipoles are ordered in a ferroic manner, one can expect a novel quantum transport induced by the breakdown of inversion symmetry.

Up to now, we have found some novel materials, in which odd-parity multipoles are ordered in a ferroic manner. Examples include $A_2Re_2O_7$ (A = Cd and Pb) and $Pb_2Ir_2O_7$ with the electric octupole order [1, 2]. In this presentation, I will introduce our recent research, which identifies a novel ferroic order of magnetic quadrupoles in $BaMn_2As_2$.

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Invited Talk #13

Photoinduced phase transitions over three phases in $AV_{13}O_{18}$

T. Katsufuji, T. Saiki, N. Yamaguchi, Y. Kakesu, and T. Kajita

Department of Physics, Waseda University, Tokyo 169-8555, Japan

$Ba_{1-x}Sr_xV_{13}O_{18}$ with V ions on a quasi-fcc lattice exhibits two different ordered phases, a V-trimer phase with orbital ordering [low-temperature (LT) phase)] and a charge-ordered phase [intermediate-temperature (IT) phase], in addition to a high-temperature (HT) phase. We performed a pump-probe spectroscopy measurement of this compound and found that when a laser pulse is applied to the LT phase, successive phase transitions over the three phases, an instantaneous ($t \ll 0.5$ ps) transition from the LT phase to the HT phase, followed by a transition within 2 ps to the IT phase, occur. These photoinduced successive phase transitions are dominated by the symmetry of the three phases; both the LT phase and the IT phase are a subgroup of the HT phase but there is no such relationship between the LT phase and the IT phase. Namely, the phase transition from the LT to the HT phase is directly caused by photoexcited electrons, whereas the transition to the IT phase occurs only after the temperature of the lattice is increased by the photoirradiation.

Invited Talk #14

Te vacancy-driven superconducting state in Weyl semimetal $MoTe_2$

Suyeon Cho[1], Se Hwang Kang[1,2], Ho Sung Yu[1,2], Hyo Won Kim[3], Wonhee Ko[3], Sung Woo Hwang[3], Woo Hyun Han[4], Duk Hyun Choe[4], Kee Joo Chang[4], Young Hee Lee[1,2], Heejun Yang[2], Sung Wng Kim[2]

[1]Center for Integrated Nanostructure Physics (CINAP), Institute for Basic Science (IBS), Sungkyunkwan University, Suwon, 440-746, Korea

[2]Department of Energy Science, Sungkyunkwan University, Suwon, 440-746, Korea

[3]Samsung Advanced Institute of Technology, Suwon 443-803, Korea

[4]Department of Physics, Korea Advanced Institute of Science and Technology, Daejeon 34141, Korea

Two-dimensional (2D) transition metal dichalcogenides (TMDs) have enriched condensed matter physics, provoking the discovery of diverse quantum electronic states such as topological insulating (TI), Weyl semimetallic (WSM) and superconducting states. The superconductivity under the high pressure or the ionic gating in group 6 TMDs becomes one of the central issues because of competition with their predicted WSM states. However, the diversity in crystal structures and the complexity of phase transitions have hindered the rigorous study on the relation between superconducting and WSM states. In this study, we found the emergence of superconductivity in Te-deficient $MoTe_{2-x}$ while stoichiometric $MoTe_2$ shows no superconducting state, but exhibits a large magnetoresistance originating from its bipolar nature. Scanning tunnelling spectroscopy and synchrotron X-ray diffraction combined with theoretical calculations clarify that Te vacancies trigger superconductivity via intrinsic electron doping. This chalcogen vacancy-induced superconductivity provides a new route for cultivating superconductivity and rich electronic states, such as WSM and TI states, in TMDs and other 2D van der Waals materials.

Invited Talk #15

Quantum Anomalous Hall Effect in Layered Magnetic Oxides

Guang-Yu Guo[1]

[1] *Department of Physics, National Taiwan University, Taipei 10617, Taiwan*

Quantum anomalous Hall (QAH) phase is a two-dimensional bulk ferromagnetic insulator with a nonzero Chern number usually in presence of spin-orbit coupling (SOC). Associated metallic chiral edge states carry dissipationless current transport in electronic devices. Due to its intriguing nontrivial topological properties and great potential application for designing dissipationless spintronics, extensive theoretical and experimental studies have been made to search for real materials to host such QAH effect. Indeed, this intriguing QAH phase has recently been observed in magnetic impurity-doped topological insulators at extremely low temperatures (~30 mK) [1]. Based on first-principles density functional calculations, we predict that the QAH phases would exist in two kinds of layered 4d and 5d transition metal oxides with honeycomb and triangular lattices at high temperatures [2-3]. Furthermore, theoretical analysis reveals that the QAH phases in these oxide systems originate from two distinctly different mechanisms [2-3], namely, the conventional one due to the presence of both the SOC and ferromagnetism in the $(LaAlO_3)_{10}/(LaOsO_3)_2$ perovskite superlattice along the [111] direction [2], and the unconventional one (quantum topological Hall effect) caused by nonzero spin chirality resulting from topologically nontrivial magnetic structure in noncoplanar antiferromagnetic oxide $K_{0.5}RhO_2$ [3].

The speaker acknowledges that the works presented here were carried out in collaboration mainly with Hirak Kumar Chandra, Jian Zhou and Qi-Feng Liang.

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Invited Talk #16

Electronic structure of the new electron-doped cuprate superconductors in bulk and thin film forms

Atsushi Fujimori

Department of Physics, University of Tokyo, Tokyo 113-0033, Japan

In the electron-doped cuprates with the T' structure, superconductivity appears only after reduction annealing in the Ce-doping range of $0.13 < x < 0.18$ for $Nd_{2-x}Ce_xCuO_4$, and strong antiferromagnetic (AFM) correlation persists even in the superconducting phase. Recently, thin films of R_2CuO_4 (R = Nd, Pr) without Ce doping [1] and bulk crystals of $Pr_{1.3-x}La_{0.7}Ce_xCuO_4$ with Ce doping as low as $x \sim 0.05$ [2] have shown superconductivity after special annealing treatment.

We have performed systematic studies of the new T'-type cuprates superconductors in bulk and thin film forms by ARPES [3], x-ray photoemission spectroscopy, and x-ray absorption spectroscopy. By the reduction annealing, the signature of AFM correlation disappeared, the electron carrier concentration increased, and the Tc increased, in particular in samples with lower Ce content. The amount of increase in carrier concentration indicates that not only apical oxygen atoms but also in-plane and/or block-layer oxygen atoms are removed by annealing.

This work has been done in collaboration with M. Horio, K. Okazaki, T. Mizokawa, T. Yoshida, A. Ino, H. Anzai, M. Arita, H. Namatame, M. Taniguchi, S. Shin, Y. Ohta, H. Wadati, S. Shin, M. Kobayashi, K. Horiba, H. Kumigashira, Y. Krockenberger, H. Yamamoto, T. Adachi, and Y. Koike.

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Invited Talk #17

Majorana Ferimons in Kitaev Quantum Spin Lattice α-$RuCl_3$

Jae-Hoon Park
Max Plank POSTECH Center for Complex Materials Research, POSTECH, Pohang 790-784, Korea
Department of Physics & Division of Advance Materials Science, POSTECH, Pohang 790-784, Korea

Geometrical constraint often enforces the electronic states of matter to be topological quantum states such as fractional quantum Hall states, topological insulators, and Weyl semi-metals. In magnetism, theoretical studies predicted an entangled magnetic quantum state with topological ordering and fractionalized spin excitations, the so-called quantum spin liquid (QSL). The Kitaev honeycomb lattice is envisioned as an ideal host for Majorana fermions (MFs), fractionalized spin excitations created out of QSL. Here I will discuss thermally fractionalized Majornara fermions in Kitaev quantum spin lattice a-$RuCl_3$.

Invited Talk #18

Evidence for weakly correlated oxygen holes in the highest-T_c cuprate superconductor $HgBa_2Ca_2Cu_3O_{8+\delta}$

A. Chainani[1]*

[1] *National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan*

We study the electronic structure of $HgBa_2Ca_2Cu_3O_{8+\delta}$ (Hg1223 ; T_c = 134 K), the highest-T_c cuprate superconductor at ambient pressure, using photoemission spectroscopy (PES) and x-ray absorption spectroscopy (XAS). Resonant valence band PES across the O K-edge and Cu L-edge identify correlation satellites originating in O 2p and Cu 3d two-hole final states, respectively. Analyses using the experimental O 2p and Cu 3d partial density of states show quantitatively different on-site Coulomb energies for the Cu-site (U_{dd} = 6.5 eV $\pm$ 0.5 eV) compared to the O-site (U_{pp} = 1.0 eV $\pm$ 0.5 eV). Cu_2O_7-cluster calculations with non-local screening explain the Cu 2p core level PES and Cu L-edge XAS spectra, confirm the U_{dd} and U_{pp} values, and provide evidence for the Zhang-Rice singlet state in Hg1223. In contrast to known results on other hole-doped cuprates and 3d-transition metal oxides, the present results indicate weakly correlated oxygen holes in Hg1223.

