2011 International Workshop on

Nanomaterials & Nanodevices

July 1st-7th, Beijing-Xiangtan, China

July 1st-3rd, 2011

Institute of Physics, Chinese Academy of Sciences, Beijing, China

July 4th-7th, 2011

Xiangtan University, Xiangtan, China

Chinese Academy of Sciences & State Administration of Foreign Experts Affairs

Institute of Physics, Chinese Academy of Sciences

Xiangtan University

中科院-国家外专局纳米材料与器件研究国际合作团队
（北京部分）
International Workshop on Nanomaterials and Nanodevices
(Beijing Part, July 1st-3rd, 2011)

Scientific Program

July 2nd, Saturday, IOP Building D212	
	Opening Ceremony and Welcome Remarks **Hongjun Gao** *(Institute of Physics ,CAS, China)* **Shouheng Sun** *(Brown University, USA)*
8：30－10：30	**Session 1** *Chair:* **Andreas J. Heinrich**
8：30－9：00	**Stephen J. Pennycook** *(Oak Ridge National Laboratory, USA)* "Colossal Ionic Conductivity in Complex Oxide Heterostructures: Atomic-Resolution Microscopy and Density Functional Theory "
9：00－9：30	**Xiaoqing Yang** *(Brookhaven National Laboratory, USA)* "Structural Changes of Layer-structured Cathode Materials During Heating and $LiFePO_4$ Based Cathode Materials During Cycling and their Effects on the Thermal Stability and Cycle Performance for Lithium-ion Batteries"
9：30－10：00	**Karl-Heinz Ernst** *(Empa, Switzerland)* "Modification of Surfaces with Buckybowls"
10：00－10：20	**Chonglin Chen** *(University of Texas, San Antonio, USA)* "Interface Structures and Anomalous Physical Properties of Highly Epitaxial Double Perovskite $LaBaCo_2O_{5.5}$ Thin Films"
10：20－10：30	**Coffee Break**

10：30－12：20	**Session 2** *Chair:* **Stephen J. Pennycook**
10：30－11：00	**Andreas J. Heinrich** *(Almaden Research Center, IBM, USA)* "Probing the Energetics and Dynamics of Individual Atomic Spins on Surfaces"
11：00－11：30	**Hanno Weitering** *(University of Tennessee, USA)* "Electronic Instabilities, Fluctuations, and Transport in Epitaxial Nanowires"
11：30－12：00	**Sheng Dai** *(Oak Ridge National Laboratory, USA)* "Self-Assembly Synthesis and Functionalization of Nanoporous Carbon Materials for Energy-related Applications"
12：00－12：20	**Jiandi Zhang** *(Louisiana State University, USA)* "Nanoscale Chemical Phase Separation in the Simplest Doped Fe-based Superconductor"
12：20	**Lunch**

13：30－15：00	**Session 3** *Chair:* **Hanno Weitering**
13：30－14：00	**Chih-Kang Shih** *(University of Texas at Austin, USA)* "Visualizing Order Parameter Landscapes in Heterogeneous Superconductor Thin Films: Geometric Influences on Proximity Effects"
14：00－14：20	**Xincheng Xie** *(Peking University, China/Oklahoma State University, USA)* "Spin Superconductor in a Ferromagnetic Graphene"
14：20－14：40	**Min Ouyang** *(University of Maryland, USA)* "Tailoring Bottom-Up Nanostructures for New Frontiers of Ultrafast Nano-Optical Physics"
14：40－15：00	**Coffee Break and Photo**

15：00－16：40	**Session 4** *Chair:* **Thomas Greber**
15：00－15：30	**Byung Hee Hong** *(Sungkyunkwan University, South Korea)* “Carbon Nanomaterials: Status and Challenges”
15：30－15：50	**Shouheng Sun** *(Brown University, USA)* “Rational Synthesis of Metallic Nanoparticles for Catalytic Applications”
15：50－16：10	**Jianxin Zhong** *(Xiangtan University, China)* “Tuning Transport Properties of Quantum Films”
16：10－16：30	**Yongqing Li** *(Institute of Physics ,CAS, China)* “Tunable Surface Conductivity in Topological Insulator Thin Films”
16：30－16：40	**Coffee Break**

16：40－18：10	**Session 5** *Chair:* **Kian Ping Loh**
16：40－17：10	**Thomas Greber** *(University of Zurich, Switzerland)* “Nanomesh and His Famous Sister Graphene as Nanotemplates”
17：10－17：30	**Siu-Wai Chan** *(Columbia University, USA)* “Nucleation and Growth of Nano Ceria: Experimental Real-time Study”
17：30－17：50	**Xiaoxiang Xia** *(Institute of Physics ,CAS, China)* “Nanostructure Metamaterials in Near-infared and Optical Region”
17：50－18：10	**Zhaohua Cheng** *(Institute of Physics ,CAS, China)* “Direct Observation of Dendritic Domain Growth with Large Activation Volume in CoFe/Pt Multilayers”

July 3rd, Sunday, IOP Building D212	
8：30－10：30	**Session 6** *Chair:* **Karl-Heinz Ernst**
8：30－9：00	**Hongjie Dai** *(Stanford University, USA)* "Carbon Nanotubes and Graphene: from Biological Imaging to Physical Properties and Energy Research"
9：00－9：30	**Kian Ping Loh** *(National University of Singapore, Singapore)* "Graphene Oxide as A Chemically Tunable Platform for Optical Applications"
9：30－10：00	**Shengbai Zhang** *(Rensselaer Polytechnic Institute, USA)* "Theory for Engineering Graphene Bandgap"
10：00－10：20	**Shuji Hasegawa** *(University of Tokyo, Japan)* "Electronic and Spin Transport at Surfaces and Nanostructures"
10：20－10：30	**Coffee Break**

10：30－12：30	**Session 7** *Chair:* **Byung Hee Hong**
10：30－10：50	**Nian Lin** *(Hong Kong University of Science and Technology, China)* "Low-temperature STM Investigation of Electronic Structure and Charge Transport of Single Conjugated Molecules"
10：50－11：10	**Jian Shen** *(Fudan University, China/ORNL, USA)* "A New Avenue towards Colossal Magnetoresistance in Organic Materials"
11：10－11：30	**Ming Liu** *(Institute of Microelectronics, CAS, China)* "Continuous Hysteresis Control in Organic Field Effect Transistors"
11：30－11：50	**Hongxing Xu** *(Institute of Physics ,CAS, China)* "Plasmonic Bus and Logic Gates in Silver Nanowire Networks for On-Chip Integrated Optical Computing"
11：50－12：10	**Guangyu Zhang** *(Institute of Physics ,CAS, China)* "Engineering of Graphene Nanostructures for Electronics"
12：10－12：30	**Hongjun Gao** *(Institute of Physics ,CAS, China)* "High Quality Graphene on Ru(0001) and its Universal Template Effect"
12：30	**Closing Remarks**

中科院-国家外专局纳米材料与器件研究国际合作团队
（湘潭部分）
International Workshop on Nanomaterials and Nanodevices
(Xiangtan Part, July 4th, 2011)

Scientific Program

8: 30－ 9：00	**Opening Ceremony and Welcome Remarks**
9：00－10：35	**Session 1** *Chair:* **Hongjie Dai**
9：00－9：25	**Stephen J. Pennycook** *(Oak Ridge National Laboratory, USA)* "Aberration-Corrected STEM and First-Principles Theory: Insights into Energy Materials"
9：25－9：50	**Karl-Heinz Ernst** *(Empa, Switzerland)* "Linear Propulsion of a Molecular Machine After Fuelling with Electrons"
9：50－10：15	**Andreas J. Heinrich** *(Almaden Research Center, IBM, USA)* "Probing the Energetics and Dynamics of Individual Atomic Spins on Surfaces"
10：15－10：35	**Coffee Break and Photo**

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11：00－11：25	**Siu-Wai Chan** *(Columbia University, USA)* "Nucleation and Growth of Nano Ceria: Experimental Real-time Study"
11：25－11：50	**Thomas Greber** *(University of Zurich, Switzerland)* "How Photons Turn the Electrons"
11：50－12：15	**Hongjie Dai** *(Stanford University, USA)* "Carbon Nanotubes and Graphene: from Biological Imaging to Physical Properties and Energy Research"
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13：30－14：55	**Session 3** *Chair:* **Karl-Heinz Ernst**
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14：20－14：45	**Guangyu Zhang** *(Institute of Physics ,CAS, China)* "Engineering of Graphene Nanostructures for Electronics"
14：45－14：55	**Coffee Break**

