Frontiers in Quantum Materials and Devices

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POSTER ABSTRACTS

1. Berg, Robbie
Wellesley College
Pipelines, Not Parachutes: A Coordinated Research Program in Quantum Materials for Wellesley College Undergraduates
Carina Belvin, Eunice Paik, Phyllis Ju, Wanyi Li, Catherine Matulis and Hanae Yasakawa

The CIQM College Network aims to attract young students to study quantum materials, providing them with exciting opportunities to become future leaders in the field. At Wellesley College we have focused on optical studies of NV centers in diamond, an area that is both accessible and engaging for undergraduates. We have built a confocal microscope and used it to image fluorescence from single centers. We have also designed and built a low-cost autocorrelation system, capable of identifying single centers. And we have constructed a simple system for making optically detected magnetic resonance measurements on ensembles of NV centers in diamond nanocrystals.

2. Chang, Cui-Zu
Massachusetts Institute of Technology
High-precision Quantum Anomalous Hall State Achieved in a Hard Ferromagnetic Topological Insulator
Cui-Zu Chang, Weiwei Zhao, Chaoxing Liu, Moses, H. W. Chan, Jagadeesh S. Moodera

The quantum anomalous Hall (QAH) effect shares a similar physical phenomenon as the quantum Hall (QH) effect, whereas its physical origin relies on the intrinsic spin-orbit coupling and ferromagnetism. We experimentally achieved the QAH state in the new TI compound V-doped (Bi,Sb)2Te3 films with the zero-field longitudinal resistance down to 0.00013Â±0.00007h/e2, Hall conductance reaching 0.9998Â±0.0006e2/h and the Hall angle reaching 89.993Â±0.004Âº at T=25mK. Further advantage of this system comes from the fact that it is a hard ferromagnet with a large coercive field (Hc>1.0T) and a relative high Curie temperature. This realization of robust QAH state in hard ferromagnetic TI is a major step towards dissipationless electronic applications without external fields.

3. Chee, Jingyee
Harvard University
Kitty Yeung, Jingyee Chee, Hosang Yoon, Yi Song, Jing Kong, Donhee Ham
Far-Infrared Graphene Plasmonic Crystals for Plasmonic Band Engineering

Plasmons in graphene have been an attractive feature due to sub-wavelength confinement and tunability. A useful method to excite graphene plasmons is to pattern a graphene sheet into specific shapes, which allow phase matching between the plasmon modes and the incident radiation. Earlier efforts have relied on exciting localized plasmons in isolated graphene islands, such as ribbons, disks and rings. The geometry and dimensions of the islands determine the boundary conditions that define the localized plasmonic resonance frequency. An additional mechanism to control the localized plasmonic resonance frequency is to use electrostatic coupling between proximate islands, suggesting a principle of engineering wave dynamics via medium periodicity. We apply this principle in the presented work. In contrast to previous work, we introduce graphene plasmonic crystals in which delocalized plasmons are excited in a continuous graphene medium with a periodic structural perturbation, creating plasmonic bands in a manner akin to photonic crystals. Fourier transform infrared spectroscopy is used to demonstrate the plasmonic band formation. By measuring the extinction spectra of the graphene plasmonic crystals, we show that the incident far-infrared light resonantly couples to plasmonic modes that belong to a specific set of plasmonic bands. These specific bands are selected because their spatial symmetry, interpreted via group theory, matches that of the free-space radiation field. Adjusting the periodic geometry thus allows manipulation of the plasmonic bands. Further tuning of the plasmonic band frequencies is achieved by chemically doping charge carriers with HNO_3 vapor. Our work is a step toward graphene plasmonic band engineering, which may lead a new class of sub-wavelength graphene plasmonic devices, such as band gap filters, modulators, switches and metamaterials.

4. de Leon, Nathalie

Harvard University
Lukin Mikhail Nathalie P. de Leon, Kristiaan De Greve, Ruffin Evans, Michael Goldman, Hongkun Park, Mikhail Lukin

Quantum Optics in the Solid State with Diamond Nanophotonics

Large-scale quantum networks will require efficient interfaces between photons and stationary quantum bits. Nitrogen vacancy (NV) centers in diamond are a promising candidate for quantum information processing because they are optically addressable, have spin degrees of freedom with long coherence times, and as solid-state entities, can be integrated into nanophotonic devices. An enabling feature of the NV center is its zero-phonon line (ZPL), which acts as an atom-like cycling transition that can be used for coherent optical manipulation and read-out of the spin. However, the ZPL only accounts for 3-5% of the total emission, and previously demonstrated methods of producing high densities of NV centers yield unstable ZPLs.