*Work done in collaboration with M. Sicot, Y. Fagot-Revurat, G. Vasseur, J. Granet, B. Kierren, L. Moreau, D. Malterre *(Institut Jean Lamour, Université de Lorraine, Nancy, France)* ; M. Oura *(RIKEN SPring-8 Centre, Hyogo 679-5148, Japan)* ; A. Yamamoto, Y. Tokura, *(Strong Correlation Physics Division, RIKEN Center for Emergent Matter Science (CEMS), Wako 351-0198, Japan).*

Invited Talk #19

Evincing Majorana fermions in Kitaev magnets

Yukitoshi Motome

Department of Applied Physics, University of Tokyo, Japan

After the inspiring proposal by P. W. Anderson in 1973, the quantum spin liquid (QSL) has attracted continuous interest as a new quantum state of matter in magnets. Although several candidate materials have been synthesized, it remains elusive to prove that their low-temperature state is a QSL, mainly because of the lack of conventional order parameters within the Landau-Ginzburg-Wilson theory. On the other hand, one of the salient features of QSLs is the fractionalization of quantum spins associated with the topological order, which may provide a key to identify QSLs. We address this issue in the Kitaev model and its extensions, in which the quantum spin fractionalizes into two types of Majorana fermions in the QSL ground state. By using the newly-developed simulation techniques in the Majorana fermion representation, we find that the paramagnetic state harboring the QSL indicates the signatures of Majorana fermions in the temperature and energy dependences of many experimentally accessible quantities, such as the specific heat, entropy, magnetic susceptibility, dynamical spin structure factor, NMR relaxation rate, Raman scattering intensity, and thermal conductivity. Our findings will be helpful as 'smoking gun' experiments for QSLs. We discuss our theoretical results in comparison with the available experimental data for several Kitaev candidate materials.

This work has been done in the collaborations with Joji Nasu, Junki Yoshitake, Masafumi Udagawa, Yasuyuki Kato, Yoshitomo Kamiya, Johannes Knolle, Dmitry Kovrizhin, and Roderich Moessner. This research has been supported by JSPS KAKENHI Grant Numbers JP15K13533, JP16K17747, and JP16H02206. Parts of the numerical calculations are performed in the supercomputing systems in ISSP, the University of Tokyo.

References will be found in http://www.motome-lab.t.u-tokyo.ac.jp/publication-e.html.

Invited Talk #20

Possible oxygen-ordering induced ferroelectric polarization and magnetic interactions in oxygen deficient $SrCoO_{2.5+x}$

Jinyoung Lim and Jaejun Yu

Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea

Layered $SrCoO_{2.5+x}$, a family of non-stoichiometric perovskites, has been reported to undergo topotactic ion exchange and intercalation reactions. Its property is expected to be useful for technology applications involving oxygen ion transport, such as solid oxide fuel cells and electrochemical sensors. We investigate the electronic structure and magnetic properties of the antiferromagnetically ordered $SrCoO_{2.5}$ with brownmillerite-type structure and the ferromagnetic $SrCoO_3$ with cubic-type perovskite structure by using first-principles electronic structure calculations. The relaxed structure of $SrCoO_{2.5}$ is compared with the experimental structure. The magnetic and orbital orderings related to the structural feature are observed in each layer, where the ordering of oxygen tetrahedra in $SrCoO_{2.5}$ attributed to the ferroelectric moment observed in similar brownmillerite compounds. The magnetic exchange interaction parameters between nearest-neighbor Co ions are obtained through fitting the total energy results to the model hamiltonians, and the results are found to be consistent with the observed magnetic structures of $SrCoO_3$ and $SrCoO_{2.5}$. A magnetic and structural configuration for the $SrCoO_{2.75}$ oxygen deficient structure is suggested from the results of electronic structure calculations. This finding provides us a way to understand how the electronic and magnetic ground states of $SrCoO_{3-x}$ vary depending on the amount of oxygen vacancies.

Poster Presentation #1

Doping effects on 2D triangular multiferroic Y(Mn,Al,Ga)O_3

Hasung Sim[1,2], Ki-Young Choi[1], K. Rule[3], and Je-Geun Park[1,2]
[1]Center for Correlated Electron Systems, Institute for Basic Science Seoul 08826, Korea &
[2]Department of Physics & Astronomy, Seoul National University, Seoul 08826151-747, Korea
[3]Bragg Institute, Australian Nuclear Science and Technology Organisation, Lucas Heights, New South Wales Australia

Hexagonal multiferroic $RMnO_3$ is one of the most extensively studied systems [1]. In addition to the multiferroic behavior, it also hosts a two-dimensional (2D) triangular lattice of Mn moments, which itself is interesting from a magnetic point of view as a 2D triangular lattice with antiferromagnetic interaction has strong frustrations. As one way of studying the 2D nature of magnetism, several attempts have been made to dope at the Mn site with a limited success up to a nominal value of 10% [2]. Generally doping perturbs the magnetic ground state, in this case a so-called 120° noncollinear antiferromagnet. Moreover, non-magnetic impurities can also induce so-called impurity-induced spin texture, which can add further interesting feature [3-5]. In this study, we report a successful growth of doped single crystals with as much as doping of 25% of Al and Ga using a floating zone furnace. Using these single crystals, we have carried out extensive studies of physical properties as well as neutron diffraction measurements. We will discuss the experimental data with respect to expected impurity effects of ferroelectricity and magnetism.

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Poster Presentation #2

Magnon phonon hybridization in multiferroic RMnO3

Joosung Oh[1], H. Sim[1], K. Park[1], J. C. Leiner[1], J-G. Park[1], M. D. Le[1,2], T. G. Perring[2], A. Q. R. Baron[3], A. L. Chernyshev[4], S-W. Cheong[5]

[1] Department of Physics & Astronomy, Seoul National University, Seoul 08826, Korea
[2] ISIS Facility, STFC Rutherford Appleton Laboratory, Didcot OX11 0QX, UK
[3] Materials Dynamics Laboratory, RIKEN SPring-8 Center, RIKEN, Hyogo 679-5148, Japan
[4] Department of Physics and Astronomy, University of California, Irvine, California 92697, USA
[5] Department of Physics and Astronomy, and Rutgers Center for Emergent Materials, Rutgers University, Piscataway, New Jersey 08854, USA

Magneto-electric coupling (ME coupling) in multifferoic materials is an actively studied subject. In many multiferroic compounds, spin lattice coupling is believed to play important role in ME coupling. However, detailed experimental probe of such coupling Hamiltonian is rare. Here we study magnon phonon coupling in multiferroic RMnO3 by using inelastic neutron and x-ray scattering technique. The observed spectra showed clear evidence of magneto-elastic excitation and electromagnon, which are reproduced by a spin lattice coupling Hamiltonian. Furthermore, the magneto-elastic excitation shows unusual damping even at low temperatures, much below TN. We will discuss the origin of such damping and implication of our findings on the ME coupling in RMnO3..

Poster Presentation #3

Properties of highly frustrated antiferromagnets: Cu$RE_2Ge_2O_8$ (RE=Pr,Nd,Sm~Tm)

Hwanbeom Cho[1], Hasung Sim[1], Darren. C. Peets[1], and Je-Geun Park[1]

[1]Center for Correlated Electron Systems, Institute for Basic Science (IBS) & Department of Physics and Astronomy, Seoul National University, Seoul 151-747, Korea

Cu$RE_2Ge_2O_8$ has a monoclinic crystalline structure (space group I 1 m 1) with rare earth polyhedrons [1] which form honeycomb like tunnel structure along its a-axis. Even though its crystal structure is not likely to allow geometrically frustrated exchange interaction, our physical property measurements show some clues of frustration. We identify crystal structure of Cu$RE_2Ge_2O_8$ system [2] using single crystal and powder X-ray diffraction methods and provide magnetization and specific heat capacity measurement data which correspond to properties of highly frustrated antiferromagnets.

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Poster Presentation #4

Low energy spin dynamics of rare-earth orthoferrites $YFeO_3$ and $LaFeO_3$

Kisoo Park[1,2], Hasung Sim[1,2], Jonathan C. Leiner[1,2], Yoshiyuki Yoshida[3], Hiroshi Eisaki[3], Shinichiro Yano[4], Jason Gardner[4], Je-Geun Park[1,2,*]

[1]Center of Correlated Electron Systems, Institute for Basic Science (IBS), Seoul 08826, Korea
[2]Department of Physics & Astronomy, Seoul National University, Seoul 08826, Korea
[3]Electronics and Photonics Research Institute, National Institute of Advanced Industrial Science and Technology (AIST), 1-1-1 Higashi, Tsukuba, Ibaraki 305-8565, Japan
[4]Australian Nuclear Science and Technology Organisation, Lucas Heights, 2234 New South Wales, Australia

$YFeO_3$ and $LaFeO_3$ are members of the rare-earth orthoferrites ($RFeO_3$) family with *Pbnm* space group. With the strong superexchange interaction between Fe^{3+} ions, both compounds exhibit the room temperature antiferromagnetic order (T_N > 600 K) with a slight spin canting. Here we report low-energy magnetic excitation of $YFeO_3$ and $LaFeO_3$ using inelastic neutron scattering measurements, showing evidence of magnon mode splitting and a spin anisotropy gap at the zone center. Spin wave calculations with the spin Hamiltonian including both Dzyaloshinsky-Moriya interaction and single-ion anisotropy accounts for the observed features well. Our results offer insight into the underlying physics of other $RFeO_3$ with magnetic rare-earth ions or related Fe^{3+}-based multiferroic perovskites such as $BiFeO_3$.

Poster Presentation #5

Transport study on antiferromagnetic van der Waals $MnPS_3$ using conductive atomic force microscopy

Sungmin Lee[1,2], Ki-Young Choi[1], Sangik Lee[3], Hae Ho Park[3], and Je-Geun Park[1,2]

[1] Center for Correlated Electron Systems, Institute for Basic Science, Seoul 08826, South Korea
[2] Department of Physics and Astronomy, Seoul National University, Seoul 08826, South Korea
[3] Department of Physics, Konkuk University, Seoul 05029, South Korea

After the successful isolation of graphene, the field of van der Waals (vdW) materials and the list of vdW systems have grown recently at an alarming rate.[1-3] Among them, we are very interested and welcome the recent entry of new magnetic vdW materials: Transition metal phosphorus tri-chalcogenide ($TMPX_3$). Successful exfoliation has been recently demonstrated down to monolayer of these materials.[4-6] So far all the initial characterization has been made by using Raman and AFM, and there has been no report of the transport characteristics of few-layer $TMPX_3$ which is an essential step for future device applications. Thus, we have investigated the tunneling transport of mono- and few-layers of $MnPS_3$ by using conductive atomic force microscopy.[7] Due to the band alignment of indium tin oxide/$MnPS_3$/Pt-Ir tip junction, the key features of both Schottky junction and Fowler-Nordheim tunneling (FNT) were observed for all the samples with varying thickness. Using the FNT model and assuming the effective electron mass (0.5 me) of $MnPS_3$, we estimate the tunneling barrier height to be 1.31 eV and the dielectric breakdown strength as 5.41 MV/cm. We expect that these values of tunneling barrier and dielectric breakdown strength would be helpful for many applications such as field effect transistor and magnetic tunnel junction.