14：55－16：20	**Session 4** *Chair:* **Hanno Weitering**
14：55－15：20	**Shouheng Sun** *(Brown University, USA)* "Rational Synthesis of Metallic Nanoparticles for Catalytic Applications"
15：20－15：45	**Jian Shen** *(Fudan University, China/ORNL, USA)* "A New Avenue towards Colossal Magnetoresistance in Organic Materials"
15：45－16：10	**Sheng Dai** *(Oak Ridge National Laboratory, USA)* "Controlled Synthesis of Nanostructured Catalysts"
16：10－16：20	**Coffee Break**

16：20－17：35	**Session 5** *Chair:* **Stephen J. Pennycook**
16：20－16：45	**Hanno Weitering** *(University of Tennessee, USA)* "Electronic Instabilities, Fluctuations, and Transport in Epitaxial Nanowires"
16：45－17：10	**Jianxin Zhong** *(Xiangtan University, China)* "Tuning Transport Properties of Quantum Films"
17：10－17：35	**Chonglin Chen** *(University of Texas, San Antonio, USA)* "Interface Structures and Anomalous Physical Properties of Highly Epitaxial Double Perovskite $LaBaCo_2O_{5.5}$ Thin Films"
17：35	**Closing Remarks** **Chonglin Chen** *(University of Texas, San Antonio, USA)*

Beijing Part

Colossal Ionic Conductivity in Complex Oxide Heterostructures: Atomic-Resolution Microscopy and Density Functional Theory

S. J. Pennycook[1,2], T. J. Pennycook[2,1], M. Varela[1,3], M. P. Oxley[1,2], J. Garcia Barriocanal[3], A. Rivera-Calzada[3], F. Y. Bruno[3], C. Leon[3], J. Santamaria[3] and S. T. Pantelides[2,1]

[1]*Oak Ridge National Laboratory, Oak Ridge, TN, USA.*

[2]*Vanderbilt University, Nashville, TN, USA.*

[3]*Universidad Complutense de Madrid, Madrid, Spain.*

E-mail: pennycooksj@ornl.gov

Recently, an ionic conductivity near room temperature eight orders of magnitude higher than found in bulk was measured in $SrTiO_3$/ Y_2O_3-ZrO_2 (STO/YSZ) superlattices grown by high pressure O_2 sputtering [1]. Finite-temperature density-fucntional simulations have have found that the origin of the colossal ionic conductivity is a complete disordering of the oxygen sublattice, induced by the combined effect of lattice-mismatch strain and a mismatch of the oxygen sublattices [2]. These structural changes can be studied by aberration corrected scanning transmission electron microscopy (STEM) and electron energy loss spectroscopy (EELS). In particular, the microscopy provides direct images of the cation and anion sublattices, and finds the O sublattice to be highly disordered at room temperature [3] in agreement with the theoretical predictions [2].

Acknowledgements: Research supported by the US Department of Energy, Office of Basic Energy Sciences, Materials Sciences and Engineering Division, at ORNL (MV, SJP) and Vanderbilt (T.J.P, S.T.P)

[1] J. Garcia-Barriocanal et al., Science **321**, 676-680 (2008).
[2] T. J. Pennycook et al., Physical Review Letters **104,** 115901 (2010).
[3] T. J. Pennycook et al., European Physical Journal, in press.

Structural Changes of Layer-structured Cathode Materials During Heating and $LiFePO_4$ Based Cathode Materials During Cycling and their Effects on the Thermal Stability and Cycle Performance for Lithium-ion Batteries

X. Q. Yang[1], K-W Nam[1], X.J. Wang[1], X.Q.Yu1, Y.N. Zhou[1], S.M. Bak[1], H.S. Lee[1], L.J. Wu[1], Y. Zhu[1] , H. Li[2], X. Huang[2], and L. Chen[2]

[1]Brookhaven National Lab. Upton, NY11973, USA

[2]Institute of Physics, Chinese Academy of Sciences, Beijing, 10090, China

E-mail: xqyang@gmail.com

Layer structured oxides with transition metals such as Ni, Co, and Mn have been considered as good cathode materials to replace $LiCoO_2$ for lithium batteries due to their lower cost and higher capacity. The thermal instability in charged, especially over charged states at elevated temperatures, however, is still a major concern on this class of materials. Recently, we have developed a technique using the combination of synchrotron base in situ x-ray absorption (XAS), x-ray diffraction (XRD), and TEM to study the thermal stability of these materials. In this presentation, we will report our in-situ transmission electron microscopy (TEM) studies on the structural changes of over charged $Li_{0.0}Ni_{0.8}Co_{0.15}Al_{0.05}O_2$ and $Li_{0.0}Ni_{1/3}Co_{1/3}Mn_{1/3}O$ cathode materials during heating, in comparison with our XRD and XAS studies. The $Li_{0.0}Ni_{0.8}Co_{0.15}Al_{0.05}O_2$ particles harvested from overcharged cell were first examined at room temperature. Electron diffraction and HRTEM show that the main phase is a layered structure with rhombohedral symmetry. Interestingly, rock-salt structure and spinel structure, which only observed at elevated temperatures using X-ray techniques, were presented at the edges and thin areas of the particles, respectively even at room temperature. This implies that after overcharging, the particles start losing some oxygen atoms near the particle surface, resulting in the structural changes. By heating the sample, we observed that the phase with the spinel structure nucleates and grows more and more into the thick area of the particles, while the rock-salt phase propagates from the surface to the interior of the particles. After heating the sample to 400 ºC, the structure of the whole sample completely transformed to the rock-salt structure. For the over-charged $Li_{0.0}Ni_{1/3}Co_{1/3}Mn_{1/3}O_2$ sample, O1 structure and spinel structure were observed on the surfaces of the particles at room temperature, but no rock-salt structure was observed. The effects of surface coating including the atomic layer deposition (ALD) on improving the thermal stability will also be discussed.

The olivine-structured $LiFePO_4$ and $LiFeMPO_4$ (M=Mn, Co, Ni) solid solution type cathode materials have been studied intensively recently, due to their high thermal and electrochemical stabilities and good safety characteristics. The in depth understanding of the structural changes during charge-discharge cycles will provide guidance for developing new materials. Using synchrotron based in situ XRD, hard and soft x-ray XAS, and TEM, the structural changes of these materials have been studied during charge-discharge cycling. The differences of phase transition processes between the surface and the bulk will be discussed.

The work at Brookhaven National Lab. was supported by the U.S. Department of Energy, Office of Basic Energy Science, and the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Vehicle Technologies, under the program of Vehicle Technology Program, under Contract Number DEAC02-98CH10886. The work at Institute of Physics, Chinese Academy of Sciences, was supported by Nature Scientific Foundation of China (50730005, 60621061), and ‘‘973” project (2007CB936501).

Modification of Surfaces with Buckybowls

Karl-Heinz Ernst[1,2], *Quirin Stöckl1, Tobias Bauert*[1], *Leo Merz*[1], *Kim K. Baldridge*[2], *Jay S. Siegel*[2]

[1]*Empa, Swiss Federal Laboratories for Materials Science and Technology, Überlandstrasse 129, CH-8600 Dübendorf*

[2]*University Zurich, Winterthurerstrasse 190, CH-8057 Zürich*

E-mail: karl-heinz.ernst@empa.ch

Modification of surfaces with aromatic organic molecules is the key approach to new materials for organic photovoltaics (OPV), organic light-emitting devices (OLEDs), and molecular electronics such as organic field effect transistors (OFETs). The interfaces between active layers and electrodes influence the electronic and optical properties as well as the device performance. Furthermore, because the spatial extent of the molecular wave functionsis rarely isotropic, the relative orientation of the molecules in the film, and thereby the degree of overlap of the frontier orbitals, will play an important role in determining film properties.[3]Bowl-shaped polynuclear hydrocarbons offer a special opportunity in this arena owing to their substantial dipole moment, large conjugated network and shape complementarity. Here we present different aspects of the consequences of adsorption of bowl-shaped fullerene-fragment derivatives on different surfaces. This includes reversible phase transitions,[1,2] 2Dtiling,[3] large induced interface dipoles,[4] and bowl-in-bowl stacking in multilayers.[5]

[1] L. Merz, M. Parschau, L. Zoppi, K. K. Baldridge, J. S. Siegel, K.-H. Ernst
Angew. Chem. Int. Ed. 48 (2009) 1966
[2] L. Merz, T. Bauert, M. Parschau, G. Koller, J. S. Siegel, K.-H. Ernst
Chem. Comm. (2009) 5871
[3] T. Bauert, L. Merz, D. Bandera, M. Parschau, J. S. Siegel, K.-H. Ernst
J. Am. Chem. Soc. 131 (2009) 3460
[4] T. Bauert, L. Zoppi, G. Koller, A. Garcia, J. S. Siegel, K. K. Baldridge, K.-H. Ernst,
Adv. Materials (2011) (submitted)
[5] T. Bauert, K. K. Baldridge, Jay S. Siegel, K.-H. Ernst
Chem. Comm. (2011) (in print)

Interface Structures and Anomalous Physical Properties of Highly Epitaxial Double Perovskite $LaBaCo_2O_{5.5}$ Thin Films

Chonglin Chen

Department of Physics and Astronomy, University of Texas at San Antonio, Texas and

The Texas Center for Superconductivity and Department of Physics, University of Houston, Texas

E-mail: Cl.Chen@utsa.edu

Interface engineered material has attracted more and more attention in the multifunctional materials research and active device fabrication. It plays a key role to control the physical properties of advanced nanomaterials and results in the discovery of various new physical phenomena with excellent opportunity for developing new metamaterials for active devices and engineered nanosystems. We have systematically studied the structures of perovskite $LaBaCo_2O_{5.5}$ thin films and their Anomalous Physical Properties. Also, a series of models were developed to understand these interface phenomena. Details will be presented in the talk.

