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SCHEDULE

2019.01.20(Sun.)~2019.01.24(Thu.)

Time	Jan. 20 Sun	Jan. 21 Mon	Jan. 22 Tue	Jan. 23 Wed	Jan. 24 Thu
9:00-9:20		Luke P. Lee	A.K. Sood	Hui-Ming Cheng	Maria C. Asensio
9:20-9:40					
9:40-10:00		Binghai Yan	Isabella Gierz	César Moreno	Tony Low
10:00-10:20					
10:20-10:40		Break (20m)	Break (20m)	Break (20m)	Break (20m)
10:40-11:00		Jun Sung Kim	L.V. Butov	Dinh Loc Duong	Søren Ulstrup
11:00-11:20		Kyung-Jin Lee		Gyung-Min Choi	
11:20-11:40		Christoph Renner	Gang Wang	Tim Wehling	Ki Kang Kim
11:40-12:00					Sung Wng Kim
12:10-13:40		Lunch (12:10-13:40)	Lunch (12:10-13:40)	Lunch (12:10-13:40)	Closing Remark
13:30-16:00	Registration	Discussion	Discussion	Discussion	
16:00-17:00	Tutorial-1 Paul S. Weiss				
17:00-17:20	Break (20m)				
17:20-18:20	Tutorial-2 Philip Kim	Dinner (17:30-19:00)	Dinner (17:30-19:00)	Break	
18:20-18:30	Break (10m)				
18:30-19:00	Welcome Reception (18:30-20:30)			Banquet (18:30-21:30)	
19:00-19:20		Olga S. Ovchinnikova	Tom Gregorkiewicz		
19:20-19:40					
19:40-20:00		Kaihui Liu	Ji-Hee Kim		
20:00-20:20			Break		
20:30-21:00		Poster-1 (20:30-22:30)	Poster-2 (20:30-22:30)		
21:00-21:30					
21:30-22:30					

The 5th MUJU INTERNATIONAL Winter School Series

SCIENTIFIC PROGRAM

January 20th, Sunday

13:30~16:00	**Registration**
16:00~17:00	**Tutorial Session Ⅰ : Paul S. Weiss (Chair: Hyoyoung Lee)** "Precise chemical, physical, and electronic nanoscale contacts"
17:00~17:20	Break
17:20~18:20	**Tutorial Session Ⅱ : Philip Kim (Chair: Sung Wng Kim)** "Atomic and electronic reconstruction at van der Waals interface in twisted 2D materials"
18:20~19:00	Break
19:00~21:00	**Welcome Reception**

January 21th, Monday

Session I : Nanomaterials for Physics I (Chair: Seung Hyun Song)	
09:00~09:40	**I-1 : Luke P. Lee** "Quantum biological electron transfer and its applications in life sciences and medicine"
09:40~10:20	**I-2 : Binghai Yan** "Topological materials: monopoles, surface states and more"
10:20~10:40	Break
Session II : Nanomaterials for Physics II (Chair: Youngkuk Kim)	
10:40~11:00	**I-3 : Jun Sung Kim** "Topological and ferromagnetic properties of iron-based van der Waals metals"
11:00~11:20	**I-4 : Kyung-Jin Lee** "Ferrimagnetic spintronics"
11:20~12:00	**I-5 : Christoph Renner** "Novel insight on the charge density wave ground state by scanning tunneling microscopy"
Session III : Nanomaterials for Devices I (Chair: Heejun Yang)	
19:00~19:40	**I-6 : Olga S. Ovchinnikova** "Towards atomically precise material fabrication: defect engineering of layered materials using focused ion beams"

19:40~20:20	**I-7 : Kaihui Liu** "Growth and application of meter-sized single-crystal graphene"
20:30~22:30	**Poster Session I**

January 22th, Tuesday

Session IV : Optical Properties of Nanomaterials I (Chair: Seong Chu Lim)	
09:00~09:40	**I-8 : A.K. Sood** "Photophysics at nanoscale using time-resolved ultrafast spectroscopy"
09:40~10:20	**I-9 : Isabella Gierz** "Ultrafast materials design with tailored light pulses"
10:20~10:40	Break
Session V : Optical Properties of Nanomaterials II (Chair: Jeongyong Kim)	
10:40~11:20	**I-10 : L.V. Butov** "Indirect excitons in heterostructures"
11:20~12:00	**I-11 : Gang Wang** "Spin- and valley-phenomena, non-linear optics in atomically thin materials"
Session VI : Optical Properties of Nanomaterials III (Chair: Hyun Seok Lee)	
19:00~19:40	**I-12 : Tom Gregorkiewicz** "Optical properties of all-inorganic perovskite nanocrystals"
19:40~20:00	**I-13 : Ji-Hee Kim** "Zero excess energy for carrier multiplication in van der Waals layered materials"
20:30~22:30	**Poster Session II**

January 23th, Wednesday

Session VII : Nanomaterials for Devices II (Chair: Yunseok Kim)	
09:00~09:40	**I-14 : Hui-Ming Cheng** "Graphene films and membranes: fabrication and applications"
09:40~10:20	**I-15 : César Moreno** "Atomically-precise graphene architectonics: 0D dots, 1D ribbons and 2D porous graphene"
10:20~10:40	Break

Session VIII : Electronic and Magnetic Control of Nanomaterials (Chair: Dongseok Suh)	
10:40~11:00	**I-16 : Dinh Loc Duong** "Room-temperature dilute magnetic semiconductor in V-doped monolayer WSe_2"
11:00~11:20	**I-17 : Gyung-Min Choi** "Spin generation from charge current, heat, and light"
11:20~12:00	**I-18 : Tim Wehling** "Electronic correlations and pseudodoping in two-dimensional materials"
18:30~21:30	**Banquet**

January 24th, Thursday

Session IX : Nano-Imaging and Light Manipulation (Chair: Mun Seok Jeong)	
09:00~09:40	**I-19 : Maria C. Asensio** "Electronic and chemical nano-imaging of 2D materials beyond graphene"
09:40~10:20	**I-20 : Tony Low** "Manipulating light flow with 2D materials plasmons"
10:20~10:40	Break
Session X : Nanomaterials for Devices III (Chair: Young Min Kim)	
10:40~11:20	**I-21 : Søren Ulstrup** "Electronic structure and ultrafast dynamics of chalcogenide heterolayers"
11:20~11:40	**I-22 : Ki Kang Kim** "Toward single-crystal 2D materials on wafer scale"
11:40~12:00	**I-23 : Sung Wng Kim** "Discovery of new two-dimensional van der Waals materials: layered Zintl phases"
12:00~12:20	**Closing Remark**