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Poster Presentation #6

Strong thermal hysteresis of Verwey transition in Fe_3O_4 Nanoparticles

Taehun Kim[1,2], Jaeyoung Hong[3,4], Sumin Lim[5], Soonmin Kang[1,2], Jisoo Lee[3,4]

Jonathan C. Leiner[2], Soon Gu Kwon[3,4], Taeghwan Hyeon[3,4], Soonchil Lee[5], Je-Geun Park[1,2]

[1]*Department of Physics and Astronomy, Seoul National University, Korea*

[2]*Center for Correlated Electron Systems, Institute for Basic Science (IBS), Korea*

[3] *School of Chemical and Biological Engineering, Seoul National University, Korea*

[4] *Center for Nanoparticle Research, Institute for Basic Science (IBS), Korea*

[5]*Depeartment of Physics, KAIST, Korea*

Fe_3O_4 which is well-known for strongly correlated electron system has the metal-insulator transition [1] and its transition temperature decreases in nm-sized case [2] which is related to intrinsic size effect. Additionally, we found a strong thermal hysteresis in nanoparticles, whereas 7 μm bulk sample has a weak hysteresis about 1 K. Hysteresis has size dependence that its width increases up to 10 K as increasing size until 120 nm and then decreases down to 1 K. We could examine that this feature comes from the single domain structure determined by the ratio between remanent magnetization (M_r) and saturated magnetization (M_s). Theoretical calculation for possible critical size which can have a single domain [3] is similar with our results. Therefore, we could conclude that our nanoparticles have almost single domain and it makes hysteretic metal-insulator transition. Moreover, from RIXS spectra, we could observed the low energy excitation and it was gradually suppressed as reducing sizes which can describes intrinsic size effect of nanoparticles.

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Poster Presentation #7

Breakdown of dimerized valence bonds in $Li_2Ru_{1-x}Mn_xO_3$

Seokhwan Yun[1, 2]

[1]IBS Center for Functional Interfaces of Correlated Electron Systems, Seoul National University, Korea
[2]Department of Physics & Astronomy, Seoul National University, Korea
**Email of Presenting Author: yunpoppy@gmail.com*

RVB(Resonating Valence bond) is a state proposed by P. W. Anderson. By this bizarre phenomenon, spins of two ions that participate in bond are predicted to be entangled [1].

Li_2RuO_3 which has 2D honeycomb layer made with ruthenium layer is a candidate of a medium of the phenomenon. One third of pair of bond in the hexagonal layer are shorter than other ruthenium bonds, also they have a long range ordering called herring bone structure. This structure has phase transition above 550 K [2][3], the dimerized bonds are melted and become a liquid of valence bond state up to 650 K [4]. For melting the bonds, I substituted Ru ion with Mn ion. As a result, the dimerized valence bonds are broken and the phase transition was vanished above 1/8 substitution.

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Poster Presentation #8

Spin glass behavior in ultrathin magnetic van der Waals materials

Suhan Son[1,2], Je-Geun Park[1,2]

[1] *Center for Correlated Electron Systems, Institute for Basic Science, Seoul 08826, South Korea*
[2] *Department of Physics and Astronomy, Seoul National University, Seoul 08826, South Korea*

Transition metal phosphorous tri-chalcogenide, TMPS3(TM=Mn,Fe,Co,Ni) can be used for the realization of 2D magnetic properties because thickness can be reduced easily by so-called scotch tape method[1]. In recent researches, TMPS3 can be cleaved to monolayers[2] and also magnetic properties of 2D FePS3 were studied[3]. TMPS3 shows the different spin Hamiltonian depending on transition metals; 2D XY Hamiltonian(NiPS3), 2D Heisenberg (MnPS3), 2D Ising(FePS3)[4]. However, if two transition metals are mixed, it is ambiguous that which Hamiltonian this sample follows or that thickness dependence. $Mn_{0.5}Fe_{0.5}PS_3$ has been known that spin glass behaviors are shown below freezing temperature. So thickness study of spin glass is not also interesting but able to be a chance to understand the spin glasses more exactly.

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Poster Presentation #9

Spin dynamics in the spin chain compound Sr_3CuPtO_6

J. C. Leiner,[1, 2] Joosung Oh,[1, 2] A. I. Kolesnikov,[3] M. B. Stone,[3] Manh Duc Le,[4] S.-W. Cheong,[5] and Je-Geun Park[1, 2]

[1]Center for Correlated Electron Systems, Institute for Basic Science (IBS), Seoul 08826, Korea
[2]Department of Physics & Astronomy, Seoul National University, Seoul 08826, Korea
[3]Quantum Condensed Matter Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831
[4]ISIS Facility, STFC, Rutherford Appleton Laboratory, Didcot, Oxfordshire OX11-0QX, United Kingdom
[5]Rutgers Center for Emergent Materials and Department of Physics and Astronomy, Rutgers University, Piscataway, New Jersey 08854, USA

Antiferromagnetic spin chain systems have attracted considerable attention since the discovery of fractional spinon excitations in spin-half chain systems and Haldane gap phases in spin-one chain systems. It has been reported from bulk susceptibility and heat capacity measurements that the magnetic Cu^{2+} ions in Sr_3CuPtO_6 exhibit S=1/2 Heisenberg spin chain behavior with a substantial amount of AFM interchain coupling. We report the magnetic excitation spectrum as measured by inelastic neutron scattering for a polycrystalline sample of Sr_3CuPtO_6. Modeling with linear spin wave theory accounts for the major features of the spinwave spectra, including a nondispersive intense magnon band at 8meV. The magnetic excitations broaden considerably as temperature is increased, persisting up to above 100K and displaying a broad transition as previously seen in the susceptibility data. No spin gap is observed in the dispersive spin excitations at low momentum transfer, which is consistent with Haldane physics in an ideal uniform S=1/2 spin-chain system.

Poster Presentation #10

Evidence of electron-phonon interaction in single crystal of (Ru^{3+}/Ru^{4+}) mixed-valence $Na_{2.7}Ru_4O_9$ and $NaRu_2O_4$

Arvind Yogi[1,2], C. I. Sathish[1,2], Hasung Sim[1,2], and Je-Geun Park[1,2]

[1]*Center for Correlated Electron Systems, Institute for Basic Science (IBS), Seoul 08826, Korea*

[2]*Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea*

We report a comprehensive investigation of the structural, electric transport, magnetic, and thermodynamic properties of $Na_{2.7}Ru_4O_9$ and $NaRu_2O_4$ single crystals. The compounds are structurally different; $Na_{2.7}Ru_4O_9$ crystalize in monoclinic (C 2/m) structure while $NaRu_2O_4$ crystalize in orthorhombic (P 2_1/ma) structure. We observed a first-order phase transition in the electrical resistivity at T_c = 335 K and T_c = 530 K for $Na_{2.7}Ru_4O_9$ and $NaRu_2O_4$, respectively. The electrical resistivity data are then theoretically analysed within the framework of the classical electron–phonon model of resistivity, *i.e.* the Bloch–Grüneisen–Mott model. Detailed analysis of the electrical resistivity of both Ru-based metallic systems $Na_{2.7}Ru_4O_9$ and $NaRu_2O_4$ suggests that the charge carrier density is strongly influenced by electron–phonon scattering and additionally inter-band electron scattering for $Na_{2.7}Ru_4O_9$. The characteristic Debye temperature (θ_D) is found to be 140 and 499 K for $Na_{2.7}Ru_4O_9$ and $NaRu_2O_4$, respectively. Magnetic susceptibility $\chi(T) = M/H$ curve shows diamagnetic behaviour for both the compounds and no magnetically ordered state was observed down to 1.9 K. The evidence for metal-like electronic contribution in the low-temperature heat capacity was also observed for both the compounds. The electronic contribution to the specific heat (γ) for $Na_{2.7}Ru_4O_9$ and $NaRu_2O_4$ was determined to be 26.91 and 3.93 mJ/mol K^2, respectively. The higher value of γ for $Na_{2.7}Ru_4O_9$ is much larger than the free electron value of 1 mJ/mol K^2 Ru, indicates that $Na_{2.7}Ru_4O_9$ belongs to the class of strongly correlated electron system.

Poster Presentation #11

Spin Precession Pumped by Pulsed Terahertz Magnetic Field in $YMn_xFe_{1-x}O_3$

Howon Lee, Taewoo Ha, Jong Hyeon Kim, Young Chan Jo, Kyung Ik Sim, Jangwon Kim, S. H. Oh, Y. J. Choi, and Jae Hoon Kim

Department of Physics, Yonsei University, 50 Yonsei-Ro, Seodaemun-Gu, Seoul 03722, Republic of Korea

We studied spin precession in canted antiferromagnetic $YMn_xFe_{1-x}O_3$ (x=0-0.45) by utilizing the pulsed magnetic field in terahertz light. Both the quasi-ferromagnetic resonance (qFMR) and quasi-antiferromagnetic resonance (qAFMR) modes were observed in YFeO3 (x=0). With increasing Mn doping, the qAFMR gradually disappeared, whereas the qFMR did not. We tracked the qFMR as a function of temperature. Spin reorientation transitions and new infrared-active absorption modes were also observed.