Dr. C. L. Chen is currently a professor of physics at the Department of Physics and Astronomy in the University of Texas at San Antonio and a joint professor at the Texas Center for Superconductivity at the University of Houston (TcSUH). He received his Ph. D. degree in solid state science from the Pennsylvania State University in 1994. He was the Director's Funded Post-doctoral Fellow in the Los Alamos National Laboratory before he became a faculty member at TcSUH in June 1996. His research interests have spanned over the areas of multifunctional oxide thin film epitaxy, nanostructure fabrication, surface and interface physics and chemistry, and modeling developments. He has authored and/or coauthored more than 100 refereed papers that have appeared in Nature, Physical Review Letters, Applied Physics Letters, and others, and has delivered near 150 plenary lectures or invited talks at international/national conferences (MRS, ACerS, IMRUS, etc.), universities, and research institutes. He has served as international advisory board members in various international conferences, chair and/or co-chair in several international and national symposiums such as the American Ceramics Society, Materials Science and Engineering, and others. His current researches are supported by NSF-NIRT and CMS programs, Department of Energy, Army Research Office, Texas Advanced Research Program, the State of Texas through the TcSUH, government labs, etc.

Probing the Energetics and Dynamics of Individual Atomic Spins on Surfaces

Andreas J. Heinrich

Almaden Research Center, IBM, USA

E-mail: heinrich.andreas@gmail.com

The scanning tunneling microscope has been an extremely successful experimental tool because of its atomic scale spatial resolution. In recent years this has been combined with the use of low temperatures, culminating in microvolt energy resolution. However the time resolution of typical STM experiments is limited to about one millisecond for spectroscopy on a single atom. In this talk we will discuss the use of inelastic tunneling spectroscopy with low-temperature STM for the study of spins, a technique coined spin-excitation spectroscopy. With this approach it is possible to measure the energy eigenstates of the quantum spin Hamiltonian that describes spins on surfaces with very high precision. We will briefly discuss its application to the measurement of the Zeeman energy and to magneto-crystalline anisotropy. We will then focus on a new way of achieving fast time resolution based on an all-electrical pump probe spectroscopy. In this approach, a strong voltage pulse applied between tip and sample drives a spin out of thermal equilibrium (the pump pulse) [Nature Physics 6, 340 (2010)]. A short time later (typically a few nanoseconds) a smaller voltage pulse (the probe pulse) is applied which probes the state of the system. I will demonstrate this technique for the measurement of the spin relaxation time of individual magnetic atoms [Science 329, 1628 (2010)] and chains of atoms on a surface.

Electronic Instabilities, Fluctuations, and Transport in Epitaxial Nanowires

Hanno H. Weitering

Department of Physics and Astronomy, The University of Tennessee, Knoxville, TN 37931, USA

Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA

Email: hanno@utk.edu

Quantum transport is at the heart of nanoscience and marries a fundamental law of nature — quantum mechanics — with applied electrical engineering and emerging materials technologies. Ultimately, nanoscale electronic devices will contain networks of wires whose cross sections will be so small as to represent one-dimensional conductors with novel transport properties. We have fabricated exceptionally long and uniform YSi_2 nanowires via self-assembly of yttrium atoms on Si(001). The wire widths are quantized in odd multiples of the Si substrate lattice constant. The thinnest wires represent one of the closest realizations of the isolated Peierls chain, exhibiting van Hove type singularities in the one-dimensional density of states and charge order fluctuations below 150 K. Conduction through individual nanowires follows an inverse Arrhenius behavior, indicative of thermally-assisted tunneling of small polarons between defect centers. Quantitative analysis of individual wire resistances, probe resistances, and negative differential resistances of nanowire networks indicates significant electronic interwire coupling below 150 K. The long-range coupling mechanism involves the dielectric polarization of the substrate, which induces current blockades in neighboring conduction channels.

This work is sponsored by the NIH/NHGRI and was partially conducted at the Center for Nanophase Materials Sciences, which is sponsored at Oak Ridge National Laboratory by the Office of Basic Energy Sciences, U.S. Department of Energy

Self-Assembly Synthesis and Functionalization of Nanoporous Carbon Materials for Energy-related Applications

Sheng Dai

Chemical Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN, 37831-6201, USA and Department of Chemistry, University of Tennessee, Knoxville, TN 37996-1600, USA

Email: dais@ornl.gov

Porous carbon materials are ubiquitous in catalysis, separation, and energy storage/conversion. Well-defined nanoporous carbon materials are essential for a number of the aforementioned applications. Ordered mesoporous carbon materials have previously been replicated using colloidal crystals and presynthesized mesoporous silicas as scaffolds. Recently, we have reported alternative methods for the synthesis of highly ordered mesoporous carbons via self-assembly. The mesostructures of these carbon materials are highly stable and can be further tailored via graphitization and surface functionalization for catalysis and energy-storage applications. This presentation will be focused on our recent development in (a) new self-assembly approaches to the preparation of highly ordered nanoporous carbon materials for controlling pore structures and morphologies and (b) surface modification techniques to control the interfacial chemistry of nanoporous carbon materials for catalysis and energy-storage applications.

Acknowledgement: This work was performed at the Oak Ridge National Laboratory and the University of Tennessee and supported by Office of Basic Energy Sciences, U.S. Department of Energy, under contract No. DE-AC05-00OR22725 with UT-Battelle, LLC.

Nanoscale Chemical Phase Separation in the Simplest Doped Fe-based Superconductor

Jiandi Zhang

Louisiana State University, Baton Rouge, LA, 70803, USA

Email: jiandiz@lsu.edu

In high temperature superconductors, both cuprates and the new Fe-based materials, superconductivity, magnetism and lattice instabilities are closely coupled. The distinct difference between the two classes of superconductors is that in the Fe-based materials the electrons are metallic but in the cuprates are Mott insulating in the parent compounds. We have used scanning tunneling microscopy/spectroscopy and quantitative low energy electron diffraction to study the structure-property relationship at the surface of the $FeTe_{1-x}Se_x$, structurally one of the simplest of the Fe-based superconductors. Atomically resolved images for both parant and doped compounds are obtained, but for $FeTe_{0.55}Se_{0.45}$ (optimal superconducting doping) nanoscale chemical phase separation between Te and Se atoms is revealed. Remarkably, there is no electronic phase separation seen in the tunneling spectroscopy in the normal state. This indicates that the optimally doped superconductor is chemically inhomogeneous but electronically homogeneous, in contrast to the cuprates and most other correlated electron systems. We will discuss the evolution of the electronic and structural properties over a wide doping range x in this family.

This work is done in collaboration with Xiaobo He, Guorong Li, A. B. Karki, Rongying Jin, and E. W. Plummer and supported by US NSF.

Visualizing Order Parameter Landscapes in Heterogeneous Superconductor Thin Films: Geometric Influences on Proximity Effects

Chih-Kang Shih

Department of Physics, The University of Texas at Austin, Austin, Texas 78712, USA

Email: shih@physics.utexas.edu

How does superconducting order propagate spatially in a heterogeneous superconductor system? This question is central to understanding the coherence and robustness of the superconducting state in the presence of significant proximity effects. In order to address this question, we use a low-temperature scanning tunneling microscope to measure the temperature-dependent landscapes of superconducting gaps in real space for a 2D superconductor system comprised of 2D superconducting islands on a single atomic layer surface metal, forming a variety of lateral junctions with diverse shapes. Our studies unravel intriguing manifestations of junction geometry on the proximity effect. For example, depending on the junction geometry, the induced superconducting gap in the surface metal region can either be confined to the boundary of the superconductor, in which the gap decays within a very short distance (~ 10 nm), or can be rather non-local, where the induced superconducting gap can be observed nearly uniformly over a distance of many coherence lengths. Our findings enlighten the understanding of geometrical factors in meso and nano-scale superconductivity and enable our ability to engineer proximity effects through geometry.