POSTER SESSION

January 21th, Monday

No.	Name	Title
PM-1	**Bing Deng**	Graphene as electronic materials: controlled growth of single-crystal graphene wafer
PM-2	**Luzhao Sun**	Visualizing the fast growth of large single-crystalline graphene
PM-3	**Xian-Gang Hu**	Fabricating high-efficiency silicon heterojunction solar cells with small-bundle single-wall carbon nanotubes
PM-4	**Zhepeng Zhang**	Epitaxial growth of 2D metallic VSe_2 single crystals and their heterostructures with semiconducting MX_2
PM-5	**Woo-Sung Jang**	Directional distribution of metal interstitials in Nb_2Se_3 compound
PM-6	**Lingxiang Qin**	Mesoporous graphene frameworks and its application in VOCs adsorption
PM-7	**Wonoh Lee**	Carbon fabric-based flexible supercapacitors with polydopamine-coated 3D carbon nanostructures
PM-8	**Jia Guo**	Synthesis of hierarchical tree-like few-layered MoS_2 nanosheets anchored on vertically aligned carbon nanotube networks
PM-9	**Gyawali Ghanashyam**	Electrochemical performance of poly sodium 4-styrenesulfonate intercalated thermally reduced graphite oxide paper for supercapacitors
PM-10	**Aryal Krishna Prasad**	Functionalization of thermally reduced graphite oxide and carbon nanotubes by p-sulfonatocalix[4]arene and supramolecular recognition of tyrosine
PM-11	**Thuy Thi Tran**	Characterization of iron cerium oxide ($FeCeO_x$) nanoparticles prepared by hydrothermal synthesis for hydrogen sulfide (H_2S) removal application
PM-12	**Young-Hoon Kim**	Hierarchically-structured core-shell design of a lithium transition metal oxide cathode material for excellent electrochemical performance
PM-13	**Olaniyan Ibukun**	Titanium dioxide- molybdenum disulfide for photocatalytic degradation of methylene blue
PM-14	**Wooseon Choi**	Quantification reliability of ADF-STEM imaging for vacancy concentration in 1L-TMDs
PM-15	**Meeree Kim**	Ligand exchange of colloidal WSe_2: counter cation-dependent hydrogen evolution reaction (HER) study
PM-16	**Thi Anh Le**	Intertwined titanium carbide MXene within 3D tangled polypyrrole nanowires matrix for enhanced Supercapacitor Performances
PM-17	**Soyeong Kwon**	Fabrication and characterizations of MoS_2/Au nanogratings
PM-18	**Xu Wei**	Toward ultraclean 2D heterostructure interfaces: h-BN as a novel tool to visualize organic residues
PM-19	**Doyoung Kim**	Carbon-based asymmetric capacitor for high-performance energy storage devices
PM-20	**Hyunjung Kim**	Colloidal synthesis of hexagonal $FeIn_2S_4$ and its layer dependent band structures
PM-21	**Vu Thi Oanh**	Non-enzymatic glucose sensor based on CuO nanoparticles modified screen-printed carbon ink electrode

PM-22	**Ngoc Quang Tran**	Ultralight and flexible sodium titanate nanowire aerogel with superior sodium storage
PM-23	**Vo Thanh Duoc**	Fabrication of hydrogen gas sensor based on SnO_2/Pt thin film on Kapton substrate
PM-24	**Jing Wu**	Engineering on Ni-Co-S bifunctional electrocatalyst for water-splitting
PM-25	**Huong Thi Diem Bui**	Theoretical insights into the size-dependent Ru clusters on N-doped graphene for electrocatalytic hydrogen evolution and oxygen reduction reactions
PM-26	**Amol R. Jadhav**	Molecularly ultrathin sheets of Fe-graphene on nickel foam supported $NiCo_2O_4$ microrod arrays as a highly efficient bifunctional electrocatalyst for oxygen and hydrogen evolution reaction
PM-27	**Soo Ho Choi**	Intercalates-assisted electrochemical transfer of monolayer WS_2 film on gold substrate
PM-28	**Suicai Zhang**	Graphdiyne nanowall for enhanced photoelectrochemical performance of Si heterojunction photoanode
PM-29	**Stephen Boandoh**	Wafer-scale van der Waals heterostructures with ultraclean interfaces via the aid of viscoelastic polymer
PM-30	**Mengyu Hong**	Influence of indium doping on dissolving behavior and stability of quasi-2D ZnO nanobelts in solution
PM-31	**Ashwani Kumar**	Activating the dull bimetallic phosphide via copper nanowire insertion towards efficient hydrogen evolution reaction
PM-32	**Se Hwang Kang**	Oxidation-resistive two-dimensional dihafnium sulfide electride with efficient electrocatalytic activities in water-based solution
PM-33	**Hee Min Hwang**	Dual function of metal doped B-TiO_2 without hole scavenger for complete degradation of nerve agent
PM-34	**Suresh Vasimalla**	Visible light mediated C-C bond formation by a single Blue TiO_2 based photo-chiral catalyst
PM-35	**Sora Bak**	Role of phase-selective defects in TiO_2 on organic photoreaction under visible light
PM-36	**Kyungwha Chung**	Inherently negatively charged copper nanoparticles with oxidation resistance
PM-37	**Woo Hyun Han**	Green phosphorus with high mobility and tunable direct band gap
PM-38	**Hongdan Wang**	Possibility to find enantiomeric excess in organic reactions by using circularly polarized light
PM-39	**Jianmin Yu**	Solution processable ReS_2-molecular Z-scheme-TiO_2 for excellent solar hydrogen generation by fast charge transfer through multiple junctions
PM-40	**Min Seok Kim**	The effect of Li and Ag intercalation to MoS_2 for memory device
PM-41	**Liu Yang**	Dual vacancies engineering of 2D MnO_2 for overall water splitting
PM-42	**Anand P. Tiwari**	Chemical strain formation through anion substitution in ternary transition metal chalcogenides for efficient hydrogen evolution reaction
PM-43	**Sara Ajmal**	Hole scavenger-free photocatalytic H_2Evolution on highly uniform 'Pt' sub-nanoclusters embeddedon partially disordered blue TiO_2
PM-44	**Byung Il Yoo**	Birch reduction of aromatic compounds by inorganic electride $[Ca_2N]^+\bullet e^-$
PM-45	**Dae Young Park**	Large area sputtered ReS_2 film for optoelectronics
PM-46	**Jinbong Seok**	Studies of electrochemically deposited Platinum on $MoTe_2$ for catalytic behavior