Poster Presentation #12

Metallic Terahertz Metamaterials Research

Young Chan Jo [1], Kyung Ik Sim [1], Jong Hyeon Kim [1], Taewoo Ha [1], Hirotake Yamamori [2], Houk Jang [3], Jong-Hyun Ahn [3], Jaewon Kim [5], Jin Young Kim [5], Se Young Jeong [4] and Jae Hoon Kim [1]

[1] Department of Physics and Institute of Physics and Applied Physics, Yonsei University, Seoul 120-749, Republic of Korea
[2] National Institute of Advanced Industrial Science and Technology, 1-1-1 Umezono, Tsukuba 305-8568, Japan
[3] School of Electrical and Electronic Engineering, Yonsei University, Seoul, 120-749, Republic of Korea
[4] Department of Cogno-Mechatronics Engineering, Pusan National University, Miryang 130546, Republic of Korea
[5] School of Energy and Chemical Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan Metroplitan City 44919, Republic of Korea

We performed finite-difference time-domain (FDTD) simulations of both intaglio metamaterials of NbN films and copper-meshed films on terahertz-transparent substrates in the spectral range from 0.1 to 3 THz and measured their optical conductivity by using terahertz time-domain spectroscopy. NbN-film metamaterials with oblique-DSRR (double split ring resonator) patterned structures exhibited open and closed resonance modes emerging from the low frequency region. Copper-meshed films with a honeycomb patterned structure exhibited smaller scattering rate than the basal copper film. By focusing on the average of current density and electric field within the unit cell of the meta-structure, the FDTD simulation demonstrates that the metamaterial film could be considered as a new effective medium in the wavelength region with the wavelength longer than the structural dimension.

Poster Presentation #13

Effect of strong spin-orbit coupling of anion p orbitals on superexchange interaction

D.-H. Kim[1,2], Jae-Young Kim[1,3], S. W. Cheong[4,5], J.-H. Park[1,2]

[1]Department of Physics, Pohang University of Science and Technology, Pohang 790-784, Republic of Korea
[2]Max Planck POSTECH Center for Complex Phase Materials, Pohang University of Science and Technology, Pohang 790-784, Republic of Korea
[3]Pohang Accelerator Laboratory, Pohang University of Science and Technology, Pohang, Korea
[4]Laboratory for Pohang Emergent Materials and Department of Physics, Pohang University of Science and Technology, Pohang 790-784, Korea
[5]Rutgers Center for Emergent Materials and Department of Physics and Astronomy, Rutgers University, Piscataway, New Jersey 08854, USA

Recent studies on the strong spin-orbit coupling (SOC) reveals many new physics like Jeff = ½ mott state [1], Kitaev Hamiltonian [2], and Rashba splitting [3]. The efforts on the SOC driven new physics are still going on. The chalcogenide systems opens a new way with strong SOC on anion sites; 500 meV for Te 5p, and 220 meV for Se 4p [4]. We have pay attention on the effect of SOC on the superexchange interaction in 90 degree geometry, which favor ferromagnetic spin-spin interaction. Interestingly, some superexchange hopping paths can be open or closed depending on the spin direction and their effects do not cancel each other's. These on-off behavior results a magnetic anisotropy described by anisotropic Heisenberg spin-spin interaction. We have done 4 site full multiplet cluster calculation and found that the plane contain transition metals and anions become easy plane, and the energy difference are order of 0.1 meV. We have applied this anisotropy in layered chromium chalcogenides Cr2Ge2Te6 and CrI3, which realize 90 degree superexchange interaction. They are ferromagnetic correlated insulator with Tc = 78 K for Cr2Ge2Te6 and Tc = 61 K for CrI3 and saturated moments are almost 3 μB/Cr [5]. The magnetic easy axes are c direction in both systems, but conventional single site anisotropy and shape anisotropy prefer ab plane as magnetic easy plane. We propose that this discrepancy can be explained by the anisotropy driven by SOC.

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Poster Presentation #14

Magnetic properties of epitaxially grown high quality LaCrO3 films by pulsed laser deposition

Jun Ho Park[1], Kyung Tae Ko[1] , Dong Hwan Kim[1] , Jong Hyun Song[2] , Jae Young Kim[3] , Seung Ran Lee[1] , Jae Hoon Park[1]

[1] CCMR and Department of Physics, Pohang University of Science and Technology, Pohang 790-784, Republic of Korea
[2] Department of Physics, Chungnam National University, Daejeon 34134, Republic of Korea,
[3] Pohang Accelerator Laboratory, Pohang University of Science and Technology, Pohang 790-784, Republic of Korea

We succeeded in epitaxial growth of $LaCrO_3$ (LCO) thin films on TiO_2 terminated $SrTiO_3$ (001) substrate by pulsed laser deposition method with a sintered stoichiometric LCO target. Atomically flat surface and its high crystallinity were confirmed by atomic force microscope and x-ray diffractometer, respectively. Stoichiometry of high crystalline film was measured by X-ray absorption spectroscopy, showing only Cr^{3+} valence feature and eventually indicating that our sample has a single phase. In bulk system, LCO exhibits the G-type antiferromagnetic ordering below the Neel temperature (T_N) of 288K. The Cr $L_{2,3}$, edge X-ray magnetic linear dichroism (MLD) and its temperature dependence were used to investigate magnetic properties of the epitaxial LCO film and its transition temperature. The results show existence of antiferromagnetic ordering in the film with the T_N of around 240K. The configuration interaction model calculations including the full atomic multiplets and crystal field splitting match well to the obtained MLD line shape and suggest the antiferromagnetic spin axis.

Poster Presentation #15

High-Resolution Soft X-ray RIXS Using Active Gratings and Energy Compensation

W. B. Wu, H. S. Fung, K. Y. Kao, C. C. Chiu, C. H. Chang, C. H. Kuo, S. C. Chung, H. Y. Huang, J. Okamoto, H. W. Fu, S. W. Lin, D. J. Wang , D. J. Huang and C. T. Chen

[1] *National Synchrotron Radiation Research Center, Hsinchu 30076, TAIWAN*

We will present a new RIXS beamline, which is based on energy compensation principle and built for the Taiwan Photon Source. A unique technique is applied for the high-efficiency, high-resolution beamline and spectrometer of inelastic soft X-ray scattering (RIXS). This new technique is based on the energy compensation principle of grating dispersion. The design of the monochromator–spectrometer system greatly enhances the data acquisition efficiency at least by one order of magnitude. The setup comprises two bendable gratings to effectively diminish the defocus, coma and high order aberrations. A proto-type RIXS beamline of this design has been constructed at the Taiwan Light Source, showing total energy resolutions of 65 meV and 130 meV at 710 eV and 930 eV, respectively [1,2]. This test beamline has yielded successful RIXS experiments of cuprate superconductors [3]. A new RIXS beamline based on this design will be constructed at the Taiwan Photon Source. To eliminate the grating surface intrinsic slope error and heat-load deformation, a novel 25-points grating bender system is designed. A CCD detector with a sub-pixel spatial resolution through a centroid algorithm will be used. Our simulations shows that the expected energy resolving power is better than 60,000 from 500 eV to 1000 eV, with an efficiency one order of magnitude better than that of a conventional design.

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Poster Presentation #16

Jahn-Teller distortion driven magnetic polarons in magnetite

H. Y. Huang [1, 2], Z. Y. Chen[3], R.-P. Wang[4], F. M. F. de Groot[4], W. B. Wu[1], J. Okamoto[1], A. Chainani[1], J.-S. Zhou[5], H.-T. Jeng[3], G. Y. Guo[6, 7], Je-Geun Park[8, 9], L. H. Tjeng[10], C. T. Chen[1], and D. J. Huang[1, 3]

1National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan
2Program of Science and Technology of Synchrotron Light Source, National Tsing Hua University, Hsinchu 30013, Taiwan
3Department of Physics, National Tsing Hua University, Hsinchu 30013, Taiwan
4Department of Inorganic Chemistry and Catalysis, Utrecht University, Sorbonnelaan 16, 3584 CA Utrecht, The Netherlands
5Department of Mechanical Engineering, Texas Material Institute, University of Texas at Austin, Austin, Texas 78712, USA
6Department of Physics, National Taiwan University, Taipei 10617, Taiwan
7Physics Division, National Center for Theoretical Sciences, Hsinchu 30013, Taiwan
8Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea
9Center for Correlated Electron Systems, Institute for Basic Science, Seoul 08826, Korea
10Max Planck Institute for Chemical Physics of Solids, N othnitzerstr. 40, 01187 Dresden, Germany

The first known magnetic mineral, magnetite (Fe_3O_4), has unusual properties which have fascinated mankind for centuries; it undergoes the Verwey transition at T_V ~120 K with an abrupt change in structure and electrical conductivity. The mechanism of the Verwey transition however remains contentious. Here we use resonant inelastic X-ray scattering (RIXS) over a wide temperature range across the Verwey transition to identify and separate out the magnetic excitations derived from nominal Fe^{2+} and Fe^{3+} states. Comparison of the RIXS results with crystal-field multiplet calculations shows that the spin-orbital *dd* excitons of the Fe^{2+} sites arise from a tetragonal Jahn-Teller active polaronic distortion of the $Fe^{2+}O_6$ octahedra. These low-energy excitations, which get weakened for temperatures above 350 K but persist at least up to 550 K, are distinct from optical excitations and best explained as magnetic polarons.