Spin Superconductor in a Ferromagnetic Graphene

Xincheng Xie

International Center for Quantum Materials, Peking University and Institute of Physics, Chinese Academy of Sciences

Email: xcxie@aphy.iphy.ac.cn

We carry out theoretical study of the existence of a spin superconductor (SSC) in the ferromagnetic grapheme, a counterpart to the charge superconductor, in which a spin-polarized electron-hole excitons play the roles of the `Cooper' pairs. We present a BCS-type theory for the SSC. With the "London-type equations" of the super-spin-current density, we show the existence of an electric "Meissner effect" against a spatial varying electric field. We further study a SSC/normal conductor/SSC junction and predict a spin-current Josephson effect.

Tailoring Bottom-Up Nanostructures for New Frontiers of Ultrafast Nano-Optical Physics

Min Ouyang

University of Maryland – College Park

Email: mouyang@umd.edu

In this talk I will discuss a few recent advances from my research group involving a new scientific interface between nanomaterials, quantum physics, and ultrafast nano-optics. I will start from materials standpoint showing how to achieve precise control of nanostructures with desired property and functionality based on bottom-up chemical synthetic paradigm. Enabled by these nanoscale material advances, fundamental chemical and physical properties can be finely tailored within nanostructures, thus leading to novel technology concepts and applications. If time allows, several specific examples centering on the emerging nanoscale light-matter interactions will be further discussed, including light-electron-phonon couplings.

Carbon Nanomaterials: Status and Challenges

Byung Hee Hong

Department of Chemistry, and SKKU Advanced Institute of Nanotechnology (SAINT),

Sungkyunkwan University, Suwon 440-746, Korea

Email: byunghee@skku.edu

Since the discovery of carbon nanotubes (CNTs) in 1991, tremendous efforts have been made to commercialize CNT technologies, but only a few applications have been realized so far after ~20 years. Recently the graphene materials have inherited the fame of CNTs, but there is still a long way to go toward the practical applications. However, it is too early to be disappointed because it usually takes 20 years or more for any new materials to make a commercial impact. In fact, it took more than 15 years for carbon fibers to be widely used in commercial aircrafts. However, we shouldn't be too optimistic, and the researchers have to take a responsibility of investigating the bright and the dark sides of the carbon nanomaterials carefully and realistically. In addition, a technology roadmap or a guideline needs to be provided to the public people who are interested in carbon nanomaterials. Thus, in this tutorial, I would like to discuss the following issues: i) Recent trends in carbon nanomaterials researches and developments, ii) Comparison with other competing materials, iii) Short/mid/long-term roadmaps for carbon nanomaterials industry, and iv) carbon nanomaterials-related health and environmental issues.

Rational Synthesis of Metallic Nanoparticles for Catalytic Applications

Shouheng Sun

Department of Chemistry, Brown University, Providence, RI 02912, USA.

Email: Shouheng_Sun@brown.edu

Using solution phase-based thermal decomposition and reduction chemistry, we have synthesized a series of monodisperse metallic (Fe, Co, Ni, Pd, Pt, Au) and their alloy nanoparticles (NPs). The metallic NPs can serve as seeds for the production of structurally more complicated core/shell Mc/Ms (Mc = Pd, Au, AgAu, or NiPd; Ms = Au, FePt, or Au/FePt) NPs. By tuning the sizes, compositions and shell thickness, these NPs have been made catalytically more active and durable for the reduction of oxygen, for the oxidation of formic acid/methanol and for the hydrolytic formation of hydrogen from ammonia borane. The work demonstrates that the solution phase-based "bottom-up" synthesis is a reliable approach to highly efficient NP catalyst for practical catalytic applications.

Tuning Transport Properties of Quantum Films

Jianxin Zhong

Institute for Quantum Engineering and Micro-Nano Energy Technology,

Xiangtan University, Hunan 411105, China

Email: jxzhong@188.com

Recent breakthrough in epitaxial growth of high-quality two-dimensional (2D) crystals such as graphene and topological insulators have opened the way for fundamental study of novel quantum phenomena in 2D quantum films. The physical properties of 2D quantum films are sensitive to structural changes because of the more direct manifestation of quantum effects at reduced dimensionality. In this talk, I will present theoretical proposals for effective tuning of electronic transport properties in 2D quantum films by structural changes, focusing on doping, folding, strain, and substrate effects in graphene and ultra-thin films of topological insulators.

Tunable Surface Conductivity in Topological Insulator Thin Films

Jun Chen, Xiaoyue, Kehui Wu, and Yongqing Li

Institute of Physics ,CAS, China

Email: yqli@iphy.ac.cn

We report our latest progress in electrical tuning of the chemical potential in topological insulator Bi_2Se_3 thin films. Clear evidence for decoupled surface transport on top and bottom surfaces is obtained from analysis of the magnetoconductivity data with the Hikami-Larkin-Nagaoka equation. It gives a good account of the magnetotransport due to weak antilocalization despite existence of considerable electron-electron interaction effects. Implications of the weak antilocalization and the electron-electron interactions will be discussed based on our temperature-dependent measurements as well as the data recorded in tilted magnetic fields. The decoupling between the top and bottom surfaces can be attributed to gate-induced suppression of the bulk conductivity. This work establishes a new method for identifying surface transport that complements those based on Shubnikov-de Haas oscillations or phase-coherent interference in quasi-1D structures. The creation of electrons and holes on opposite surfaces by gating also offers opportunity for unveiling novel quantum phenomena related to excitons.

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Nanomesh and His Famous Sister Graphene as Nanotemplates

Thomas Greber

University of Zürich

Email: greber@physik.unizh.ch

Single layers of hexagonal Boron nitride and graphite are attractive new materials. Growing such layers on transition metals such as rhodium or ruthenium leads to so called nanomesh superstructures with about 10 times the lattice constant of the substrate. For the case of h-BN nanomeshes are found [1], which trap molecules at room temperature [2]. They can be used as a 2 nm nano-test tube array [3] where processes like the self-assembly of water may be studied. Interestingly the intercalation of atomic hydrogen removes the corrugation of the h-BN skin, which restores after hydrogen desorption [4]. For the case of graphene structures with similar properties and function, though with inverted topography are found [5]. Recently it was proposed that the hill-like protrusions with a size of about 2 nm act as quantum dots [6].

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Nucleation and Growth of Nano Ceria: Experimental Real-time Study

Siu-Wai Chan

Columbia University, USA

Email: sc174@columbia.edu

Many properties of nanoparticles depend on their size, while technological applications depend on the degree of their size distribution. Ideally, if all particles are nucleated at the same time and grow together, all particles will have the same size and therefore, the same properties, enabling maximum control. Such control of material properties will underpin their productive applications. Yet details about the nucleation and growth of nanoparticles are often a black-box event. Here we study a proven synthesis that yields near mono-disperse nanoparticles. Results are presented for an in situ synchrotron-based ultra-small-angle X-ray scattering (USAXS) study of the solution mediated precipitation of nanocrystalline ceria (n-CeO_2) using a remote-controlled, isothermal, circulating fluid flow cell. The combination of highly brilliant x-ray source and the use of a flow cell has enabled measurement in real time, of structural characteristics from 10 Å to a few micrometers in size as a function of the changing physical and chemical conditions. Control and online monitoring of flow rate, temperature and pH suspension conditions have permitted real-time studies of the nucleation and growth of the individual n-CeO_2 particles from homogeneous dilute solution over severalhours. Decrease of incubation time with increasing temperature is observed and the activation energy for growth is calculated from the temperature dependent growth rate. Aspects of the nanoparticle nucleation and growth are revealed that have not been observed directly in measurements on this system.

Nanostructure Metamaterials in Near-Infrared and Optical Region

Xiaoxiang Xia

Institute of Physics ,CAS, China

Emai : xiaong@aphy.iphy.ac.cn

In the past decade, metamaterials (MMs) with unique electromagnetic (EM) properties has been an intensive focus in physics and material science. The metamaterials, consisted of metal patterns with sub-wavelength structure, can realize certain EM response which is impossible to obtain in naturally occurring materials, such as negative refractive index, cloaking and “perfect lens”. For the sub-wavelength unit of MMs in near-infrared and optical, nano-fabrication processing with high accuracy is necessary. By using different nanofabrication technologies with both conventional (such as UV, EBL exposal) and fresh (such as nanoimprint, template stripping) processing, a series of metamaterials in high frequency were precisely fabricated. And the new complex EM modulation mechanism in the near-infrared and optical MMs were studied.