PM-47	**Zhiyang Zeng**	Nanoporous graphene membrane for separation
PM-48	**Jinsun Lee**	The synergistic effect of nitrogen fixation over partially reduced titanium dioxide For solar-driven nitrogen conversion to ammonia
PM-49	**Yonas Assefa Eshete**	Hetrophase homojunction in single crystal $MoTe_2$ for enhanced catalytic performance
PM-50	**Ning Ling**	Hydrogen bubble-assisted synthesis of reduced graphene oxide-WTe_2 hybrid catalyst for hydrogen evolution
PM-51	**Won Tae Kang**	Direct growth of doping controlled monolayer WSe_2 by selenium-phosphorus substitution
PM-52	**Jae Hyeon Ryu**	Wafer scale continuous bilayer graphene films synthesis by using inductively coupled plasma - chemical vapor deposition
PM-53	**Ganesh Ghimire**	Study of defect on atomically thin ReS_2 through chemical treatment effect
PM-54	**Shrawan Roy**	Microscopic origin of vacancy healing in two-dimensional semiconductors via chemical treatment
PM-55	**Ho Beom Jeon**	Fabrication of perovskite films using solvent engineering with $CsPbBr_3$ seed crystallization
PM-56	**Chau T. K. Nguyen**	Blue TiO_2/WO_3/Ag hybrid nanostructures for solar light-driven CO_2 reduction into 100% CO
PM-57	**Jeong-Gyun Kim**	Carbon-nanotube based hybrid composite superconducting wire
PM-58	**Joosung Kim**	The effect of alcohol solvent on the synthesis of MoS_2 quantum dots with solvothermal method
PM-59	**Bong Ho Kim**	Large-area and low-temperature synthesis of few-layered WS_2 films for photodetectors
PM-60	**Mondal Shuvra**	TMDs-assisted graphene foam/polymer hybrid nano-structures for wearable strain-pressure sensor
PM-61	**Soon Hyeong Kwon**	Microstructural evolution of sputtered SnS_2, SnS thin films by room temperature electron beam irradiation
PM-62	**Pengfei Yang**	Wafer-scale few-layer molybdenum disulfide as a multifunctional optical material
PM-63	**Hyun Kim**	Direct growth of layered antimonene on transition metal dichalcogenides by chemical vapor deposition
PM-64	**Thi Suong Le**	Quantum dots embedded hexagonal iron oxide for fiber-shaped battery-like anode
PM-65	**Thi Hoai Thuong Luu**	A free-standing SnS_2 nanoparticles/CNT thin film for sodium ion battery anode electrode
PM-66	**Yunhee Cho**	$CsPbBr_3$@metal nanocrystals for photocatalytic application
PM-67	**Hanchul Kim**	Energetics and bias-dependent scanning tunneling microscope images of intrinsic defects in 2H-$MoTe_2$
PM-68	**Sung-Gyu Lee**	Flexible broadband Cr/PET/Cr solar absorber
PM-69	**Hyang Mi Yu**	Degradation analysis of perovskite films using the photo thermal induced resonance spectroscopy

January 22th, Tuesday

No.	Name	Title
PT-1	Jing Liang	Monitoring local strain vector in atomic layered $moSe_2$ by second-harmonic generation
PT-2	Shun Feng	Multilayer MoS_2 field-effect transistors using 2-dimensional α-Mo_2C film as electrodes
PT-3	Bo Li	High-performance phototransistors based on a hybrid channel of $CsPbBr_3$ quantum dot and carbon nanotube network
PT-4	Jing Chen	Designing nanoscale elastic structures of 2D materials-based electrodes
PT-5	Jun Suk Kim	Unusual K-point phonons in noble metal/graphene heterostructure
PT-6	Youngkuk Kim	Z2 monopole nodal lines and the Stiefel-Whitney insulator in the ABC graphdiyne
PT-7	Youngjo Jin	Coulomb drag behavior in graphene/MoS_2 heterointerface
PT-8	Chinh Tam Le	Spin orbit engineered resonant second harmonic generation of artificially stacked Van der waal multilayers
PT-9	Doan Viet Truong	Simulation and study of the influence of the hole selective contact, buffer intrinsic layer, densities of interface defects, and transparent conductive oxide on TMO/c-Si heterojunction solar cell
PT-10	Minh Dao Tran	Two-terminal multibit optical memory via van der Waals heterostructure
PT-11	Subash Adhikari	Bandgap renormalization in $CsPbBr_3$ perovskite quantum Dot/MoS_2 heterostructure via charge transfer at room temperature
PT-12	Hye-Jin Jin	Interplay of free charges of 2D van der Waals materials with the large polarization of ferroelectric oxides: a clue to photo-memristors
PT-13	Dinh Hoa Luong	Enhanced light–matter interactions in self-assembled plasmonic nanoparticles on 2D semiconductors
PT-14	Jinbao Jiang	Ultra-short vertical-channel 2D transistors
PT-15	Sidi Fan	Tunable negative differential resistance in van der Waals heterostructures at room temperature by tailoring interface
PT-16	Junhong Na	Negative differential resistance in few-layer black phosphorus/$SnSe_2$ heterostructure
PT-17	Changjiu Teng	Gate-tunable memory synaptic photomemristor based on two-dimensional transition metal di-chalcogenide
PT-18	Eunah Kim	Optical absorption enhancement in 2D MoS_2 monolayers: influences of interference and 3D dielectric material refractive index
PT-19	Youngbum Kim	Near-field imaging of charge separation and transfer at $MoSe_2$-WSe_2 lateral heterojunction
PT-20	Yashar Mayamei	Electrical characterization of graphene nanoribbon on h-BN
PT-21	Lei Li	RF Characterization and modeling of black phosphorus MOSFETs
PT-22	Yongjun Lee	Bright light emission by suppressed exciton-exciton annihilation in monolayer WS2 by laser irradiation
PT-23	Yang Ou	Edge introduced barrier in MoS_2-WS_2 van der Waals heterojunctions

PT-24	**Yong Ju Yun**	Multifunctional reduced graphene oxide based electronic textiles for wearable electronic/optoelectronic applications
PT-25	**Yong Ju Yun**	Highly stretchable and biocompatible porous reduced graphene oxide films toward epidermal electronics
PT-26	**Jongho Park**	Ferromagnetic heavy fermion system with non-fermi liquid behavior in antiperovskite Gd_3SnC
PT-27	**Simgeon Oh**	Energy band modulation to improve HER performance by phase selective reduction of TiO_2
PT-28	**Ho Min Choi**	Edge contact for carrier injection and transport in MoS_2 field-effect transistor
PT-29	**Thanh Luan Phan**	A high on/off ratio of top gate ZnO thin films transistors array with a buffer layer of self-assembled monolayer of molecule
PT-30	**Seung Yong Lee**	Quasi-atomic electrons in two-dimensional ferromagnetic electride
PT-31	**Michael Neumann**	Noise nanospectroscopy as a probe for defect dynamics in monolayer MoS_2
PT-32	**Yong Seon Shin**	Mobility engineering in the vertical field effect transistor based on van der Waals heterostructures
PT-33	**Junseong Song**	Discovery of two-dimensional van der Waals Zintl phase and bidimensional polymorphism of ZnSb
PT-34	**Hyun Yong Song**	Ferromagnetic two-dimensional van der Waals electride
PT-35	**Young Rae Kim**	Application for high sensitive proximity sensor with CVD-growth MoS_2
PT-36	**Ui Yeon Won**	Very high open-circuit voltage in dual-gate graphene/silicon heterojunction solar cells
PT-37	**Ilmin Lee**	High responsivity, fast molybdenum disulfide photo-transistor using tunable schottky barrier
PT-38	**Kye Whan Cho**	High performance graphene photodetector with van der Waals heterostructure through tuning carrier tunneling
PT-39	**Chanwoo Lee**	Unveiling defect-related raman mode of monolayer tungsten disulfide via tip-enhanced resonance raman scattering
PT-40	**Hayoung Ko**	2D Heterostructure for enhanced gas barrier performance via synergetic effect
PT-41	**Duc Anh Nguyen**	Highly enhanced photoresponsivity of monolayer WSe_2 photodetector with nitrogen-doped graphene quantum dots
PT-42	**Dohyun Kim**	Thermal-driven electronic band change in layered semimetallic $MoTe_2$
PT-43	**Sera Kim**	Layer-decoupling and stacking order modulation of multi-layered graphene by electride-based electron injection
PT-44	**Isabella Gasparutti**	Ultraclean van der Waals heterostructure assembly with unity yield by solvent-assisted polydimethylsiloxane stamping
PT-45	**Dongyeun Won**	Polymorphic 2D charge density waves in VTe_2
PT-46	**Chulho Park**	Development of P-N diode in few-layer ReS_2/WSe_2 stacking structure
PT-47	**Ngoc Thanh Duong**	Thickness-dependent functionality of $MoS_2/MoTe_2$ van der Waals heterostructure
PT-48	**Jung Ho Kim**	All-optical logic devices via plasmon-exciton interconversion