We will present methods and technologies for gaining both spectral and spatial control over NV emission by coupling NV centers to nanophotonic devices. In particular, we have developed a method to create a high-density device layer of NVs with stable ZPLs in high purity diamond, and have devised a fabrication scheme to carve single mode waveguides out of the surface of the bulk diamond substrate. Using this technique, we are able to fabricate high quality factor, small mode volume photonic crystal cavities directly out of diamond, and deterministically position these photonic crystal cavities so that a stable NV center sits at the maximum electric field. We observe an enhancement of the spontaneous emission at the cavity resonance by a factor of up to 100. The NV emission is guided efficiently into a single optical mode, enabling integration with other photonic elements, as well as networks of cavities, each with their own optically addressable qubit. These nanophotonic elements in diamond will provide key building blocks for quantum information processing such as single photon transistors, enabling distribution of entanglement over quantum networks.

5. Demir, Ahmet
Massachusetts Institute of Technology
Ahmet Demir, Neal Staley, Efren Navarro-Moratalla, Pablo Jarillo-Herrero, Raymond Ashoori
Capacitance Measurements on Transition Metal Dichalcogenides

Transition metal dichalcogenides(TMDCs) are layered materials with tunable direct bandgap structure. This feature allows them to be open to a variety of applications and rich physics. We investigate atomically thin tungsten diselenide(WSe2) using capacitance measurements since it overcomes the high contact resistance problem to monolayer flakes. Here we present the capacitance data that shows the carrier population and depopulation as a function of gate voltage. We also observed some unpredicted capacitance peaks which needs further investigation.

6. Fang, Wenjing
Massachusetts Institute of Technology
Wenjing Fang, Allen Hsu, Yong Cheol Shin, Albert Liao, Shengxi Huang, Yi Song, Xi Ling, Mildred S. Dresselhaus, Tomas Palacios and Jing Kong
Application of Tungsten as a Carbon Sink for Synthesis of Uniform Monolayer Graphene free of Bilayers/Multilayers

We have found that tungsten (W) foils can be used for controlling the carbon diffusion within copper (Cu) enclosures to synthesize large-domain bi-/multi-layer-free monolayer graphene via chemical vapor deposition. We have observed that bi-/multi-layer graphene that nucleate underneath the monolayer graphene can be selectively removed by a W foil placed inside of the Cu enclosure. Both X-ray photoelectron spectroscopy and X-ray diffraction reveal the formation of tungsten sub-carbide (W2C), suggesting the role of the W foil as a carbon sink that alters the carbon concentration inside of the enclosure. Consequently, the bi-/ multi-layers appear to dissolve. Utilizing this selective removal process, we were able to demonstrate largedomain (>200 Î¼m) monolayer graphene that is free of any bi-/multi-layers by using Cu double enclosures.

7. Fang, Shiang
Harvard University
Shiang Fang, Bertrand Halperin, Efthimios Kaxiras
Ab-initio Tight-Binding Model for 2D Transition Metal Dichalcogenides and 1D Bismuth Nanowires

Our ab-initio Wannier-function derived tight-binding (TB) method is an efficient tool for simulations of experimental systems and nanostructures, bridging novel applications and theoretical understanding of devices employing superconductors, 2D layered materials and topological insulators. One application of this method has been to develop TB models for 2D transition metal dichalcogenides (TMDCs). In our work, we have constructed the general TB model for a one-unit TMDC layer with spin orbit coupling corrections. For heterostructure composed of several layers, we have constructed an empirical transferrable interlayer interaction model that depends only on interatomic distances and is applicable when there are arbitrary translations and rotations between layers.We have also been developing TB models to describe Bi and Bi/Sb nanowires. Tito Huber's group has studied transport properties of such nanowires, grown by several techniques, with different crystal orientations, and has studied the effects of strong magnetic fields, applied parallel or perpendicular to the wire axis. The results have indicated that the transport is dominated by surface states in many circumstances. Our TB model gives the correct band structure for a surface perpendicular to the hexagonal c-axis. As the next step, we plan to study the structure of surfaces with other orientations, which necessarily occur on the surface of a nanowire, and we plan to include effects of a strong magnetic field parallel to the surface.