Direct Observation of Dendritic Domain Growth with Large Activation Volume in CoFe/Pt Multilayers

Hao-Liang Liu,[1] Wei He,[1] Hai-Feng Du,[1] Qiong Wu,[1] Ya-Peng Fang,[1] Yun Zhu,[2] Jian-Wang Cai,[1] and Zhao-Hua Cheng[1]

[1]State Key Laboratory of Magnetism and Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, P. R. China

[2]College of Physics and Electronic Information Science, Tianjin Normal University, Tianjin 300387, P. R. China

Email: zhcheng@aphy.iphy.ac.cn

CoFe/Pt multilayered structures are promising materials for applications in magnetic recording media,[1] spin-current driven device,[2] and Hall sensors.[3] Most of work dedicated to investigate the magnetic noise[4] and scaling law[5] of this system for fundamental understanding of magnetic properties. However, domain dynamics of magnetization reversal for CoFe/Pt multilayers, closely related to its application such as time stability and irregularity of recording unit, have been seldom investigated. In this talk, we investigated thermally activated magnetization reversal of $[Co0.9Fe0.1(5.0Å)/Pt(20Å)]^4$ multilayers and domain evolution process. Magneto-optical Kerr effect (MOKE) microscope observation demonstrates that a rare nucleation followed by dendritic domain growth with successive branching in the motion of the domain walls. Monte Carlo simulation based on a uniaxial anisotropy model suggests that the macroscopic magnetic properties may be responsible for the dendritic domain growth and a relatively large activation volume, which possibly originates from small uniaxial magnetic anisotropy of the sample, plays a crucial role in the domain growth of this system.

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Carbon Nanotubes and Graphene: from Biological Imaging to Physical Properties and Energy Research

Hongjie Dai

Stanford University, USA

Email: hdai1@stanford.edu

This talk will present our latest results on using carbon nanotubes for biological applications including near-IR imaging of biological systems and NIR fluorescence enhancement by plasmonic gold nanostructures. I will then switch to graphene research, including several methods we developed recently to form ribbons with narrow widths and smooth edges. Atomic structures of GNRs by STM and high resolution TEM will be shown. Magnetic edge states in our GNRs will be discussed. Lastly, hybrid materials of metal oxides with graphene for energy storage and conversion will be presented.

Graphene Oxide as A Chemically Tunable Platform for Optical Applications

Kian Ping Loh,[1] *Qiaoliang Bao*,[1] *Goki Eda2 & Manish Chhowalla*[2, 3]

[1]*Department of Chemistry, National University of Singapore, Singapore*

[2]*Department of Materials, Imperial College London, UK.*

[3]*Department of Materials Science and Engineering, Rutgers University, USA.*

Email:chmlohkp@nus.edu.sg

Chemically derived graphene oxide (GO) is an atomically thin sheet of graphite that has traditionally served as a precursor for graphene, but is increasingly attracting chemists for its own characteristics. It is covalently decorated with oxygen-containing functional groups — either on the basal plane or at the edges — so that it contains a mixture of sp2- and sp3-hybridized carbon atoms. In particular, manipulation of the size, shape and relative fraction of the sp2-hybridized domains of GO by reduction chemistry provides opportunities for tailoring its optoelectronic properties. For example, as-synthesized GO is insulating but controlled deoxidation leads to an electrically and optically active material that is transparent and conducting. Furthermore, in contrast to pure graphene, GO is fluorescent over a broad range of wavelengths, owing to its heterogeneous electronic structure. In this Review, we highlight the recent advances in optical properties of chemically derived GO, as well as new physical and biological applications.

Theory for Engineering Graphene Bandgap

Shengbai Zhang

Rensselaer Polytechnic Institute, Troy, New York 12180

Email: zhangs9@rpi.edu

The ability to engineer bandgap holds the key for graphene-based electronics and optoelectronics. In this talk, two cases will be examined by first-principles calculations. The first case concerns with the opening of band gap with least amount of covalent addition to maintain a high carrier mobility and hence high conductivity. We will introduce a basic principle that dictates univocally what addition pattern should be used for a given coverage. To demonstrate the principle, we examine the upper limit by hydrogen addition for coverage from 0 to 100%. It reveals that the bandgap can be continuously tuned from semimetal to UV insulator. This result defines a roadmap for the design and synthesis of functionalized graphene. The second case concerns with the bifurcation of Dirac fermions upon gap opening by the formation of zigzag nanoribbons. First-principles calculations, coupled with tight-binding modeling, revel that it is an intrinsic property of the Dirac fermions that an ensemble of stable graphene nanoribbons should contain nearly equal amounts of low- and high-gap materials.

Electronic and Spin Transport at Surfaces and Nanostructures

Shuji HASEGAWA and Toru HIRAHARA

Department of Physics, University of Tokyo, Japan

Email: shuji@surface.phys.s.u-tokyo.ac.jp

Conductivity measurements in sub-micron or nano-meter scale with/without spin resolution are of great interest in nanoscience and nanotechnology. For example, nano-electronics such as semiconductor devices requires low and stable electrical resistance of interconnects to maintain device performance. Spin transport is restricted in nanometer scale in many cases because of a short spin-relaxation length. Several kinds of methods to measure the conductivity at nano scales have been developed including fixed electrodes made by microlithography techniques. A method which adopts tips of scanning tunneling microscope (STM) as electrodes, however, has great advantages in positioning of the probes in arbitrary configurations as well as in high spatial resolution of measurements. We have developed a four-tip scanning tunneling microscope (STM) and metal-coated carbon-nanotube (CNT) tips for it, and demonstrated the ability to measure transport properties at nanometer scale. Resistance of self-assembled silicide nanowires on Si(110) surface [1] and damascene Cu nanowires used in LSI industry [2]. The resistance is now measured at 20 nm scale, and individual scattering events are directly seen as discrete change in resistance. By using CNT tips coated with magnetic metal layer, we can measure spin flow as an additional voltage drop by inverse spin-Hall effect. At a surface of strong-spin-orbit coupling materials, we can expect spin-polarized current due to spin-split surface-state bands [3]. By using ultra-thin films of pure Bi, BiSb, BiSe, and BiTe (so-called topological insulators), I will show that the surface-state bands are really spin-split and the Dirac-cone conductivity is directly measured by microscopic four-point probe method. An on-going project to detect the spin-polarization of surface current by using magnetic tips in a four-tip STM will be also introduced.

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Low-temperature STM Investigation of Electronic Structure and Charge Transport of Single Conjugated Molecules

W. Wang, S. Wang and N. Lin

Department of Physics, The Hong Kong University of Science and Technology, Hong Kong

Email: phnlin@ust.hk

In this presentation, I will discuss following three topics based on low-temperature STM studies on single phenyl-based conjugated molecules:

(1) Probing the energy-momentum dispersion of single poly-para-phenyl oligomers of different length. We demonstrate an evolution of a continuous band structure out of discrete molecular orbitals as the oligomers become longer. With the help of tight-binding calculation, we derive conduction band bandwidth, band gap and effective carrier mass of the oligomers. We identify two types of defects and confirm both can effectively destroy the delocalization of the polymers.[1]

(2) Demonstrating due to the localization characteristics of molecular orbitals, the Cu-atom contact modifies the state localized at the end group of a molecule which is in contact with the Cu atom but does not affect the states localized at other parts of the molecule. We fabricate atom-molecule contacts by attachment of single Cu atoms to the end functional group(s) of bis-terpyridine tetra-phenyl ethylene molecules. These results illustrate the contact effects at individual orbitals and offer possibilities to manipulate orbital alignments within molecules.[2]

(3) Characterizing the single-molecule conductance of bis-terpyridine tetra-phenyl ethylene molecules adsorbed on mono-atomic thick CuN patches grown on a Cu(100) substrate. Site-dependent tunneling spectra evidence that electrons tunnel through a series of vibronic states of the tetra-phenyl ethylene group lying in a double-barrier-tunneling junction. Surprisingly, as the end group(s) adsorbed on Cu with strong coupling, the tetra-phenyl ethylene group which was adsorb on a CuN patch retained the double-barrier-tunneling behaviors. This phenomenon can be understood with introducing intra-molecular capacitance and an effective capacitance of 0.9 aF (3.4 aF) for single (double) molecular group(s) has been derived.[3]

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A New Avenue towards Colossal Magnetoresistance in Organic Materials

Jian Shen

Department of Physics, Fudan University, Shanghai, China

Email: shenj5494@yahoo.com

Talk Abstract: A major challenge for the field of organic spintronics is how to achieve large magnetoresistance (MR) in a reliable manner. We have developed a new avenue that dramatically improves MR up to 80,000%. The devices prepared by the conceptually new method are highly reliable as well.