PT-49	**Nahee Park**	Analysis of anomalous behavior at ferroelectric/two-dimensional material interface
PT-50	**Van-Tam Nguyen**	Significantly enhanced electromagnetic interference shielding effectiveness in graphene porous network with Fe_3O_4 nanoparticles-intercalated 2D Ti_3C_2 Mxene
PT-51	**Gwanmu Lee**	Graphene/PMN-PT field effect transistor with interdigitated electrode
PT-52	**Geunwoo Hwang**	A tunneling device for optoelectronic application with near-infrared light: Au/h-BN/$MoTe_2$ tunneling device study
PT-53	**Joonggyu Kim**	Hall magnetic sensor based on two-dimensional van der Waals materials
PT-54	**Kyungrok Kang**	Temperature-driven Lifshitz transition triggering non-Fermi liquid behavior in semimetal Nb_2Se_3
PT-55	**Yourack Lee**	Continuous thermopower from capillary-induced carbon nanotube yarn Thermoelectric Candle
PT-56	**Hyeonbeom Kim**	Charge trap effect at graphene channel caused by strong electrical affinity of fluorine
PT-57	**Dongseok Shin**	Plasma treatment induced n-type doping effect on few-layer WSe_2 field-effect transistors
PT-58	**Jin Cheol Park**	Real bandgap investigation of CVD grown 1T'-$MoTe_2$ via infra-red spectroscopy
PT-59	**Tuan Khanh Chau**	Unusual quantum hall effect across graphene grain-boundary grown by chemical vapor deposition
PT-60	**Hojoon Yi**	Thermal conductivity of metal-coated carbon fibers
PT-61	**Hamza Zad Gul**	Presence of photothermal and photoelectric in partially suspended $PtSe_2$
PT-62	**Won Kil Sakong**	Broadband photoresponse of multi-layer MoS_2 from ultraviolet to infrared through metal-insulator transition
PT-63	**Dang Xuan Dang**	The broad range pressure detection by electro-thermal response of metal-coated carbon fiber
PT-64	**Sungyu Park**	Transport characteristics of van der Waals junction assembled with $NbSe_2$ and FeSe
PT-65	**H. C. Jeon**	Electronic and optical properties of staggered ZnO/$ZnO_{1-x}S^x$-$ZnO_{1-y}S_y$/ZnO quantum well for bluish-green light-emitting diodes
PT-66	**Ngoc Quang Tran**	Anion-cation double substitution in transition metal dichalcogenide to accelerate water dissociation kinetic for electrocatalysis
PT-67	**Seungho Bang**	Augmented quantum yield of a 2D monolayer photodetector by surface plasmon coupling
PT-68	**Hyeon Jun Jeong**	Organometal halide perovskite to optoelectronic devices fabricated with homogeneous Nano-seed
PT-69	**Juchan Lee**	High peak-to-valley current ratio in $SnSe_2$/$MoTe_2$ tunnel diode
PT-70	**Bora Kim**	2-D Transition metal dichalcogenides charge transport layers for perovskite solar cells
PT-71	**Ji Eun Kim**	Highly sensitive graphene biosensor by monomolecular self-assembly of receptors on graphene surface

Abstract

Invited Session

- Tutorial Session (T)
- Invited Talks (I)

T-1

Precise chemical, physical, and electronic nanoscale contacts

Paul S. Weiss

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The physical, electronic, mechanical, and chemical connections that materials make to one another and to the outside world are critical. Just as the properties and applications of conventional semiconductor devices depend on these contacts, so do nanomaterials, many nanoscale measurements, and devices of the future. We discuss the important roles that these contacts can play in preserving key transport and other properties. Initial nanoscale connections and measurements guide the path to future opportunities and challenges ahead. Band alignment and minimally disruptive connections are both targets and can be characterized in both experiment and theory. I discuss our initial forays into this area in a number of materials systems [1,2].

References

[1] P. Han et al., ACS Nano, 9, 12035 (2014).
[2] J. Kim et al., Nano Letters, 14, 2946-2951 (2014).

T-2

Atomic and electronic reconstruction at van der Waals interface in twisted 2D Materials

Philip Kim

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Control of the interlayer twist in the vdW interface has been widely used to engineer an artificial 2-dimensional (2D) electronic systems by the formation of a moiré superlattice. Many exotic physical phenomena occur associated with the incommensurability of the moiré superstructures; the fractal energy spectrum of Hofstadter butterfly and recently discovered Mott insulating and unconventional superconducting behavior of the 'magic' twist angle bilayer graphene have demonstrated the wealth of the nontrivial topology of electronic band structures. However, the atomic scale microstructures and electronic structures of vdW interfaces have been understood in the frame of rigid rotational moiré structures without atomic scale relaxation. In this presentation, we will discuss the engineered atomic scale reconstruction at twisted vdW interface [1]. We find that the vdW interaction energy that favors interlayer commensurability competes against the intralayer elastic lattice distortion to form a quasi-periodic domain structure, inducing profound changes in electronic structure. Particularly, we show quantitative analysis of the engineered atomic-scale reconstruction completely controlled by the twist angle between two graphene layers and anomalous electron transport occurring in the network of topologically protected propagation modes along the domain boundaries. Interfaces between vdW materials are a crucial material platform for realization of novel quantum electronics. Our discoveries of atomic scale reconstruction at vdW interfaces will provide a new route to engineer the 2D materials for exceptional functionalities.

References

[1] H. Yoo et al., arXiv:1804.03806.