8. Fatemi, Valla
Massachusetts Institute of Technology
Valla Fatemi, Benjamin Hunt, Hadar Steinberg, Stephen L. Eltinge, Fahad Mahmood, Nicholas P. Butch, Kenji Watanabe, Takashi Taniguchi, Nuh Gedik, Raymond C. Ashoori, and Pablo Jarillo-Herrero

Electrostatic Coupling between Topological Surface States

Three dimensional topological insulators are undergoing extensive research to probe the properties of their surface states, which have often proven elusive due to bulk carriers and lack of device control. Dual-gated structures will be useful for probing low-density TI materials so that effects due to the top and bottom surfaces can be separately distinguished. Here, for the first time, we demonstrate individually tunable top- and bottom-surface states on a single topological insulator device via dual gated structures on the low-density quaternary compound Bi1.5Sb0.5Te1.7Se1.3. We find that electric fields penetrate the bulk of only thin devices, and we extend previous theory to understand the thick-thin discrepancy. We also develop an electrostatic charging model to explain the electric field penetration in thin devices, and we find a surface state density of states in excellent agreement with independent spectroscopic measurements. Finally, we observe unusual high magnetic field behaviors that may indicate surface state band gap opening.

9. Fauzi, M. Hamzah
Tohoku University
M. F. Sahdan, S. Maeda, M. H. Fauzi, S. Miyamoto, and Y. Hirayama

Electron Transport in Triple-gated Quantum Point Contacts

We have investigated linear and non-linear electron transport in triple-gated quantum point contacts fabricated on a relatively low mobility GaAs two-dimensional electron wafer. We measured transport characteristics as a function of asymmetric split gate bias voltages âˆ† to laterally shift the channel position between the split gates. We found that at a certain range of âˆ† away from âˆ† = 0 Volt, a number of fine structures due to disorders induced potential fluctuation appeared below the first integer plateau but weaken at elevated temperature (> 1 K). As we further increased âˆ†, we enter a regime where the first integer plateau disappeared. Remarkably, the first plateau reappeared as we further increased âˆ†. These results probably reflect the interplay between one-dimensional channel and disorders located at certain position. Non-linear transport measurement indicated that the confinement potential weakened in the regime very close to the destroyed first plateaus area. In addition, the 0.7 plateau was less affected by changing âˆ†.

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10. Frenzel, Alex
Massachusetts Institute of Technology
A. J. Frenzel, C. H. Lui, Y. C. Shin, J. Kong, N. Gedik
Semiconducting-to-Metallic Photoconductivity Crossover in Graphene

We investigate the transient photoconductivity of graphene at various gate-tuned carrier densities by optical-pump terahertz-probe spectroscopy. We demonstrate that graphene exhibits semiconducting positive photoconductivity near zero carrier density, which crosses over to metallic negative photo- conductivity at high carrier density. These observations can be accounted for by the interplay between photoinduced changes of both the Drude weight and carrier scattering rate. Our findings provide a complete picture to explain the opposite photoconductivity behavior reported in (undoped) graphene grown epitaxially and (doped) graphene grown by chemical vapor deposition. Notably, we observe nonmonotonic fluence dependence of the photoconductivity at low carrier density. This behavior reveals the nonmonotonic temperature dependence of the Drude weight in graphene, a unique property of two-dimensional massless Dirac fermions.

11. Hong, Jin-Yong
Massachusetts Institute of Technology
Jin-Yong Hong, Yong Cheol Shin, Jing Kong
Synthesis of Graphene by Chemical Vapor Deposition and Their Transfer Process

Since graphene was discovered by isolating single atomic layer from graphite in 2004, intense research and development has been devoted to exploring this unique material. Among various synthesis methods, metal-catalyzed chemical vapor deposition (CVD) has been the main process of 2D materials because of their high film quality, scalability, and low production cost. Nevertheless, the quality of 2D materials synthesized by CVD is inferior to their mechanically exfoliated counterparts. In this presentation, we identify challenging issues yet to be solved by separating the preparation process into two sections: synthesis and transfer. The addressed challenges and proposed solutions in this presentation will provide criteria in the preparation of other 2D materials synthesized by CVD processes.