Poster Presentation #17

Electronic structure of $Ce_3Co_4Sn_{13}$ using hard X-ray photoelectron spectroscopy & x-ray absorption spectroscopy

A. Singh,[1] Y. Y. Chin,[1] H. Y. Huang[1] Y. F. Liao,[1] K. D. Tsuei,[1] H. J. Lin,[1] C. N. Kuo,[2] H. F. Liu,[2] C. S. Lue,[2] C. T. Chen,[1] D. J. Huang[1] and A. Chainani[1]

[1]National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan

[2]Department of Physics, National Cheng Kung University, Tainan 70101, Taiwan

The compound $Ce_3Co_4Sn_{13}$ is a heavy fermion system which exhibits a charge density wave (CDW) phase transition at ~155 K [1, 2]. In the present study, we used hard X-ray photoelectr on spectroscopy (HAXPES) and x-ray absorption spectroscopy (XAS) to investigate the electronic structure of $Ce_3Co_4Sn_{13}$. HAXPES measurements are carried out below and above the CDW transition using an incident photon energy of hν ~6.480 keV. Core levels and valence band spectra of $Ce_3Co_4Sn_{13}$ have been measured at 20 K and 170 K temperature. A small finite change (~90-110 meV) in the binding energy is observed across the CDW transit ion for the Sn 3p and Co 2p core level spectra, while Ce 3d core level shows negligible change. This observation is consistent with a recent x-ray fluorescence study at the Ce L (≡ 2p)-edge and Co K (≡ 1s)-edge [2]. Further, valence band spectra show a feature at ~1.5 eV binding energy, which is attributed to Co 3d partial density of states. In the CDW phase, the valence band spectra show a clear Fermi edge, which is consistent with the metallic behavior observed by electrical resistivity in the CDW phase[1]. Similar to HAXPES results, the XAS spectra for Co L (≡ 2p)-edge also shows an energy shift of (~90 meV), while Ce M (≡ 3d)-edge shows negligible change. The present HAXPES & XAS study suggests very weak charge-disproportionation in $Ce_3Co_4Sn_{13}$ across the CDW transition.

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Poster Presentation #18

Raman Study on Photostrictive Perovskite $SrIrO_3$ Thin Films

Yi-De Liou[1], Yi-Chun Chen[1], Ying-Hao Chu[2], Jan-Chi Yang[1]

[1] Department of Physics, National Cheng Kung University, Tainan, Taiwan
[2] Department of Materials Science and Engineering, National Chiao Tung University, Hsinchu, Taiwan

Photostrictive effect is a light-matter interaction which generates a reversible mechanical deformation in a material by illumination of light, which is also called “photostriction”. Materials which possess photostrictive property can serve as energy conversion system, wireless remote control, photo sensor and so on, offering gifted potential towards novel photonic devices. However, the light-induced lattice changes in most of photostrictive materials are very small so that there are no practical applications hitherto. In this study, we investigated the visible-light-induced deformation of perovskite SrIrO3 (SIO), taking advantages of its strong spin-orbit coupling, sizable crystal field and high absorption across the visible spectrum at room temperature. By using Raman spectroscopy, the Raman mode assignments were made by group theory and the phonon behaviors of the SIO thin film under various incident laser intensities were analyzed. The phonon deformation potential of SIO was calculated by lattice mismatch induced Raman shift, and the photon-induced strain is then obtained. We found that SIO shows significant photostriction compared to conventional semiconductors, polymers and perovskite oxides under the same experiment configuration. The strong photostrictive effect of SIO at room temperature paves a promising route towards new applications and multifunctionalities of photon-driven devices.

Poster Presentation #19

Heteroepitaxy of Fe_3O_4/Muscovite: A New Perspective for Flexible Spintronics

Ping-Chun Wu[1,2], Ping-Fan Chen[3], Thi Hien Do[3], Ying-Hui Hsieh[2,4], Chun-Hao Ma[5], Thai Duy Ha[6], Kun-Hong Wu[7], Yu-Jia Wang[8], Hao-Bo Li[8], Yi-Chun Chen[7], Jenh-Yih Juang[6], Pu Yu[8], Lukas M. Eng[4], Chun-Fu Chang[1], Po-Wen Chiu[5], Liu Hao Tjeng[1], and Ying-Hao Chu[2,3,6*]

[1]*Max Planck Institute for Chemical Physics of Solids, Noethnitzerstr. 40, 01187 Dresden, Germany*
[2]*Department of Materials Science and Engineering, National Chiao Tung University, Hsinchu 30010, Taiwan*
[3]*Institute of Physics, Academia Sinica, Taipei 11529, Taiwan*
[4]*Institut fur Angewandte Photophysik, Technische Universitat Dresden, George-Bahr-Str. 1, 01069 Dresden, Germany*
[5]*Department of Electrical Engineering, National Tsing Hua University, Hsinchu 30013, Taiwan*
[6]*Department of Electrophysics, National Chiao Tung University, Hsinchu 30010, Taiwan*
[7]*Department of Physics, National Cheng Kung University, Tainan City 701, Taiwan*
[8]*Department of Physics, Tsinghua University, Beijing 100084, China*

Spintronics has captured a lot of attention since it was proposed. It has been triggering numerous research groups to make their efforts on pursuing spin-related electronic devices. Recently, flexible and wearable devices are in a high demand due to their outstanding potential in practical applications. In order to introduce spintronics into the realm of flexible devices, we demonstrate that it is feasible to grow epitaxial Fe_3O_4 film, a promising candidate for realizing spintronic devices based on the tunneling magnetoresistance, on flexible muscovite. In this study, the heteroepitaxy of Fe_3O_4/muscovite is characterized by x-ray diffraction, high-resolution transmission electron microscopy, and Raman spectroscopy. The chemical composition and magnetic feature are investigated by a combination of x-ray photoelectron spectroscopy and x-ray magnetic circular dichroism. The electrical and magnetic properties are examined to show the preservation of the primitive properties of Fe_3O_4. Furthermore, various bending tests are performed to show the tunability of functionalities and to confirm that the heterostructures retain the physical properties under repeated cycles. These results illustrate that the Fe_3O_4/muscovite heterostructure can be a potential candidate for the applications in flexible spintronics.
Keywords: Heteroepitaxy, Spintronics, Magnetite, Muscovite, Flexible electronics

Poster Presentation #20

Van der Waals Epitaxy of Flexible and Transparent VO_2 Film on Muscovite

Chien-I Li[1], Yen-Pei Lin[1], Heng-Jui Liu[1], Ming-Wen Chu[2], Hsiao-Wen Chen[3], Chun-Hao Ma[4], Hsiang-Lin Liu[3], Po-Wen Chiu[4], Ying-Hao Chu[1,5]

[1] Department of Materials Science & Engineering, National Chiao Tung University, Hsinchu 30010, Taiwan

[2] Center for Condensed Matter Sciences, National Taiwan University, Taipei 106, Taiwan

[3] Department of Physics, National Taiwan Normal University, Taipei 11677, Tai wan

[4] Institute of Electronics Engineering, National Tsing Hua University, Hsinchu 3 0013, Taiwan

[5] Institute of Physics, Academia Sinica, Taipei 11529, Taiwan

A strong demand on electronic devices with new functionalities triggers researchers to explore new materials or architecture design that silicon-based electronics cannot reach. A great attention has been paid to Vanadium dioxide (VO_2). The crystal structure of VO_2 can be transformed between the rutile and monoclinic phases accompanied by a first-order metal-insulator transition (MIT). This transition is fully reversible and the T_c of the MIT is v ery close to room temperature. More importantly, the structure transition of VO_2 happ ens at ultrafast timescale and can be triggered by multiple approaches, making it very attractive to practical applications. Recently, flexible electronics represents a fast-developing field and has a strong impact to our daily life. However, to fabricate high-quality VO_2 on flexible substrates remains a grand challenge. Traditionally, high-quality VO_2 thin films can be deposited on the rigid substrates. In this study, the growth of VO_2 film directly on a transparent and flexible muscovite via van der Waals epitaxy is established. The unique metal-insulator transition of VO_2 is further revealed with a change in electrical resistance over 10^3 and a more than 50% variation of optical transmittance. Furthermore, due to the nature of muscovite, the VO_2/muscovite heterostructure possesses superior flexibility and optical transparence. The approach developed in this study paves an intriguing way to fabricate functional VO_2 film for the applications in flexible electronics.

Poster Presentation #21

High Mobility Transparent Heteroepitaxy (Ba, La)SnO_3/Muscovite for Flexible Optoelectronics

Chih-Yu Yang[1], Min Yen[1] and Ying-Hao Chu[1, 2, 3, 4*]

[1]*Department of Materials Science and Engineering, National Chiao Tung University*
[2]*Department of electrophysics, National Chiao Tung University*
[3]*Institute of Physics, Academia Sinica*
[4]*Department of Material and Chemical Research Laboratories, Industrial Technology Research Institute*

Transparent conducting oxides (TCOs) play an important role in modern optoeletronic applications such as solar cells, flexible displays and sensor devices. As there is an increasing demand in next generation devices with high performance, improving the mobility is an essential issue for developing transparent logic devices. In this study, we propose the Lanthanum-doped barium stannate (Ba, La)SnO_3 – a new TCO with high electron mobility in perovskite structure – which captured significant attention in the last decade. Recent studies have focused on the advanced synthesis as well as the intriguing properties of (Ba, La)SnO_3. In this work, we introduce pulsed laser deposition process to synthesize heteroepitaxial (Ba, La)SnO_3 thin film on transparent flexible muscovite. This combination not only elegantly exhibits excellent electrical properties but also enhances optical and flexible characteristics. Our study offers a pathway to fabricate flexible transparent high-power functional devices for optoelectronic applications.

Keywords: high mobility, Lanthanum doped barium stannate, perovskite, transparent conducting oxides, muscovite

* Corresponding author's email: yhc@nctu.edu.tw

Poster Presentation #22

Creating Flexoelectrity via Composition gradient

Ying-Hui Hsieh[1], Ping-Chun Wu[1], Jhih-Wei Chen[2], Yue-Wen Fang[3], Yi-Chun Chen[2], Chung-Lin Wu[2], Rong Huang[3], Chun-Gang Duan[3], Ying-Hao Chu[1]

[1]Department of Materials Science & Engineering, National Chiao Tung University, Hsinchu 30010, Taiwan
[2]Department of Physics, National Cheng Kung University, Tainan City 701, Taiwan
[3]Key Laboratory of Polar Materials and Devices Ministry of Education, East China Normal University, Shanghai 200241, China

Complex oxides present versatile properties, such as ferroelectricity, superconducting, and colossal magnetoresistance, making the complex oxides is widely studied. To improve or manipulate the properties, complex oxides are designed and well grown into different structures, from thin film of single material to hetero-structure combined at least two materials. As the advancement of growth technique, the accuracy can be controlled into a unit cell via the assistance of reflection high energy electron diffraction (RHEED). Hence, a new type of hetero-structure is proposed as shown in Fig. 1. Utilizing the ability to control the growth in the atomic scale, a non-uniformity with composition gradient along the out-of-plane (OOP) direction is created. The model system is constituted by $SrTiO_3$ (STO) and $LaAlO_3$ (LAO). Under this circumstance of OOP composition gradient, a strain gradient is accompanied. Polarity discontinuities between STO and LAO are also expected compared to the bi-layer system[1]. Through the coupling among the charge, orbital and lattice, a spontaneous polarization is created. As the spontaneous polarization is induced and manipulated by strain gradient, we name it "flexoelectricity". This study is expected as a model system of periodic non-uniformity to design the artificial charge/spin density wave.