I-1

Quantum biological electron transfer and its applications in life sciences and medicine

Luke P. Lee

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Electron transfer (ET) essentially involves in virtually all biological processes such as photosynthesis, cellular respiration, DNA repair, cellular homeostasis, cell death, cancer, neurodegenerative diseases, etc. In particular, ET in between biological molecules and cytochromes in mitochondria plays a vital role in the process of cell life and death. However, there is no real-time imaging method to capture spatiotemporal ET dynamics in living cells to date. In this talk, I will present the quantum biological electron tunneling (QBET) junction and its applications in *in vivo* ET imaging of living cells and *in vitro* molecular diagnostics. For the exploration of cellular galaxy, we created *in vivo* nanosatellites using QBET junctions, which are formed by resonant optical antennas, barriers, and cytochromes. These QBET junctions allow us to see not only ET dynamics of enzymes in live cells, but also the mechanism of cytochromes in mitochondrial control of cellular apoptosis and necrosis, which might shed new light on the treatments of cancer or neurodegenerative diseases. For *in vitro* molecular diagnostics, QBET junctions can create ultrafast photonic PCR on chip and form integrated molecular diagnostic systems (iMDx). In order to accomplish low-cost rapid precision molecular diagnostics, our iMDx are established with three key elements of precision medicine: (1) ultrafast photonic PCR for the early detection of DNA and RNA biomarkers and signal amplifications of protein markers, (2) a self-contained sample preparation from whole blood that allows a sample-to-answer readout platform, (3) interactive e-healthcare IT with smart analytics. If time permits, I will also discuss microphysiological analysis platforms (MAP), or organoids on chip, which provides a solution to form physiologically relevant models of organoids with the capability of non-invasive real-time monitoring for patient-oriented precision drug screening and mini-brains MAP for understanding ET in mitochondria and mitochondrial dysfunction in neurodegenerative diseases.

I-2

Topological materials: monopoles, surface states and more

Binghai Yan

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The classification and discovery of topological materials have attracted intensive research attention in the past decade. After explaining basic concepts of the topological states, I will introduce our most recent progress on novel topological states discovered in a well-known family of materials, transition metal dichalcogenides. Beyond surface states, the topology also brings exotic transport phenomena, such as a nonlinear version of the Hall effect (verified by recent experiments), but without breaking the time-reversal symmetry.

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I-3

Topological and ferromagnetic properties of iron-based van der Waals metals

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Topological semimetals, new states of matters whose low energy electronic structure possesses several band contact points or lines, are generally expected to exhibit intriguing topological responses. Up to now, most of the studies on topological semimetals are limited to non-magnetic materials with time-reversal symmetry. However, magnetic materials can also be endowed with topological band structures in which the interplay of magnetism and band topology can generate novel correlated topological phenomena. In this talk, I will introduce iron-based van der Waals (vdW) materials, where combination of magnetism, spin-orbit interaction, and topological band structures gives rise to unusual physical properties and magnetic tunability [1,2]. This demonstrates that topological and ferromagnetic vdW materials have great potential for various spin-dependent electronic functionalities

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I-4

Ferrimagnetic spintronics

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Spintronics is a multidisciplinary field whose central theme is the active manipulation of spin degrees of freedom in solid-state systems. The core magnetic system for spintronics research has been ferromagnets since they serve as spin-polarizers/detectors and offer non-volatile memory and logic technologies. Recently, much effort has been expended in employing antiferromagnets and ferrimagnets as core elements in spintronic applications because of their fast dynamics. This talk will discuss the underlying mechanism of fast dynamics of compensated and uncompensated staggered moments, driven by magnetic fields or spin-transfer torques [1-5].

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I-5

Novel insight on the charge density wave ground state by scanning tunneling microscopy

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Charge density wave (CDW) phases permeate the phase diagram of many correlated electron systems. Despite decades of research, CDWs are still lacking a detailed understanding. There is renewed interest in CDWs motivated by the possible competition of this quantum phase with superconductivity, in particular in high temperature superconductors. Moreover, robust evidence for nesting at the Fermi level, the preferred mechanism, is firmly established only in very few CDW systems, while the nature and amplitude of the associated gap in the band structure remain largely unsettled. We will discuss recent scanning tunneling microscopy and spectroscopy experiments providing novel insight on the CDW phase observed in transition metal dichalcogenides (TMDs). After a brief review of some open issues in selected CDW systems, we discuss unique investigation opportunities offered by the recent developments preparing exfoliated TMDs of variable thicknesses, from bulk to monolayer. We find a striking non-monotonic thickness dependence of the CDW phase transition temperature (T_{CDW}) in VSe_2 [1]. T_{CDW}, determined directly from the charge modulation amplitude imaged by STM, is found to diminish with thickness above 20nm. Meanwhile, below 10nm thickness, T_{CDW} is increasing to exceed the bulk values by nearly 40% in the thinnest specimen. Although a detailed theoretical understanding is yet to be developed, this behavior reflects a 3D to 2D dimensional crossover followed by quantum confinement in the thinnest samples. Next, we introduce a powerful real space fitting procedure, allowing us to map the full complex CDW order parameter with a spatial resolution of the order of half a CDW period. Thus obtained images of the local amplitude, phase and wavelength provide unprecedented insight into the CDW ground state. We find in particular that the CDW in TMDs consists of three individual components. Phase contrast images reveal domain walls, discommensurations and topological defects such as vortices and vortex anti-vortex pairs in each of the three components. Finally, we show how the atomic resolution capabilities of scanning probe imaging [3] gives insight into the three dimensional real space structure of the CDW reconstruction.

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I-6

Towards atomically precise material fabrication: defect engineering of layered materials using focused ion beams

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The scalability of electronic and information technology devices depends on the ability to tune layered materials. With the recent development of CVD-growth processes for high quality 2-dimensional materials, large scale fabrication of these materials is become routine. However, critical is the structuring and functional tuning of these materials, as currently being done for semiconductors. Here, I will discuss the use of focused helium ion beams in tailoring the functionality of 2D materials including graphene, dichalcogenides and copper indium thiophosphate (CIPS) with nanometer precision. Using a helium ion beam under high dosing allows for milling and structuring of devices with nanometer precision and prevents ion implantation and resist contamination effects. For lower helium ion doses we are able to tune the mobility as ascertained by local transport measurements. The nature of the associated properties of this material were explored using a combination of aberration-corrected scanning transmission electron microscopy (STEM), scanning probe microscopy (SPM) and optical spectroscopy and mass spectrometry techniques that provided insight into local mechanical, electromechanical, chemical and atomic structure properties of these devices and elucidate the effect of ion beam dose on device performance. Future perspective and scalability of this approach to device fabrication will also be discussed.

I-7

Growth and application of meter-sized single-crystal graphene

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Graphene is of only one atomic layer thick and its property is therefore very sensitive to the interfacial interaction with other materials. By designing and utilizing this interfacial interaction, we have lots of opportunity in engineering the growth and applications of graphene. In this talk I will introduce several our recent works on this topic, including ultrafast graphene growth [1, 2], epitaxial meter-sized single-crystal graphene growth [3], and ultrafast broadband charge collection [4].

Key words: Graphene, Growth, Physics

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I-8

Photophysics at nanoscale using time-resolved ultrafast spectroscopy

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Ultrafast lasers offer unique possibilities to control and probe transient processes in nano materials. Following photoexcitation by a femtosecond laser pulse, the carrier dynamics includes many important processes like thermalization, energy relaxation, exciton formation and spin dynamics which are impacted by dimensionality. Their understanding is crucial not only for many optoelectronic applications, but also to gain a deeper understanding of physical processes in nano-materials. My talk will discuss some of our recent work on the dynamics of optical pump induced photocarriers in single and bilayer graphene, graphane (hydrogen functionalized graphene) and carbon nanotubes as probed by time-resolved optical pump-terahertz probe spectroscopy.