12. Ikeda, Susumu
Tohoku University
Susumu Ikeda
Graphoepitaxy of Organic Semiconductors and Its Application to Electronic Devices

I will report oriented film growth of organic semiconductors on micro-patterned substrates. Controlling in-plane orientation and obtaining single-crystalline thin films are among the important factors to improve carrier transport in organic field effect transistors (OFETs). Since the surface of substrates is often amorphous in OFETs, epitaxial growth is not applicable to control the orientation of thin films. We focused on graphoepitaxy as the technique to control the in-plane orientation of organic thin films and improve carrier transport. While graphoepitaxy has been studied for nearly forty years in inorganic materials, we have found some peculiar characteristics in organic graphoepitaxy and further expansion of this field is expected. We are investigating the effect of graphoepitaxy on the performance of OFET devices.

13. Lee, Changmin

Massachusetts Institute of Technology
Changmin Lee, Ferhat Katmis, Pablo Jarillo-Herrero, Jagadeesh S. Moodera, and Nuh Gedik

Direct Measurement of Ferromagnetism Induced at the Interface of a Magnetic Topological Insulator

When a topological insulator (TI) is brought into contact with a ferromagnetic insulator (FMI), both time reversal and inversion symmetries are broken at the interface. An energy gap is formed at the surface, and its electrons at the TI surface gain a net magnetic moment through short-ranged exchange interactions. These magnetic topological insulators can host various exotic phenomena, such as massive Dirac fermions, the topological magnetoelectric effect, Majorana fermions, and the quantum anomalous Hall effect (QAHE). However, selectively measuring magnetism induced at the buried interface has remained a challenge. Using magnetic second harmonic generation (MSHG), we directly probe magnetism induced at the interface between the ferromagnetic insulator EuS and the three-dimensional TI Bi2Se3. We simultaneously measure both the in-plane and out-of-plane magnetizations at the interface through the nonlinear Faraday effect. Our findings not only allow us to characterize magnetism at the TI-FMI interface, but also open up possibilities of optically imaging chiral current modes that are predicted to exist along the magnetic domain boundaries.

14. Markovich, Thomas

Harvard University
Thomas Markovich, Martin Blood-Forsythe, Rob DiStasio, Alan Aspuru-Guzik

Enabling Large-Scale Simulation of Many-Body Dispersion Forces in Condensed Phase Systems

Dispersion interactions are ubiquitous in nature, and extremely important for explaining the structure and function of many systems, from soft matter to surfaces and solids. Due to their long-range and scaling with system size, dispersion interactions can prove particularly important in modeling nanostructured systems where reduced dimensionality creates large polarizable surfaces. Standard pairwise approximations are insufficient for such systems, and the true non-additive and many-body character of dispersion plays a crucial role. The many-body dispersion (MBD) method of Tkatchenko and co-workers [A. Tkatchenko et al., Phys. Rev. Lett. 108, 236402 (2012); A. Ambrossetti et al., J. Chem. Phys. 2014, 140, 18A508] seeks to address this behavior by computing the full many-body correlation energy for a fictutious set of coupled quantum harmonic oscillators that mimic the fluctuations of the real polarizable valence-electron density. Much of the work on MBD, to date, has focused on the energetics of various molecules and materials, with all necessary gradient information being obtained through numeric differentiation. We recently presented an implementation of the relevant analytic gradients with respect to nuclear displacements, which permitted fast and accurate geometry optimizations of many gas-phase systems and showed that PBE+MBD geometries matched those of highly accurate wavefunction theories at a fraction of the cost. In this talk I will describe an efficient implementation of the MBD energy and analytic gradients, which has enabled their application to larger simulations of condensed-phase systems. I will show examples of geometry and unit-cell optimizations with MBD corrections in the condensed phase, as well as the first ever MBD corrected molecular dynamics calculations.

15. Mtengi, Bokani

Howard University

Delta Doping of Nitrogen, Silicon and Germanium Vacancies on Diamond Films

Bokani Mtengi, Gary L. Harris, James A. Griffin

Color centers in diamond are widely recognized as a promising solid-state platform for quantum cryptography and quantum information processing applications . We report successful delta doping in diamond film with the use of hot-filament chemical vapor deposition technology. The technology allows deposition of high quality, single and polycrystalline diamond films from 5 to 50 microns thick and large deposition areas. The technique provides options for delta doping with minimum damage to the film. By performing in-situ growth rate monitoring, we are able to precisely add dopants within a specific growth layer, which is significant for delta doping (10-100nm) from the substrate surface. Nanocrystalline epi layers of diamond were grown on different substrates and delta doped with silicon, nitrogen and germanium to create vacancies in diamond films. Optical characterization techniques, including photoluminescence (PL) were used to analyze the quality of the vacancy centers as shown by their different intensity peaks and the vacancy centers.