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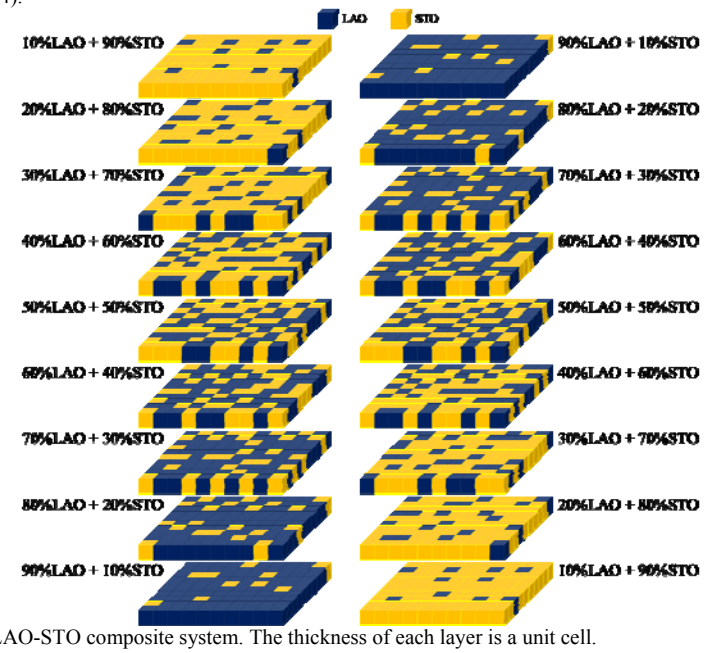

Figure 1. The schematic of LAO-STO composite system. The thickness of each layer is a unit cell.

Poster Presentation #23

Search for complex orbital order in magnetite Fe_3O_4 by magnetic-field-direction dependent XAS and XMCD measurements

Y. Nonaka[1], C. F. Chang[2], G. Shibata[1], X. Liu[2], S. Sakamoto[1], K. Ikeda[1], Z. Chi[1], A. Tanaka[3], M. Sakamaki[4], K. Amemiya[4], L. H. Tjeng[2], A. Fujimori[1]

[1]*Department of Physics, University of Tokyo, Tokyo 113-0033, Japan*

[2]*Max Planck Institute for Chemical Physics of Solids, Nöthnitzerstr. 40, 01187 Dresden, Germany*

[3]*Department of Quantum Matters, ADSM, Hiroshima University, Hiroshima 739-8530, Japan*

[4]*Photon Factory, Institute of Materials Structure Science, High Energy Accelerator Research Organization, Ibaraki 305-0801, Japan*

The nature of the Verwey transition of magnetite Fe_3O_4 at ~120K showing a large conductivity jump has been controversial for many decades. Recently, two theoretical models for the low-temperature phase were proposed. One is the charge-(real-)orbital order [1] model and the other is the charge-complex-orbital order (COO) [2] model.

In order to examine the validity of these models, we have performed angle-dependent x-ray magnetic circular dichroism (XMCD) measurement above and below the Verwey transition temperature T_V on a thin film sample grown on a stepped MgO substrate (the twin of the Verwey order was suppressed by the epitaxial strain from the step edges) .

As shown in Fig. 1, we obtained the magnetic field direction dependence of the orbital magnetic moment. We also found changes in the spectral line shape depending on the magnetic field direction and temperature (XMCD spectra of three different temperatures and magnetic field directions are shown in Fig. 2 (a) and (b), respectively for example). These behavers are well explained by the COO model.

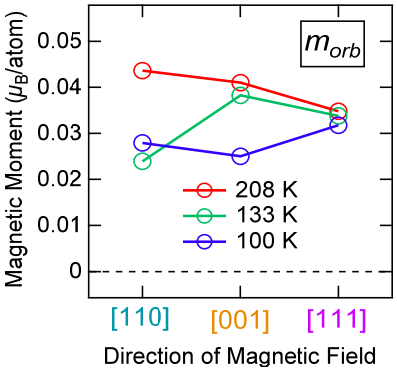

Fig.1 Magnetic field direction dependence of the orbital magnetic moment deduced from XMCD.

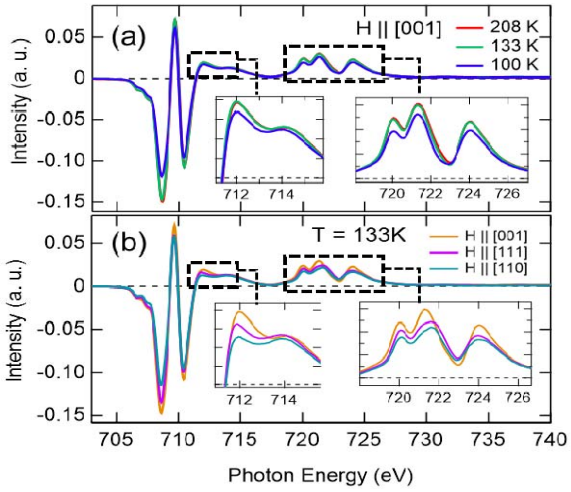

Fig. 2 XMCD spectra obtained under different conditions. (a) Spectra at three different temperatures under the magnetic field of 1T along the [001] direction. (b) Spectra for three different magnetic field directions under 133 K.

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Poster Presentation #24

High-Pressure Synthesis of a Third-Family Perovskite Bismuthate

Minu Kim[1], Masahiko Isobe[1], and Hidenori Takagi[1,2,3]

[1]Max Planck Institute for Solid State Research, Stuttgart 70569, Germany
[2]Department of Physics, University of Tokyo, Tokyo 113-0033, Japan
[3]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany

Perovskite bismuthates have been widely known to be a parent compound of high-T_c superconductors, namely, $Ba(Pb,Bi)O_3$ (T_c = 13 K)[1] and $(Ba,K)BiO_3$ (T_c = 30 K)[2]. Since the first-family compounds were found, subsequent studies have continued and led to the discovery of a second-family compound $(Sr,K)BiO_3$ with $T_c \sim 12$ K[3]. A central question is to understand the role of structural distortions driven by A-site ion[4], and to control the distortions further by designing a new material. Here, we report the first synthesis of a third-family of perovskite bismuthates, $CaBiO_3$, using a high-pressure technique. A stoichiometric mixture of CaO_2, Bi, and Bi_2O_3 powders was reacted at 850 °C, 6 GPa, for 1 hour using a cubic anvil apparatus (TRY Engineering, 500-ton press). Structural refinement using power XRD revealed a perovskite $CaBiO_3$ phase, with the smallest and lowest-symmetry lattice structure among the bismuthate families. These results suggest that $CaBiO_3$ could be applied to elucidating the relation between lattice distortions and superconductivity in bismuthates.

Reference
1. A. W. Sleight, J. L. Gillson and P. E. Bierstedt, *Solid State Commun.* **17**, 27 (1975).
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3. S. M. Kazakov, C. Chaillout, P. Bordet, J. J. Capponi, M. Nunez-Regueiro, A. Rysak, J. L. Tholence, P. G. Radaellik, S. N. Putilin and E. V. Antipov, *Nature* **390**, 148 (1997).
4. T. Bazhirov, S. Coh, S. G. Louie, and M. L. Cohen, *Phys. Rev. B* **88**, 224509 (2013)

Poster Presentation #25

Structure analysis of LaNiO 3 /LaAlO 3 interface by surface X-ray diffraction

Kazuhiro Kowa, Masato Anada, Enju Sakai A , Miho Kitamura A , Hiroshi Kumigashira A , Yoshinori Nakanishi-Ohno B , Masato Okada C , Tsuyoshi Kimura, and Yusuke Wakabayashi
Graduate School of Engineering Science, Osaka Univ.

A Institute of Materials Structure Science (IMSS), KEK ,
B Graduate School of Arts and Sciences, The Univ. of Tokyo,
C Graduate School of Frontier Science, The Univ. of Tokyo,

The perovskite oxide LaNiO 3 (LNO) shows a metallic behavior over the whole temperature range. When we make LNO ultrathin films thinner than 2 monolayers on the analogous material LaAlO 3 (LAO), the films exhibit an insulating behavior . Several scenarios have been proposed for this insulating ground states such as dimensional-crossover [1] and local field given by the surface termination [2]. However, interfacial structure of LNO/LAO as a function of the thickness has not been clarified. In this study, we performed surface x-ray diffraction experiments on LNO/LAO interfaces (1~5 monolayer) at BL-4C and 3A of the Photon Factory, KEK to clarify interfacial structure of LNO/LAO and investigate the origin of its insulating ground state. Unit cell volume of metallic (4~5 unit cell thick) LNO was found to be larger than that of insulating (2~3 unit cell thick) ones. Internal electric field estimated by the cation displacements shows little difference among the samples measured.

[1] E. Sakai *et al*., Phys. Rev. B **87** , 075132(2013).
[2] Divine P. Kumah *et al*., Phys. Rev. Appl. **2** , 054004(2014).