Our recent ongoing work on tunable Plasmon-assisted generation of hot carriers in graphene on an ultrathin gold film with periodic array of holes (showing anomalous transmission resonances) as probed by ultrafast time-resolved differential reflectance will also be discussed.

I-9

Ultrafast materials design with tailored light pulses

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The electronic properties of solids are mainly determined by the orbital overlap between neighbouring atoms. Therefore, electronic properties are commonly controlled via the chemical composition that determines the relevant structural parameters such as bond angles and lengths.

My group follows a different approach where control of the effective orbital overlap is achieved by periodic modulation of the solid with strong laser fields in the (mid-)infrared spectral range. We investigate the resulting band structure changes with time- and angle-resolved photoemission spectroscopy (tr-ARPES).

The stable crystal structure and therefore the band structure of a solid is determined by the deepest minimum on the potential energy surface. We follow three different approaches to modify the shape of the potential energy surface with light and thereby control the electronic properties of different low-dimensional materials:

I will present results on the light-induced insulator-to-metal phase transition in one-dimensional indium wires where strong electronic excitation quenches the minimum on the potential energy surface associated with the insulating ground state [1,2].

Next I will show how resonant driving of an infrared-active lattice vibration in bilayer graphene results in a transient enhancement of the electron-phonon coupling constant [3,4].

Recently, coherent modulation of the Bloch electron's momentum with strong light fields has emerged as a new route for dynamical band structure engieneering. There are predictions for various light-induced phase transitions including the formation of Floquet topological insulators [5] and Mott insulating states [6]. I will present our recent results concerning the observation of photon-dressed states in graphene and bulk WSe_2 and end with an outlook on future projects.

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I-10

Indirect excitons in heterostructures

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An indirect exciton (IX), aka interlayer exciton or charge transfer exciton, is a bound pair of an electron and a hole confined in spatially separated layers.

Due to their long lifetimes, IXs can cool below the temperature of quantum degeneracy. This gives an opportunity to realize and study cold excitons. We will present direct measurements of spontaneous coherence and Bose-Einstein condensation of IXs. We will present phenomena observed in the IX condensate, including the commensurability effect of exciton density wave, spin textures, and Pancharatnam-Berry phase and long-range coherent spin transport.

IXs are dipoles and their energy can be controlled by voltage. This gives an opportunity to build devices, which operate with excitons in place of electrons. We will present excitonic devices, including excitonic transistor, trap, lattice, conveyer, ramp, storage, and split-gate devices.

We will present van der Waals heterostructures where IX condensation can be realized at high temperatures. We will present IXs at room temperature in van der Waals heterostructures.

I-11

Spin- and valley-phenomena, non-linear optics in atomically thin materials

Gang Wang

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Atomically thin materials are a promising platform for optoelectronics and spin/valley related phenomena, due to their reduced dimensionality, crystal symmetry and the possibility to arrange them in heterostructures. In semiconducting monolayer transition metal dichalcogenides (TMDs), due to the missing inversion symmetry and strong spin-orbit interaction, spin and valley degrees of freedom are coupled [1]. The resulting valley dependent optical selection rules make TMD monolayers and heterostructures ideal candidates for future valleytronics applications [2]. Confinement to a single layer and reduced dielectric screening result in a strong Coulomb interaction [3]. Excitons dominate the optical response and spin/valley properties [4], with clear differences from what expected from individual carriers. The non-linear optical response in layered materials and graphene is significant and can be modified by tuning the electronic properties [5]. This also allows external control of the non-linear optical generation [5]. I will outline recent progress on the exciton properties in monolayer TMDs [4]. I will discuss the spin-forbidden dark excitons [6] and related biexciton species [7] as examples to illustrate the unique spin and valley properties in monolayer TMDs. I will then discuss second and third harmonic generation from TMDs and Graphene [8], showing that the harmonic generation efficiency can be enhanced by over one order of magnitude by controlling the interplay between input fundamental frequency and Fermi energy.

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I-12

Optical properties of all-inorganic perovskite nanocrystals

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All-inorganic cesium lead halide perovskite nanocrystals (NCs, $CsPbX_3$ NCs, X = Cl, Br, I) attract much attention recently due to their outstanding optical properties. Here I will discuss our recent results concerning three important aspects of their micro-scopic characteristics: (i) an explicit demonstration of a relation between NC size and shape with their bandgap, and the effective coupling between proximal NCs; (ii) simultaneous formation of insulating Cs_4PbBr_6 nanohexagons and $Cs_4PbBr_6/CsPbBr_3$ hybrid nanospheres during the synthesis of $CsPbX_3$ NCs; and (iii) spontaneous merging of drop-casted colloid at room conditions by seamless stitching of aligned NCs [1]. The latter process is accelerated by humidity and heat treatments, while arrested with electron beam irradiation. Further, I will present some detailed information on carrier dynamics in perovskite NCs, their water-resistant encapsulation, and on energy exchange within their ensembles obtained by using high-resolution induced absorption and emission spectroscopies. Finally, I will also discuss the most recent results concerning successful observation of efficient carrier multiplication in $CsPbI_3$ NCs with bandgap energy around 1.8 eV [2].

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I-13

Zero excess energy for carrier multiplication in van der Waals layered materials

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Carrier multiplication (CM), a photo-physical process to generate multiple electron-hole pairs by exploiting excess energy of free carriers, is explored for efficient photovoltaic conversion of photons from the blue solar band, predominantly wasted as heat in standard solar cells [1,2]. Current state-of-the-art approaches with nanomaterials have demonstrated the improved CM but are not satisfactory due to high energy loss and inherent difficulties with carrier extraction.

Here, we report efficient CM phenomena in van der Waals (vdW) multilayer that commences at the energy conservation limit and proceeds with high conversion efficiency [3]. A small threshold energy, as low as twice the bandgap, was achieved, marking an onset of quantum yield with enhanced carrier generation. Strong Coulomb interactions between electrons confined within vdW layers allow for rapid electron-electron scattering to prevail over electron-phonon scattering. In addition, the presence of electron pockets spread over momentum space could also contribute to the observed high CM efficiency. Combined with high conductivity and optimal bandgap, these superior CM characteristics identify vdW materials as an attractive candidate for third-generation solar cells.

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I-14

Graphene films and membranes: fabrication and applications

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Graphene is a single-atom-thick sheet of hexagonally arranged, sp2-bonded carbon atoms that is not an integral part of a carbon material but is freely suspended or adhered on a foreign substrate, and has excellent properties, such as high mechanical strength and modulus, high thermal and electrical conductivities, very stable thermal and chemical stabilities, and unique electronic properties. Graphene films and membranes are expected to be used in various applications. Therefore, synthesis of graphene films and membranes in large area at reasonable cost is very important.