16. Musengua, Mpho

Howard University

Growth of Graphene on Various Substrates using Different Growth Techniques

Mpho Musengua, Gary Harris, Crawford Taylor, James Griffin

Graphene is a promising new material with excellent electrical and thermal properties (Hemani 2011). Their unique planar hexagonal carbons–carbon structure, as well as the sp^2 hybridization that is responsible for excellent charge transport properties determine its electrical properties. Electron mobility's exceeding 200,000 $cm^2V^{-1}s^{-1}$ have been measured. These excellent properties make single layer graphene a suitable material for high-performance devices. The fact that monolayer graphene has no band gap makes it difficult to be used as a material for field-effect transistors. Since monolayer graphene has, these restrictions are due to no band gap; having a bilayer graphene will solve this problem. According to (Abderrazak , Houyem and Bel Hady Hmid, Emna Selmane 2013) bilayer graphene exhibit a gap under the application of an applied external electric field (Bao 2012). Some of the obstacles faced when growing graphene are, the current growth methods, especially chemical vapor deposition (CVD) and epitaxial growth (SiC) need a transfer step to transfer the graphene onto a preferred substrate. According to previous researchers, using a transfer process degrades the electrical properties of the graphene layer (Ahmad Umair and Hassan Raza 2012). In this work, an alternate unconventional growth method using radio frequency chemical vapor deposition shows that it is possible to obtain graphene directly onto the insulator (SiO_2) or the Si substrate. Graphene growth was attempted on various substrates using radio frequency chemical vapor deposition and the conventional chemical vapor deposition. The growth of graphene was successful on Nickle evaporated on SiO_2,Copper foil, Palladium and Platinum evaporated on SiO_2. The results were confirmed by the Raman Spectroscopy test.

17. Navarro-Moratalla, Efren

Massachusetts Institute of Technology
Efren Navarro-Moratalla, Yafang Yang, Hugh Churchill, Pablo Jarillo-Herrero

Electric Double Layer Gating of Transition Metal Dichalcogenides

Charge carrier density control is a keystone in the study of 2D semiconductors. The use of ionic liquids as gate electrodes gives rise to the formation of high capacitance electrical double layers (EDLs) that permit exploring very high carrier density regimes, opening the door for the study of field-induced correlated states, such as ferromagnetism or superconductivity. Though pioneering works on transition metal dichalcogenides have provided with proof of the use of EDLs for the induction of superconductivity in bulk crystals or in the surface of thick flakes, no reports of single layer superconductivity have been put forward. We take advantage of crystal growth techniques, the EDL approach, the wide range of metal dichalcogenides and the van der Waals stacking to fabricate ultraflat samples that will permit exploring the high carrier density regime in search for switchable single layer superconductivity. The use of a liquid gate opens the possibility of studying the effect that strain or even the presence of molecular species may have in the superconducting state.

18. Ren, Hechen

Harvard University
Hechen Ren, Sean Hart, Timo Wagner, Philipp Leubner, Mathias Mahlbauer, Christoph Brane, Hartmut Buhmann, Laurens Molenkamp, Amir Yacoby

Induced Superconductivity in Topological Insulators

Topological insulators are a newly discovered phase of matter characterized by a gapped bulk surrounded by novel conducting boundary states. Since their theoretical discovery, these materials have encouraged intense efforts to study their properties and capabilities. Among the most striking results of this activity are proposals to engineer a new variety of superconductor at the surfaces of topological insulators. These topological superconductors would be capable of supporting localized Majorana fermions, particles whose braiding properties have been proposed as the basis of a fault-tolerant quantum computer.