Continuous Hysteresis Control in Organic Field Effect Transistors

Ming Liu

Laboratory of Nano-Fabrication and Novel Devices Integrated Technology, Institute of Microelectronics, Chinese Academy of Sciences, Beijing 100029,

Email: liuming@ime.ac.cn

Hysteresis effect of organic field effect transistors (OFETs) has been observed when the devices were applying bidirectional sweeping gate voltage under light irradiation [1]. The OFETs that with light induced hysteresis effect have great potential in the application of light detection and memory in a single organic device for organic photoelectric integration [2-3]. However, it is difficult to strictly control the hysteresis window in a single device. In this talk, using pentacence as semiconductors, hysteresis properties of the OPTs were studied and it is found the hysteresis window could be continuous controlled by controlling the grain size of semiconductor film, the electric dipoles in dielectrics and the applied electric field. The mechanism for control of hysteresis effect was proposed.

Plasmonic Bus and Logic Gates in Silver Nanowire Networks for On-Chip Integrated Optical Computing

Hongxing Xu

Institute of Physics ,CAS, China

Email: hongxingxu@aphy.iphy.ac.cn

Modern electronics based on semiconductors is meeting the fundamental speed limit caused by the interconnect delay and large heat generation when the sizes of components reach nanometer scale. Photons as a carrier of the information are superior to electrons in bandwidth, density, speed, and dissipation. More over, photons could carry intensity, polarization, phase, and frequency information which could break through the limitation of binary system as in electronic devices. But due to the diffraction limitation, the photonic components and devices can not be fabricated small enough to be integrated densely. Surface plasmon polariton is quanta of collective oscillations of free electrons excited by photons in metal nanostrucrures, which offers a promising way to manipulate light at the nanoscale and to realize the miniaturization of photonic devices. Hence, plasmonic circuits and devices have been proposed for some time as a potential strategy for advancing semiconductor-based computing beyond the fundamental performance limitations of electronic devices, as epitomized by Moore's law.

Here we investigate plasmon propagation on branched silver nanowires by using polarization dependent scattering spectroscopy. By controlling the polarization of the incident laser light, the wire plasmons can be routed into different wire branches and result in light emission from the corresponding wire ends. This routing behavior is found to be strongly dependent on the wavelength of light. Thus for certain incident polarizations, light of different wavelength will be routed into different branches. The branched nanowire can thus serve as a controllable router and multiplexer in integrated plasmonic circuits.

In branched NW structures composed of a primary NW and a branch NW, the plasmons on the NW can also be excited by laser illumination at the branch tip. If two plasmon beams are generated on the primary NW by excitation at the primary NW tip and the branch tip, these two beams will interfere on the NW and modulate the near field distribution and the output scattering intensity. Plasmonic OR, XOR or NOT gates can be obtained by tuning the intensity, the phase and the polarization of the incident lasers in a single branched silver nanowire structure. In a more complex nanowire network consisting of a primary wire with an additional input and an additional output, the interference of two plasmon beams by changing incident light polarizations and phases can result in controllable “ON” or “Off” light scattering behaviors in two outputs. By defining specific intensity thresholds for “ON” and “OFF”states of the outputs, additional logic operations can be realized, e.g. plasmonic AND gate and Half Adder.

It is interesting to note that all the plasmonic devices demonstrated here are based on the same principle: interference of plasmons in a primary wire with those introduced by a secondary, adjacent nanowire, or in a reverse way routing plasmons from the primary wire to the adjacent wire. This primary wire can thus be viewed as the plasmonic equivalent of a bus in a central processing unit. By loading the primary wire with plasmons launched with specific input properties at the secondary input NWs, the resulting plasmonic interference enables routing and out-coupling to specific output NWs. We believe this concept can be further generalized and expanded to more complex structures that can combine optical signals in various ways, and that a multiple-input, multiple-output plasmonic bus may serve as an efficient splitter, router, switcher and/or multiplexer in future complex plasmonic networks designed for computation and information processing functions. It worthwhile to note that the phase sensitivity of the plasmon structures presented here presents significant challenges for cascaded devices, as one would find in information processing applications. Precise design and fabrication criteria with specific plasmon propagating lengths for phase control would be a necessary requirement for practical plasmon-based interferometric logic. Such cascaded devices will be also discussed.

Engineering of Graphene Nanostructures for Electronics

Guangyu Zhang

Nanoscale Physics and Devices Lab, Institute of Physics, CAS, Beijing 100190, China

E-mail: gyzhang@aphy.iphy.ac.cn

Graphene shows great potential for future electronics due to its extraordinary electrical properties and structure-tailorable nature. Controlling the graphene's structure, including it morphology, sizes, and edges, is crucial during graphene fabrication process as these factors can affect the electric properties of graphene strongly, especially for confined structures. In this talk, we present our recent progress on engineering of graphene nanostructures by lithographic and etching assisted fabrication techniques. We developed a dry anisotropic etching technique for graphene, which has been proposed as a key technique for controllable graphene edge fabrication with atomic precision etching method for graphite/graphene. We are also able to create periodic graphene ripples by controlling the surface morphology of graphene on flexible substrates. Electrical transport and some devices applications based on these unique structures will be discussed.

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High Quality Graphene on Ru(0001) and its Universal Template Effect

Yi Pan, Min Gao, Haigang Zhang, Jinhai Mao, Wende Xiao, Shixuan Du, and Hong-jun Gao

Institute of Physics, Chinese Academy of Sciences, PO Box 603, Beijing 100190, China

E-mail: hjgao@aphy.iphy.ac.cn

Because of its novel physical properties and attractive potential applications, graphene has been a hot topic in the passed few years. As a basis of further intensive research, the reliable methods to produce high quality, large scale, and single-crystalline graphene are of crucial importance. We achieved that by growing graphene on Ru(0001) simply through thermal annealing of a ruthenium single crystal containing carbon.[1] A hexagonal Moiré pattern was formed because of the lattice mismatch. Low-energy electron diffraction (LEED) measurements indicate that the graphene covered the whole surface of the Ru substrate with good long-range order; scanning tunneling microscopy (STM) images show perfect crystallinity and continuity at substrate edges. This ordered Moiré pattern of graphene on Ru can be used as templates to grow mono-dispersed metal nanoclusters (NCs) or molecular superstructure. Using this template, we successfully fabricated monodispersed platinum NCs. [2] The Pt NCs are directed to nucleate at a unique site in the Moiré unit cell, and grow in a layer-by-layer mode up to 4-atomic-layer height without coalescence at room temperature. The size of Pt NCs can be controlled by tuning the coverage. This system may find application in the study of Pt nanocatalyst. Following the lattice of Moiré pattern of graphene on Ru, the template-directed supramolecular Kagome lattices of Pc molecules can be obtained. [3] Varying the central metal ion of the Pc molecule affords Kagome lattices with tunable molecular spins, providing ideal 2D model systems for studying spin frustration.

Our findings offer an effective method for producing high-quality single-crystalline graphene for fundamental research, as well as a great Moiré pattern based template for fabrication of organic and inorganic nanoarchitectures with remarkable properties.

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Xiangtan Part

Aberration-Corrected STEM and First-Principles Theory: Insights into Energy Materials

S. J. Pennycook[1,2], M. Varela[1], T. J. Pennycook[2,1], W. Zhou[1,2], J. C. Idrobo[1,2], J. Lee[1,2], H. J. Chang[1], D. N. Leonard[1], M. P. Oxley[1,2], A. Y. Borisevich[1] and S. T. Pantelides[2,1]

[1]*Materials Science and Technology Division, Oak Ridge National Laboratory, TN, USA*

[2]*Department of Physics and Astronomy, Vanderbilt University, TN, USA*

E-mail: pennycooksj@ornl.gov

The recent introduction of next-generation aberration correctors has propelled the capabilities of the scanning transmission electron microscope (STEM) to even higher levels, allowing quantitative imaging of light atoms with the annular dark field (ADF) and annular bright field (ABF) detectors and two-dimensional spectroscopic mapping of composition and electronic structure. Several case studies of complex oxides for energy applications will be presented, showing how microscopy data can be compared to results of density functional calculations to provide microscopic insights into functionality.

ADF images of $LiFePO_4$ are able to resolve Li columns. Many of these columns show anomalous intensities, suggesting occupation by Fe. Spectroscopic analysis of such sites confirms the presence of Fe, and shows it to be in a $^{+2}$ configuration instead of the expected +1 for Li. Theoretical simulations indicate the origin of the effect and explain the anisotropic Li diffusivity in the plane.

Insights into solid oxide fuel cell cathodes include the imaging of O vacancy clustering, the formation of an amorphous phase on cycling, as well as the generation of voids and cracks. In the case of multiferroics, the influence of interfaces on local properties will be shown, mediated by the suppression of octahedral rotations that cause local changes in lattice parameters and electronic structure [1]. Finally, future mapping of solar cell efficiency through electron-beam-induced current and mapping of light emission by cathodoluminescence will be discussed.