Basically, graphene films and membranes can be synthesized by CVD and assembly from chemically exfoliated graphene sheets. We developed an ambient pressure CVD to synthesize large and small size single crystal graphene grains, and their continuous films [1,2,3,4]. Moreover, we invented an electrochemical bubbling method to efficiently transfer these grains and films [2]. Large area and continuous graphene transparent conductive films are produced by an integrated R2R process of CVD and bubbling transfer. Very recently, we have developed a green electrochemical water oxidation exfoliation process of graphite to produce high-quality graphene oxide in large quantity and high yield [5], and invented a continuous centrifugal casting process to rapidly produce high-quality graphene membranes in large area and tunable thickness from chemically exfoliated graphene sheets [6]. These graphene films and membranes may have wide applications in many fields, from electronics to optoelectronics, from sensors to wearable devices, and from separation to water treatment [7,8]. However, great efforts are highly needed for the research, development, commercialization and market explorations of graphene films and membranes.

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I-15

Atomically-precise graphene architectonics: 0D dots, 1D ribbons and 2D porous graphene

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On-surface reactions, via programmed interactions of molecular building blocks, has recently emerged as a promising route to synthesis atomically precise materials from the 'bottom-up'. This approach ensures exquisite atomic-scale control of the structural and chemical functionalization, allowing to design a vast number of carbon-based nanoarchitectures not available by traditional solution chemistry nor with the 'top-down' methodologies. In particular, graphene nanoribbons (GNRs) with different structures can be synthesized with atomic precision and fine-tuned electronic band gap.

In this talk, I will describe the recent advances in the on-surface synthesis field. Then, I will discuss our recent results to synthetize 0D dots [1], atomically precise nanoporous graphene [2], graphene nanoribbons and their chemical functionalization and how to organize them into superlattices [3].

At the end of the day, this talk will demonstrate the full path to synthetize a semiconducting graphene material with a bandgap similar to that of silicon, its atomic-scale characterization, and its implementation in an electronic device. Further potential applications include in photonics and highly selective molecular filtration and sensing systems.

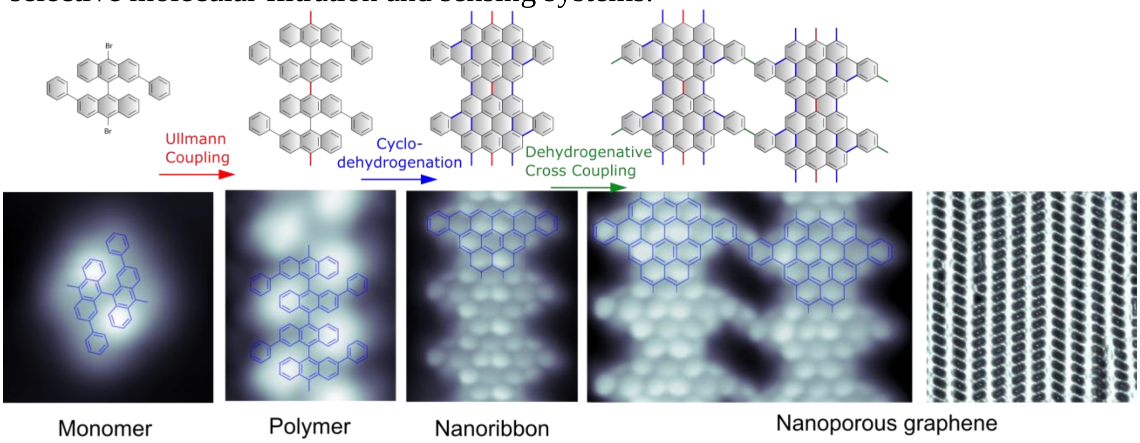

Figure 1. STM images (bottom) and schematic representation (top) of the precursor, intermediates and final product of the hierarchical synthesis of nanoporous graphene.

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I-16

Room-temperature dilute magnetic semiconductor in V-doped monolayer WSe_2

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Diluted magnetic semiconductors (DMSs) such as Mn-doped GaAs are attractive materials for gate-controlled spintronic devices but the low Currie temperature of the ferromagnetic order is far from room temperature, limiting for practical applications. In this talk, research challenges of DMSs will be reviewed. I will present our unambiguous observations of the long range ferromagnetic order occurring above room temperature in diluted V-doped mono layer WSe_2. Magnetic hysteresis curves, micro magnetic domains and the well-defined structure of V-substituted W atoms are characterized by the vibrating sample magnetometer, magnetic force microscopy and high-resolution transmission electron microscopy, respectively. The possible mechanism of such high transition temperature in V-doped WSe_2 will be introduced by our band structure calculations based on density functional theory.

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I-17

Spin generation from charge current, heat, and light

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Manipulating magnetization by a spin current rather than a magnetic field is a fundamental issue in spintronics. To generate a spin current, some forms of energy is required. In this talk, I will review physical mechanisms for the spin generation from charge current, heat, and light, and my research for the spin generation will be shown accordingly. The mechanisms for the electrical spin generation are spin-filter effect, spin Hall effect, and Rashba effect [1-3]. The mechanisms for the thermal spin generation are spin-dependent Seebeck effect, spin Seebeck effect, and spin pumping effect [4-7]. The mechanisms for the optical spin generation are inverse Faraday effect, optical orientation, and photo-spin current [8-12].

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I-18

Electronic correlations and pseudodoping in two-dimensional materials

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Two-Dimensional materials are in most cases not isolated but in direct contact to a substrate or part of vertical heterostructures. In this talk, we discuss how vertical coupling affects the electronic system of correlated two-dimensional materials. We firstly explain the effect of “pseudodoping”, i.e. apparent doping of metallic 2d materials without actual charge transfer, which occurs due to coupling to supporting substrates [1]. We then address the question of how electronic correlations and coupling to substrates can be exploited to switch 2d materials between conductive and insulating states. Examples of 2d Mott insulators [2] and impurities in 2d semiconductors will be considered.

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I-19

Electronic and chemical nano-imaging of 2D materials beyond graphene

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Recently, remarkable progress has been achieved in modern microscopies. However, even if they have attained exceptional lateral resolution, the problem of providing powerful spectroscopic characterization at the nano- and mesoscopic-scale still remains. This gap is particularly filled by an innovative and powerful technique named k-space nanoscope or NanoARPES (Nano Angle Resolved Photoelectron Spectroscopy). This cutting-edge nanoscope is able to determine the momentum and spatial resolved electronic structure, disclosing the implications of heterogeneities and confinement on the valence band electronic states typically present close to the Fermi level, see Fig. 1. The k-momentum space nanoscope can be effectively combined with chemical imaging based on core level scanning photoemission and X-ray absorption able to detect even very tiny different chemical environments.