19. Rodriguez-Nieva, Joaquin

Massachusetts Institute of Technology
Y. Zhao, J. Wyrick, F.D. Natterer, J.F. Rodriguez-Nieva, C. Lewandowski, K. Watanabe, T. Taniguchi, L.S. Levitov, N.B. Zhitenev, J.A. Stroscio

Creating and Probing Electron Whispering-Gallery Modes in Graphene

The design of high-finesse resonant cavities for electronic waves faces challenges due to short electron coherence lengths in solids. Complementing previous approaches to confine electronic waves by carefully positioned adatoms at clean metallic surfaces, we demonstrate an approach inspired by the peculiar acoustic phenomena in whispering galleries [1]. Taking advantage of graphene's gate-tunable light-like carriers, we create whispering-gallery mode (WGM) resonators defined by circular pn junctions, induced by a scanning tunneling probe. We can tune the resonator size and the carrier concentration under the probe in a back-gated graphene device over a wide range. The WGM-type confinement and associated resonances are a new addition to the quantum electron-optics toolbox, paving the way to develop electronic lenses and resonators.

[1] Science 348, 672 (2015)

20. Sato, Koji
Tohoku University
M. Furuta, S. Hayashi, M. Kotani, Y. Kubota, S. Matsuo, and K. Sato
K-theoretical Understanding of Bulk-edge Correspondence

Topological insulators and superconductors can be characterized by nontrivial bulk band curvatures and associated gapless edge states. The bulk curvature is given by the bulk index such as Chern number, and the number of edge states is given by the edge index. The bulk-edge correspondence states the equivalence of these two indexes, which has been explicitly shown in some cases such as integer quantum Hall effect. We extend the bulk-edge correspondence to more general framework. We introduce a new type of topological invariant, which we call "gap index", and it allows us to relate bulk and edge indexes through K-theoretic relations. Both bulk and edge indexes can be generated from the gap index and furthermore can be mapped to the same index, and the commutativity of this structure shows the bulk-edge correspondence in a concise way.

21. Sohn, Young-Ik
Harvard University
Young-Ik Sohn, Srujan Meesala
Nitrogen Vacancy Centers in Diamond Nanomechanical Resonators

We explore the interaction between nitrogen vacancy (NV) center in diamond and the phonon through strain. To impose significant strain at NV center site, nanomechanical resonator is fabricated and resonantly driven. Spin echo measurement is performed to deduce single phonon coupling rate of the system.

22. Tryputen, Lara
Massachusetts Institute of Technology
L. Tryputen, S. Piotrowski, S. Bapna, H. Almasi, W. Wang, S. Majetich, C. A. Ross
Switching Properties of 45 nm to 1 µm Perpendicular Magnetic Tunnel Junctions

Perpendicular magnetic tunnel junctions (p-MTJs) have great potential for realizing next-generation high-density non-volatile memory devices and spin logic applications. We present our recent results on fabrication of high resolution CoFeB/MgO/CoFeB-based p-MTJs and characterization of their switching properties as well as topography and current mapping by using nanoscale conductive Atomic Force Microscopy. Our patterning method is based on using hydrogen silsesquioxane resist mask combined with ion beam etching. It allows to fabricate devices down to 15 nm in diameter while maintaining the magnetic quality of the multilayers. Repeatable, consistent switching behaviour has been observed in the obtained p-MTJ devices of 500 nm down to 45 nm p-MTJs devices with 10 - 800 mV voltage applied. Switching field increased as device diameter decreased. We discuss the effect of device sizes on their switching properties.

23. von Cube, Felix
Harvard University
Felix von Cube, Estelle Kalfon-Cohen, Yachin Ivry, Andrea Knaller, Dafei Jin, Anna Shneidman, Marko Loncar, and David C. Bell
Imaging Quantum Materials with Electron Microscopy

We investigate quantum materials with high resolution transmission electron microscopy (HR-TEM). For this, we use low beam voltages of 40 and 80 kV to reduce the damage to the sample. The microscopes allow for atomic resolution imaging, which helps to understand the astonishing mechanical and electric properties of hybrid quantum materials. Our research currently focuses on graphene-based quantum materials, as well as topological insulators and nitrogen vacancies in diamond nano-particles.