Poster Presentation #26

The pressure effect on magnetoelectricity in Cr2O3

Yusuke Yoshimori[1], Tsuyoshi Kimura[1]

[1] *Graduate School of Engineering Science, Osaka University*

In recent years, the linear magnetoelectric (ME) effect in which electric polarization (magnetization) is linearly induced by applied magnetic field (electric field) attracts large attention because this effect is expected to be used for fabricating new-type devices based on the electric-field control of magnetism. However, there are few materials that display such an effect at room temperature and the magnitude of the effect is too small to use for practical use. Chromia, Cr2O3, is the most classical compound which represents the linear ME effect below the Néel temperature TN≈307 K. In this study, we investigated the effect of hydrostatic pressure on magnetic and ME properties in single crystals of Cr2O3. To elucidate TN under high pressure, we measured dielectric constant at various pressures by using a clamp cell and a diamond anvil cell. Since TN corresponds to a ME phase transition temperature, the dielectric constant exhibits a divergent anomaly at TN in the pressure of a magnetic field through the ME coupling. Thus, dielectric measurements can be a sensitive probe to determine TN in Cr2O3. Our result clearly shows the enhancement of TN in Cr2O3 by applying hydrostatic pressure. More detail of the result will be presented.

Poster Presentation #27

Novel relaxation behaviors in the orbital-ordered vanadates

T. Kajita[1], Y. Kakesu[1], Y. Obata[1], M. Hoshino[1]
S. Kouno[3], Y. Katayama[3], K. Ueno[3], and T. Katsufuji[1, 2]

[1] *Department of Physics, Waseda University, Tokyo 169-8555, Japan*
[2] *Kagami Memorial Laboratory for Material Science and Technology, Waseda University, Tokyo 169-0051*
[3] *Department of Basic Science, University of Tokyo, Tokyo 153-8902, Japan*

Relaxation phenomena have been observed in various materials, for example, CMR manganites [1], where the spin degree of freedom plays an important role. We found that $Ba_{1-x}Sr_xV_{13}O_{18}$ and $Ba_{1-x}Sr_xV_{10}O_{15}$ exhibit a time-dependent resistivity and susceptibility, which is caused by the novel relaxation phenomena dominated by the orbital/charge degrees of freedom in the V ions.

$Ba_{1-x}Sr_xV_{13}O_{18}$ and $Ba_{1-x}Sr_xV_{10}O_{15}$, in which the average of valence of the V ions is +2.62 and +2.8 respectively, have orbital/charge degrees of freedom in the V ions. $Ba_{1-x}Sr_xV_{13}O_{18}$ exhibits three different phases with temperatures [2,3]: The high-temperature (HT) phase is characterized by three V tetramers and a lone V ion in the unit cell. In the intermediate temperature (IT) phase, the unit cell is doubled, indicating a charge ordering with a localized *d* electron in the lone V ion. In the low temperature (LT) phase, the V tetramers are decomposed and changed into V trimers. $Ba_{1-x}Sr_xV_{10}O_{15}$ also exhibits three different phases [4,5]: the HT phase with no ordering, the IT phase with the tripling of the unit cell, and the LT phase with the V trimerization.

We measured the time dependence of the electrical resistivity and the magnetic susceptibility for the single crystals of these compounds. We found that with a rapid cooling rate (>50K/min), the IT phase survives down to the lowest temperature as a metastable phase for both compounds. We observed a time dependence of the resistivity and the magnetic susceptibility when the temperature is slightly increased after such a rapid cooling, indicating a relaxation from the IT phase to the LT phase in both compounds. Furthermore, we found that $Ba_{1-x}Sr_xV_{10}O_{15}$ exhibits a percolative relaxation, whereas $Ba_{1-x}Sr_xV_{13}O_{18}$ exhibits a relaxation with an exponential decay.

[1] A. Anane *et al*., Phys. Rev. B. **59**, 77 (1999).
[2] M. Ikeda *et al*., Phys. Rev. B. **83**, 134417 (2011).
[3] T. Kanzaki *et al*., Phys. Rev. B. **89**, 140401 (2014)
[4] T. Kajita *et al*., Phys. Rev B **81**, 060405(R) (2010)
[5] Y. Shimizu *et al*., Phys. Rev. B **84**, 064421 (2011)

APPENDIX

Bus Pick-up Service from Airport

18th (Sat.)	Incheon Airport	Gimpo Airport	SNU	YongPyong Resort
Bus A	12:30	13:30	14:30	17:00
Bus B	14:40	15:40	—	18:00

		Name	Venue	Arrival time	18th Bus schedule
18th (Sat.)	1	Prof. Di-Jing Huang	Incheon	10:20	Bus A
	2	Prof. Cheng-Maw Cheng	Incheon	10:20	Bus A
	3	Prof. Ashish Atma Chainani	Incheon	10:20	Bus A
	4	Wen-Bin Wu	Incheon	10:20	Bus A
	5	Hsiao-Yu Huang	Incheon	10:20	Bus A
	6	Amol Singh	Incheon	10:20	Bus A
	7	Kazuhiro Kowa	Incheon	11:25	Bus A
	8	Yusuke Yoshimori	Incheon	11:25	Bus A
	9	Prof. Atsushi Fujimori	Incheon	11:40	Bus A
	10	Yosuke Nonaka	Incheon	11:40	Bus A
	11	Prof. Hidenori Takagi	Incheon	12:00	Bus B
	12	Minu Kim	Incheon	12:00	Bus B
	13	Prof. Jan-Chi Yang	Incheon	12:20	Bus B
	14	Yi-De Liou	Incheon	12:20	Bus B
	15	Prof. Ming-Wen Chu	Gimpo	12:50	Bus A
	16	Prof. Guang-Yu Guo	Gimpo	12:50	Bus A
	17	Ping-Chun Wu	Gimpo	12:50	Bus A
	18	Min Yen	Gimpo	12:50	Bus A
	19	Prof. Tsuyoshi Kimura	Incheon	12:55	Bus B
	20	Prof. Je Geun Park	Gimpo	13:30	Bus A
	21	Tomomasa Kajita	Incheon	13:40	Bus B
	22	Prof. Kenya Ohgushi	Incheon	14:10	Bus B
	23	Prof. Shik Shin	Gimpo	14:40	Bus B
	24	Prof. Ying-Hao Chu	SNU	14:30	Bus A
	25	Yen-Pei Lin	SNU	14:30	Bus A
	26	Ying-Hui Hsieh	SNU	14:30	Bus A
		Elika	Incheon		Bus A(타진않음)

Others	Bus A	Bus B
24	18	8

Bus Service To SNU / Ariport

Date	YongPyong Resort	SNU	Gimpo Airport	Incheon Airport
21st Bus A	13:00	15:30	16:30	17:30
24th Bus B	14:00	17:00	—	—

		Name	Destination	Departure time	24th Bus Schedule
21st (Tue.)	1	Prof. Shik Shin	Gimpo	12:35	Taxi
	2	Prof. Yukitoshi Motome	Incheon	13:35	Taxi
	3	Prof. Tsuyoshi Kimura	Incheon	15:00	Shuttle 9:15
	4	Prof. Hidenori Takagi	Incheon	15:10	Shuttle 9:15
	5	Prof. Takuro Katsufuji	Incheon	17:20	Bus A
	6	Yosuke Nonaka	Incheon	18:50	Bus A
	7	Prof. Guang-Yu Guo	Gimpo	19:00	Bus A
	8	Kazuhiro Kowa	Incheon	19:05	Bus A
	9	Yusuke Yoshimori	Incheon	19:05	Bus A
	10	Prof. Di-Jing Huang	Incheon	19:45	Bus A
	11	Prof. Ying-Hao Chu	Incheon	19:45	Bus A
	12	Ping-Chun Wu	Incheon	19:45	Bus A
	13	Yen-Pei Lin	Incheon	19:45	Bus A
	14	Min Yen	Incheon	19:45	Bus A
	15	Ying-Hui Hsieh	Incheon	19:45	Bus A
	16	Prof. Jan-Chi Yang	Incheon	20:40	Bus A
	17	Yi-De Liou	Incheon	20:40	Bus A
	18	Minu Kim	Incheon		Bus A
	19	Almo Singh	Incheon	19:45	Bus A
	20	Prof. Jae Hoon Kim	SNU		Bus A
	21	Prof. Suyeon Cho	SNU		Bus A
	22	* Prof. Kenya Ohgushi	Incheon	21nd / 9:35	Bus A
24th (Fri.)	1	Tomomasa Kajita	Incheon	17:20	Shuttle 9:15 or 12:15
	2	Wen-Bin Wu	Incheon	19:45	Shuttle 12:15
	3	Hsiao-Yu Huang	Incheon	19:45	Shuttle 12:15
	4	Prof. Ashish Atma Chainar	Incheon	19:45	Shuttle 12:15
	5	Hasung Sim	SNU	14:00	Bus B
	6	Joosung Oh	SNU	14:00	Bus B
	7	Soonmin Kang	SNU	14:00	Bus B
	8	Hwanbeom Cho	SNU	14:00	Bus B
	9	Sungmin Lee	SNU	14:00	Bus B
	10	Taehun Kim	SNU	14:00	Bus B
	11	Seokhwan Yun	SNU	14:00	Bus B
	12	Suhan Son	SNU	14:00	Bus B
	13	Jonathan Leiner	SNU	14:00	Bus B
	14	Arvind Yogi	SNU	14:00	Bus B
	15	Inho Hwang	SNU	14:00	Bus B
	16	Howon Lee	SNU	14:00	Bus B
	17	Young Chan Jo	SNU	14:00	Bus B
	18	Jaejun Yu	SNU	14:00	Bus B
	19	Prof. Tae Heon Kim	SNU	14:00	Bus B
	20	Prof. Jea Hoon Park	SNU	14:00	Bus B
	21	Prof. Zheong Gou Kim	SNU	14:00	Bus B
	22	Prof. Hanjo Lim	SNU	14:00	Bus B
	23	Urusova Natalia	SNU	14:00	Bus B
Others	1	Kisoo Park			집으로 귀가
	2	Se Jeong Oh 의원			Depart 19th
	3	Andreas Heinrich			Depart 20th
	4	Prof. Cheng-Maw Cheng	Incheon	19:45	Depart 22nd
	5	Prof. Ming-Wen Chu	Gimpo	20:20	Depart 22nd
	7	Prof. Je-Geun Park			Depart 23rd
	8	Prof. Atsushi Fujimori	Incheon	18:50	Depart 23rd
	9	Donghwan Kim	Pohang		
	10	Junho Park	Pohang		

Others	Bus A	Bus B
15	18	16

Airport Shuttle Bus Info.