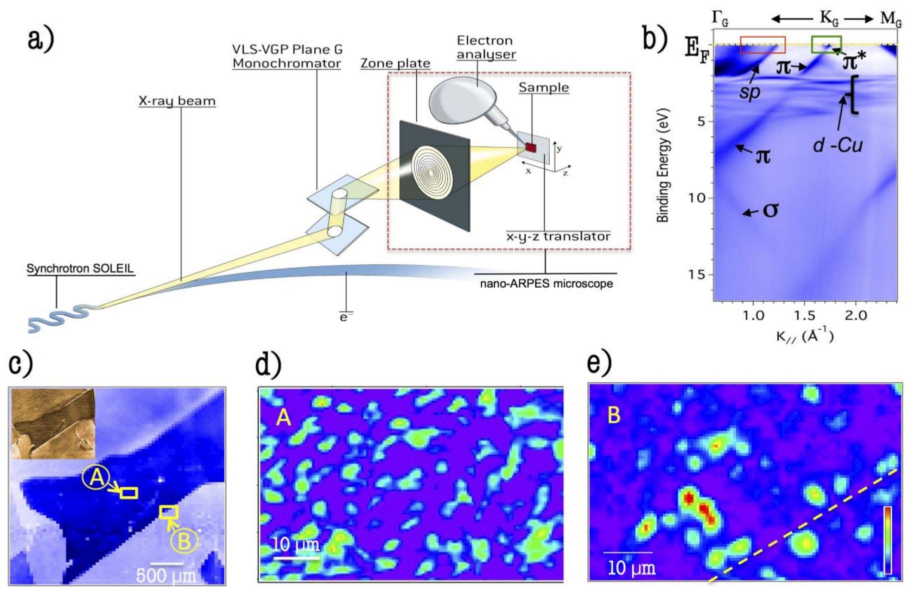

Figure 1. Mixed real- and reciprocal-space images of a polycrystalline graphene film, grown on copper foils. (a) scheme of the nano-ARPES apparatus (b) ARPES data inside one of a large copper grain of the sample. (c) real-space image of the copper states intensity. *Panels (d) and (e) show graphene grain distribution at the "A" and "B" yellow rectangles*

In the present talk, the more relevant innovations in the field of chemical and electronic imaging of 2D materials will be disclosed, highlighting the basic principles, associated instrumental and appealing scientific cases. In particular, nanoARPES findings describing the electronic band structure of mono-atomic exfoliated graphene on SiO_2 substrates, epitaxial and polycrystalline monolayer graphene films grown on copper and SiC [2] will be presented and Graphene/MoS_2 heterostructures. Electronic and chemical mapping with high energy, momentum and lateral resolution have provided relevant features like gap-size, doping, effective mass, Fermi velocity and electron-phonon coupling, among other properties for diverse 2D materials [3-6].

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I-20

Manipulating light flow with 2D materials plasmons

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Recent years have observed a plethora of strong dipole type polaritonic excitations in 2D materials owing to the reduced screening. These polaritons can be sustained as electromagnetic modes at the interface between a positive and negative permittivity material. In the case of the plasmon-polaritons (e.g. in semi-metallic graphene), the negative permittivity is provided by the coherent oscillations of the free carriers. For exciton-polaritons (e.g. in semiconducting transition metal dichalcogenides, TMD) and phonon-polaritons (e.g. in diatomic hexagonal boron nitride, hBN), it is associated with their resonant optical absorption, resulting from a highly dispersive permittivity. These optical resonances can also result in a negative permittivity, albeit over a narrow spectral window.

In this talk, I will discuss our recent efforts in understanding plasmons behavior in 2D materials and using them to control the flow of light both in the far- and near-field. The general constitutive materials response of 2D materials, in conjunction with metasurface approaches, can potentially enable arbitrary control of phase, amplitude, polarization of light. The flow of light within the 2D materials can also exhibit rich transport behavior, such as hyperbolic rays, non-reciprocal chiral propagation, time reversal of waves and coupling of light spin to induce one-way propagation.

I-21

Electronic structure and ultrafast dynamics of chalcogenide heterolayers

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The single-layer (SL) transition metal dichalcogenides (TMDs) display a diverse collection of intriguing electronic phenomena. These include single-particle and many-body effects encoded with spin- and valley-degrees of freedom [1,2]. By stacking SL TMDs of different compounds in bi-layer (BL) heterostructures an additional layer-degree of freedom becomes available, leading to further tunablility of the optoelectronic properties [3].

I will present angle-resolved photoemission spectroscopy (ARPES) measurements incorporating micro- and nano-scale spatial resolution (microARPES and nanoARPES) performed on stacked layers of different TMD compounds (WS_2, MoS_2, $MoSe_2$) with other two-dimensional materials such as graphene and hexagonal boron nitride (hBN). Our experiments reveal distinct superlattice effects associated with the type and twist-angle of adjacent materials in the stack, as well as the presence of one-dimensional scroll-like features around the edges of our stacks.

Using a single-domain crystal of two stacked layers of MoS_2 (BL MoS_2) we have explored the ultrafast response of a BL TMD to a polarization-tunable optical excitation in time-resolved ARPES (TR-ARPES) measurements. I will discuss the observation of a new type of layer-pseudospin effect emerging from quantum intereference in the two TMD layers. This effect appears to completely dominate the ultrafast response of charge carriers near the K-point valleys of the BL TMD.

Finally, I will discuss the implications of our time- and spatially-resolved photoemission measurements for exploring non-equilibrium electronic and optical properties of low-dimensional materials *in situ*.

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I-22

Toward single-crystal 2D materials on wafer scale

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Although large-area polycrystalline 2D materials have been realized by chemical vapor deposition, the structure defects such as grain boundary and point defects still degrades the unique material's properties. Here, we present the unique strategy of the self-collimation for the synthesis of single-crystal hexagonal boron nitride (SC-hBN) on a wafer scale [1]. The self-collimation bewteen hBN grains is induced by the electrostatic interaction between boron and nitrogen atoms at peripheral hBN grains to eventually form the SC-hBN film on a liquid substrate. Furthermore, the synthesis of single-crystal graphene and transition metal dichalcogenides film on SC-hBN via epitaxial growth technique is demonstrated. The detailed growth mechanism and analysis will be presented.

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I-23

Discovery of new two-dimensional van der Waals materials: layered Zintl phases

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The discovery of new families of two-dimensional (2D) van der Waals (vdW) layered materials has always attracted great attention to pursue beyond graphene. It has been challenging to artificially develop the van der Waals bonded layer structure that is constructed by the stacking of honeycomb atomic lattice composed of two elements as in hexagonal boron nitride. In this talk, a new class of 2D vdW materials, layered Zintl phases will be introduced. These new 2D layered Zintl phases can allow unlimited extent of 2D science in terms of the diversity of materials and their physical properties. A new class of 2D materials was developed from a 3D structured material that has (1) a multicomponent system, (2) primary atomic bonds in three-dimensionality, (3) thermodynamic and chemical stability, and (4) diversity in chemical compositions. Through the dimensional manipulation of crystal structure, we create an unprecedented 2D vdW zinc antimonide (2D-ZnSb), which is the layered Zintl phase with sp2-hybridized bonding characters in Zn-Sb honeycomb atomic layers. The vdw layered structure of 2D-ZnSb is evolved by selectively etching the lithium cations from the layered LiZnSb Zintl phase that is formulated by alloying the lithium atoms into sp3-hybridized bonded three-dimensional ZnSb (3D-ZnSb), demonstrating the bidimensional polymorphism of 3D- and 2D-ZnSb. The recent experimental and theoretical studies on diverse physical properties obtained in the new 2D materials will be discussed.

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