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Linear Propulsion of a Molecular Machine After Fuelling with Electrons

Karl-Heinz Ernst[1,2]

[1]*Empa, Swiss Federal Laboratories for Materials Science and Technology, Dübendorf*

[2]*University Zurich, Winterthurerstrasse, Zürich*

E-mail: karl-heinz.ernst@empa.ch

Adsorbate motions are the most fundamental steps in surface chemistry. In particular when collisionswith other reaction partners or reactive surface sites are required, adsorbate motions are typically therate-determining steps of a heterogeneously catalyzed reaction. Studying the movement of adsorbates,induced by phonons, photons, or electrons, is therefore of paramount interest. Manipulation of singlemolecules at surfaces with the scanning tunneling microscope (STM) has been performed for morethan a decade. However, the mechanisms of molecular excitation by electrons that inelastically tunnelthrough the molecule are not entirely understood. We will present results of manipulation experimentsperformed with single molecules of the hydrocarbon propene on Cu(211). Propene was found in two different adsorbate geometries, both appearing as two distinct enantiomorphs, i.e., in two mirrorconfigurations.The adsorption geometry has been identified via density-functional theory (DFT).Inelastical electron tunneling (IET) has been applied to excite molecular vibrations in the molecule.Exceeding the threshold energy for certain vibration excitations, we observe different actions of themolecule at the surface. This includes hopping, rotation, inversion of the handedness anddehydrogenation [1-3]. All actions are mode-selective, that is, only certain vibrations cause a certainaction. The product of the single molecule chemical reaction has been identified in turn by IET-actionspectroscopy, i.e., hopping was observed after excitation of a C-H stretching vibration in the =CH2 group of the product molecule.
Finally, we report the activation of a chiral molecular rotor (Fig. 1) by electron attachment that leadsto unidirectional rotation [4].

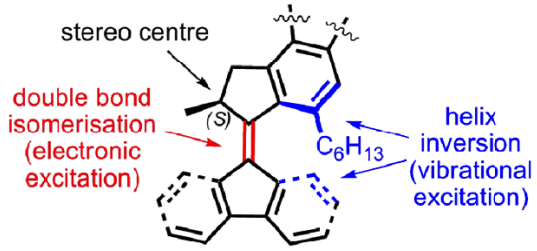

Fig. 1. A helical molecular motor undergoes unidirectional rotation in two steps.

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Probing the Energetics and Dynamics of Individual Atomic Spins on Surfaces

Andreas J. Heinrich

Almaden Research Center, IBM, USA

E-mail: heinrich.andreas@gmail.com

The scanning tunneling microscope has been an extremely successful experimental tool because of its atomic scale spatial resolution. In recent years this has been combined with the use of low temperatures, culminating in microvolt energy resolution. However the time resolution of typical STM experiments is limited to about one millisecond for spectroscopy on a single atom. In this talk we will discuss the use of inelastic tunneling spectroscopy with low-temperature STM for the study of spins, a technique coined spin-excitation spectroscopy. With this approach it is possible to measure the energy eigenstates of the quantum spin Hamiltonian that describes spins on surfaces with very high precision. We will briefly discuss its application to the measurement of the Zeeman energy and to magneto-crystalline anisotropy. We will then focus on a new way of achieving fast time resolution based on an all-electrical pump probe spectroscopy. In this approach, a strong voltage pulse applied between tip and sample drives a spin out of thermal equilibrium (the pump pulse) [Nature Physics 6, 340 (2010)]. A short time later (typically a few nanoseconds) a smaller voltage pulse (the probe pulse) is applied which probes the state of the system. I will demonstrate this technique for the measurement of the spin relaxation time of individual magnetic atoms [Science 329, 1628 (2010)] and chains of atoms on a surface.

Electronic and Spin Transport at Surfaces and Nanostructures

Shuji HASEGAWA and Toru HIRAHARA

Department of Physics, University of Tokyo, Japan

Email: shuji@surface.phys.s.u-tokyo.ac.jp

Conductivity measurements in sub-micron or nano-meter scale with/without spin resolution are of great interest in nanoscience and nanotechnology. For example, nano-electronics such as semiconductor devices requires low and stable electrical resistance of interconnects to maintain device performance. Spin transport is restricted in nanometer scale in many cases because of a short spin-relaxation length. Several kinds of methods to measure the conductivity at nano scales have been developed including fixed electrodes made by microlithography techniques. A method which adopts tips of scanning tunneling microscope (STM) as electrodes, however, has great advantages in positioning of the probes in arbitrary configurations as well as in high spatial resolution of measurements. We have developed a four-tip scanning tunneling microscope (STM) and metal-coated carbon-nanotube (CNT) tips for it, and demonstrated the ability to measure transport properties at nanometer scale. Resistance of self-assembled silicide nanowires on Si(110) surface [1] and damascene Cu nanowires used in LSI industry [2]. The resistance is now measured at 20 nm scale, and individual scattering events are directly seen as discrete change in resistance. By using CNT tips coated with magnetic metal layer, we can measure spin flow as an additional voltage drop by inverse spin-Hall effect. At a surface of strong-spin-orbit coupling materials, we can expect spin-polarized current due to spin-split surface-state bands [3]. By using ultra-thin films of pure Bi, BiSb, BiSe, and BiTe (so-called topological insulators), I will show that the surface-state bands are really spin-split and the Dirac-cone conductivity is directly measured by microscopic four-point probe method. An on-going project to detect the spin-polarization of surface current by using magnetic tips in a four-tip STM will be also introduced.

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Nucleation and Growth of Nano Ceria: Experimental Real-time Study

Siu-Wai Chan

Columbia University, USA

Email: sc174@columbia.edu

Many properties of nanoparticles depend on their size, while technological applications depend on the degree of their size distribution. Ideally, if all particles are nucleated at the same time and grow together, all particles will have the same size and therefore, the same properties, enabling maximum control. Such control of material properties will underpin their productive applications. Yet details about the nucleation and growth of nanoparticles are often a black-box event. Here we study a proven synthesis that yields near mono-disperse nanoparticles. Results are presented for an in situ synchrotron-based ultra-small-angle X-ray scattering (USAXS) study of the solution mediated precipitation of nanocrystalline ceria (n-CeO_2) using a remote-controlled, isothermal, circulating fluid flow cell. The combination of highly brilliant x-ray source and the use of a flow cell has enabled measurement in real time, of structural characteristics from 10 Å to a few micrometers in size as a function of the changing physical and chemical conditions. Control and online monitoring of flow rate, temperature and pH suspension conditions have permitted real-time studies of the nucleation and growth of the individual n-CeO_2 particles from homogeneous dilute solution over severalhours. Decrease of incubation time with increasing temperature is observed and the activation energy for growth is calculated from the temperature dependent growth rate. Aspects of the nanoparticle nucleation and growth are revealed that have not been observed directly in measurements on this system.

How Photons Turn the Electrons

Thomas Greber

University of Zürich

Email: greber@physik.unizh.ch

Photoemission with circularly polarized light results in the transfer of angular momentum to the emitted electrons [1]. For the case of a magnetic system it is shown that this rotation is reflected in the x-ray circular dichroism as measured by angular and energy resolved photoemission[2].

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Carbon Nanotubes and Graphene: from Biological Imaging to Physical Properties and Energy Research

Hongjie Dai

Stanford University, USA

Email: hdai1@stanford.edu

This talk will present our latest results on using carbon nanotubes for biological applications including near-IR imaging of biological systems and NIR fluorescence enhancement by plasmonic gold nanostructures. I will then switch to graphene research, including several methods we developed recently to form ribbons with narrow widths and smooth edges. Atomic structures of GNRs by STM and high resolution TEM will be shown. Magnetic edge states in our GNRs will be discussed. Lastly, hybrid materials of metal oxides with graphene for energy storage and conversion will be presented.

Theory for Engineering Graphene Bandgap

Shengbai Zhang

Rensselaer Polytechnic Institute, Troy, New York 12180

Email: zhangs9@rpi.edu

The ability to engineer bandgap holds the key for graphene-based electronics and optoelectronics. In this talk, two cases will be examined by first-principles calculations. The first case concerns with the opening of band gap with least amount of covalent addition to maintain a high carrier mobility and hence high conductivity. We will introduce a basic principle that dictates univocally what addition pattern should be used for a given coverage. To demonstrate the principle, we examine the upper limit by hydrogen addition for coverage from 0 to 100%. It reveals that the bandgap can be continuously tuned from semimetal to UV insulator. This result defines a roadmap for the design and synthesis of functionalized graphene. The second case concerns with the bifurcation of Dirac fermions upon gap opening by the formation of zigzag nanoribbons. First-principles calculations, coupled with tight-binding modeling, revel that it is an intrinsic property of the Dirac fermions that an ensemble of stable graphene nanoribbons should contain nearly equal amounts of low- and high-gap materials.