Incheon Airport -> Yongpyong Resort (3시간반정도소요/ 24,000원)
(Gate1 -> Platform 1C)

7:30

9:00
11:00
15:00
19:30

Yongpyong Resort -> Incheon Airport

9:15
12:15
16:15

Gimpo Airport -> Yongpyong Resort (3시간정도 소요 / 30,000원)

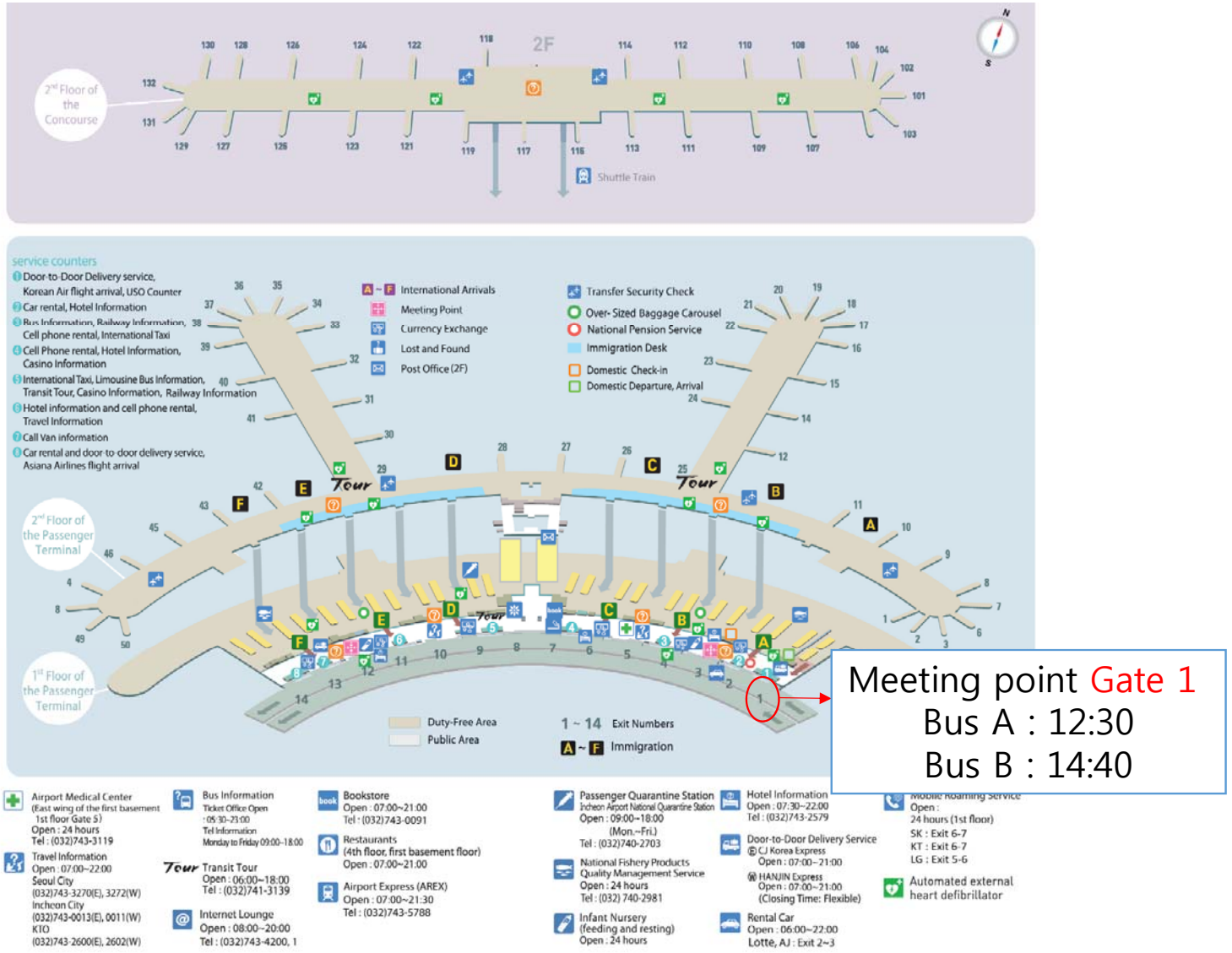
7:50
9:20
11:20

15:20
19:50

Yongpyong Reosrt -> Gimpo Airport

9:15
12:15
16:15

Incheon Airport Information

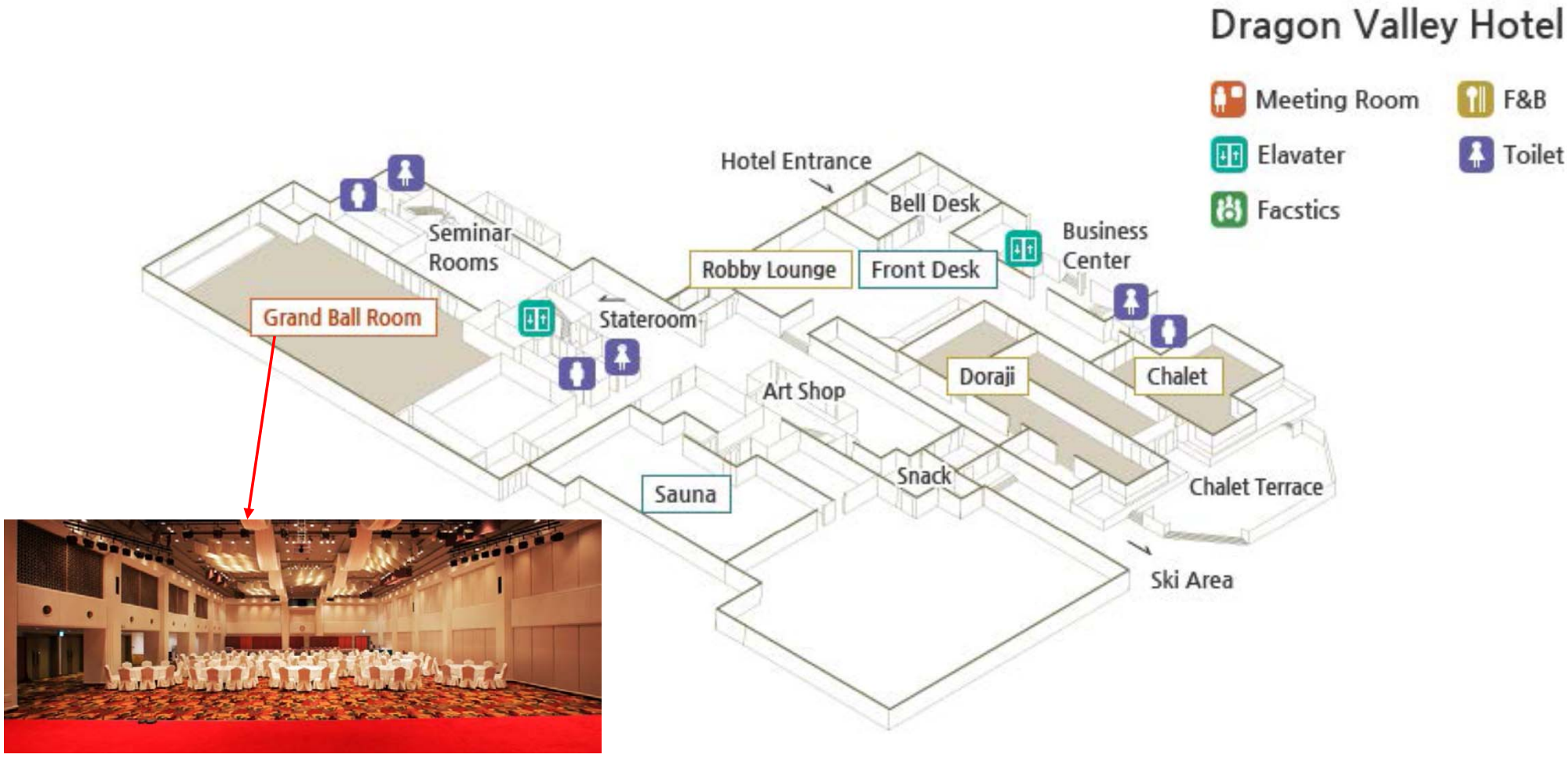


Meeting point Gate 1
Bus A : 12:30
Bus B : 14:40

Gimpo Airport Information

Yong Pyong Resort Map

Dragon Valley Hotel_1F Grand Ball Room



Restaurants: Dragon Valley Hotel

Enjoy a variety of tastes of high quality Korean, Japanese, and Western style cuisine.

FACILITIES > Food & Beverage > Restaurant > Hotel

Hotel	Tower	Greenpia	Others	Dragon Peak

Doragi

Location	Dragon Valley Hotel 1F	Menu	Korean cuisine

Restaurants: Dragon Valley Hotel

Chalet

Location	Dragon Valley Hotel 1F	Menu	Korean cuisine

* This information may be change.

Restaurants: Tower Condominium

Enjoy a variety of tastes of high quality Korean, Japanese, and Western style cuisine.

Wonhalmoney Bossam

Location	Tower Condominium 2F	Menu	Korean cuisine

* This information may be change.

Restaurants: Others

Enjoy a variety of tastes of high quality Korean, Japanese, and Western style cuisine.

Café Cheoeum

Location	In Complex / Valley Center 1F in front of Dragon Valley Hotel	Menu	Korean cuisine