24. Webb, Tatiana
Harvard University
Tatiana A. Webb, Dennis Huang, Can-Li Song, Harris Pirie, Shiang Fang, Cui-Zu Chang, Jagadeesh S. Moodera, Efthimios Kaxiras and Jennifer E. Hoffman
Monolayer FeSe/SrTiO3

Monolayer FeSe grown on SrTiO3 has a superconducting transition temperature an order of magnitude higher than bulk FeSe. The large energy scales which have been observed in the high Tc (65 K; He Nature Materials 2013), superconducting gap (15 meV; Wang Chinese Physics Letters 2012), and high energy phonons (near 100 meV; Lee Nature 2014) point to a pairing mechanism involving states at comparable energies from the Fermi level, including empty bands. We use in-situ scanning tunneling microscopy to study both the filled and empty electronic states of monolayer FeSe/SrTiO3 grown via molecular beam epitaxy. Quasiparticle interference imaging reveals a new electron band above the Fermi level, such that both empty and filled states exist near the center of the Brillouin zone within 100meV of the Fermi surface (Huang arXiv 2015).

25.Yamamoto, Hideaki
Tohoku University
Hideaki Yamamoto, Ayumi Hirano-Iwata, Michio Niwano
Nano/Micro-Engineering of Biointerfaces for Reconstructing Neuronal Circuits with Living Cells

Human brain is a complex, hierarchical system comprised of 10 billion neurons. By engineering a simple neuronal network in a dish that mimics the architecture and functions of the brain's network, a novel system for studying of the neural basis of information processing in the brain will become available. Although reconstructing the whole circuitry is way beyond our expectation, we can still focus on its functional module, or local circuit, which consists of a small number of neurons. Here we present our recent work on (1) the development of surface nano/micro-modification techniques for manipulating single neurons and designing neuronal networks and (2) experimental/computational study on the analysis of spontaneous dynamics of micropatterned neuronal networks.

26. Yang, Yuan
Harvard University
Eric Heller, Yuan Yang, Lucas Kocia
Raman Scattering in Carbon Nanosystems

Raman spectroscopy is very widely used to characterize graphene samples. The understanding of the spectroscopy depends critically on the underlying theory. For a doze of years, a Raman scattering narrative theory called "double resonance" has developed, created for and applied only to graphene, carbon nanotubes and graphite. It relies heavily on post-photoabsorption electron-phonon scattering, which is intrinsically a non Born-Oppenheimer, nonadiabatic process, and neglects the nuclear position dependence of the electronic transition moment. In the talk, we will show electron-phonon scattering is in fact not needed to explain the Raman spectra, the transition moment coordinate dependence explains and predicts graphene spectroscopy more directly and simply. This general understanding also applies to the one dimensional equivalence of graphene, polyacetylene system.

27. Zhang, **Xu**
Massachusetts Institute of Technology
Xu Zhang, Allen Hsu, Han Wang, Yi Song, Yong Cheol Chin, Wenjing Fang, Jing Kong, Mildred Dresselhaus, Tomas Palacios
Noninvasive Doping in Graphene through Chlorination

Plasma-based chlorination on graphene is a unique surface functionalization to realize effective and non-invasive doping. Surface electronic states of p-doped graphene by chlorine plasma are systematically investigated through synchrotron-based X-ray spectroscopy. It is significant that Cl-doping is a highly non-intrusive process, leaving long-range periodicity of electronic states of graphene intact. It is a unique advantage for chlorinated graphene and distinguishes this approach from many other doping methods. Transport properties of chlorinated graphene field effect transistors are also studied.

28. Zhao, Shu Yang Frank
Harvard University
SYF. Zhao, GA. Elbaz, DK. Efetov, J. Ravichandran, Y Guo, L. Brus, X. Roy, J. Kong, L. Levitov, P. Kim
Lithium Intercalation of Single-Layer Graphene / Boron Nitride Heterostructures

Few layer graphene (FLG) intercalate compounds form a new generation of graphene derivative systems where carrier densities are expected to reach 6E14/cm^2 per graphene layer, and novel physical phenomena such as superconductivity and magnetism may emerge. Experimental realization of intercalated FLGs have been limited by harsh intercalation processes which are often incompatible with mesoscopic device fabrication techniques. We developed techniques to electrochemically intercalate few- and single-layer graphenes encapsulated in boron nitride heterostructures with lithium in a controlled manner, minimizing sample degradation from parasitic reactions in the electrolyte. By performing simultaneous Raman spectroscopy as the samples intercalate, we were able to confirm the successful intercalation of the graphene samples as well as the reversibility of this chemical process. Simultaneous transport measurement further demonstrates that the process is due to electrochemical reactions, as opposed to electrolytic gating.