Low-temperature STM Investigation of Electronic Structure and Charge Transport of Single Conjugated Molecules

W. Wang, S. Wang and N. Lin

Department of Physics, The Hong Kong University of Science and Technology, Hong Kong

Email: phnlin@ust.hk

In this presentation, I will discuss following three topics based on low-temperature STM studies on single phenyl-based conjugated molecules:

(1) Probing the energy-momentum dispersion of single poly-para-phenyl oligomers of different length. We demonstrate an evolution of a continuous band structure out of discrete molecular orbitals as the oligomers become longer. With the help of tight-binding calculation, we derive conduction band bandwidth, band gap and effective carrier mass of the oligomers. We identify two types of defects and confirm both can effectively destroy the delocalization of the polymers.[1]

(2) Demonstrating due to the localization characteristics of molecular orbitals, the Cu-atom contact modifies the state localized at the end group of a molecule which is in contact with the Cu atom but does not affect the states localized at other parts of the molecule. We fabricate atom-molecule contacts by attachment of single Cu atoms to the end functional group(s) of bis-terpyridine tetra-phenyl ethylene molecules. These results illustrate the contact effects at individual orbitals and offer possibilities to manipulate orbital alignments within molecules.[2]

(3) Characterizing the single-molecule conductance of bis-terpyridine tetra-phenyl ethylene molecules adsorbed on mono-atomic thick CuN patches grown on a Cu(100) substrate. Site-dependent tunneling spectra evidence that electrons tunnel through a series of vibronic states of the tetra-phenyl ethylene group lying in a double-barrier-tunneling junction. Surprisingly, as the end group(s) adsorbed on Cu with strong coupling, the tetra-phenyl ethylene group which was adsorb on a CuN patch retained the double-barrier-tunneling behaviors. This phenomenon can be understood with introducing intra-molecular capacitance and an effective capacitance of 0.9 aF (3.4 aF) for single (double) molecular group(s) has been derived.[3]

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Engineering of Graphene Nanostructures for Electronics

Guangyu Zhang

Nanoscale Physics and Devices Lab, Institute of Physics, CAS, Beijing 100190, China

E-mail: gyzhang@aphy.iphy.ac.cn

Graphene shows great potential for future electronics due to its extraordinary electrical properties and structure-tailorable nature. Controlling the graphene's structure, including it morphology, sizes, and edges, is crucial during graphene fabrication process as these factors can affect the electric properties of graphene strongly, especially for confined structures. In this talk, we present our recent progress on engineering of graphene nanostructures by lithographic and etching assisted fabrication techniques. We developed a dry anisotropic etching technique for graphene, which has been proposed as a key technique for controllable graphene edge fabrication with atomic precision etching method for graphite/graphene. We are also able to create periodic graphene ripples by controlling the surface morphology of graphene on flexible substrates. Electrical transport and some devices applications based on these unique structures will be discussed.

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Rational Synthesis of Metallic Nanoparticles for Catalytic Applications

Shouheng Sun

Department of Chemistry, Brown University, Providence, RI 02912, USA.

Email: Shouheng_Sun@brown.edu

Using solution phase-based thermal decomposition and reduction chemistry, we have synthesized a series of monodisperse metallic (Fe, Co, Ni, Pd, Pt, Au) and their alloy nanoparticles (NPs). The metallic NPs can serve as seeds for the production of structurally more complicated core/shell Mc/Ms (Mc = Pd, Au, AgAu, or NiPd; Ms = Au, FePt, or Au/FePt) NPs. By tuning the sizes, compositions and shell thickness, these NPs have been made catalytically more active and durable for the reduction of oxygen, for the oxidation of formic acid/methanol and for the hydrolytic formation of hydrogen from ammonia borane. The work demonstrates that the solution phase-based "bottom-up" synthesis is a reliable approach to highly efficient NP catalyst for practical catalytic applications.

A New Avenue towards Colossal Magnetoresistance in Organic Materials

Jian Shen

Department of Physics, Fudan University, Shanghai, China

Email: shenj5494@yahoo.com

Talk Abstract: A major challenge for the field of organic spintronics is how to achieve large magnetoresistance (MR) in a reliable manner. We have developed a new avenue that dramatically improves MR up to 80,000%. The devices prepared by the conceptually new method are highly reliable as well.

Controlled Synthesis of Nanostructured Catalysts

Sheng Dai

Chemical Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6201

Department of Chemistry, University of Tennessee, Knoxville, TN 37966

Email: dais@ornl.gov

Catalysis is critically important to energy production and to meeting the environmental quality mission of promoting the development and utilization of clean, efficient, and reliable energy resources. It is essential to understand the relationships between the atomic and nanoscale structure of metal nanoparticles and catalyst supports and the crucial role these play in promoting or altering catalytic pathways. The key focus of this talk lies in the controlled synthesis of metallic catalysts with unique metal-support interactions and nanostructured nonmetallic catalysts for heterogeneous catalysis. Critical issues and emerging science and technology in heterogeneous catalysis will be discussed in context of controlled synthesis.

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Electronic Instabilities, Fluctuations, and Transport in Epitaxial Nanowires

Hanno H. Weitering

Department of Physics and Astronomy, The University of Tennessee, Knoxville, TN 37931, USA

Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA

Email: hanno@utk.edu

Quantum transport is at the heart of nanoscience and marries a fundamental law of nature — quantum mechanics — with applied electrical engineering and emerging materials technologies. Ultimately, nanoscale electronic devices will contain networks of wires whose cross sections will be so small as to represent one-dimensional conductors with novel transport properties. We have fabricated exceptionally long and uniform YSi2 nanowires via self-assembly of yttrium atoms on Si(001). The wire widths are quantized in odd multiples of the Si substrate lattice constant. The thinnest wires represent one of the closest realizations of the isolated Peierls chain, exhibiting van Hove type singularities in the one-dimensional density of states and charge order fluctuations below 150 K. Conduction through individual nanowires follows an inverse Arrhenius behavior, indicative of thermally-assisted tunneling of small polarons between defect centers. Quantitative analysis of individual wire resistances, probe resistances, and negative differential resistances of nanowire networks indicates significant electronic interwire coupling below 150 K. The long-range coupling mechanism involves the dielectric polarization of the substrate, which induces current blockades in neighboring conduction channels.

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Tuning Transport Properties of Quantum Films

Jianxin Zhong

Institute for Quantum Engineering and Micro-Nano Energy Technology,

Xiangtan University, Hunan 411105, China

Email: jxzhong@188.com

Recent breakthrough in epitaxial growth of high-quality two-dimensional (2D) crystals such as graphene and topological insulators have opened the way for fundamental study of novel quantum phenomena in 2D quantum films. The physical properties of 2D quantum films are sensitive to structural changes because of the more direct manifestation of quantum effects at reduced dimensionality. In this talk, I will present theoretical proposals for effective tuning of electronic transport properties in 2D quantum films by structural changes, focusing on doping, folding, strain, and substrate effects in graphene and ultra-thin films of topological insulators.

Interface Structures and Anomalous Physical Properties of Highly Epitaxial Double Perovskite $LaBaCo_2O_{5.5}$ Thin Films

Chonglin Chen

Department of Physics and Astronomy, University of Texas at San Antonio, Texas and

The Texas Center for Superconductivity and Department of Physics, University of Houston, Texas

E-mail: Cl.Chen@utsa.edu

Interface engineered material has attracted more and more attention in the multifunctional materials research and active device fabrication. It plays a key role to control the physical properties of advanced nanomaterials and results in the discovery of various new physical phenomena with excellent opportunity for developing new metamaterials for active devices and engineered nanosystems. We have systematically studied the structures of perovskite $LaBaCo_2O_{5.5}$ thin films and their Anomalous Physical Properties. Also, a series of models were developed to understand these interface phenomena. Details will be presented in the talk.

Dr. C. L. Chen is currently a professor of physics at the Department of Physics and Astronomy in the University of Texas at San Antonio and a joint professor at the Texas Center for Superconductivity at the University of Houston (TcSUH). He received his Ph. D. degree in solid state science from the Pennsylvania State University in 1994. He was the Director's Funded Post-doctoral Fellow in the Los Alamos National Laboratory before he became a faculty member at TcSUH in June 1996. His research interests have spanned over the areas of multifunctional oxide thin film epitaxy, nanostructure fabrication, surface and interface physics and chemistry, and modeling developments. He has authored and/or coauthored more than 100 refereed papers that have appeared in Nature, Physical Review Letters, Applied Physics Letters, and others, and has delivered near 150 plenary lectures or invited talks at international/national conferences (MRS, ACerS, IMRUS, etc.), universities, and research institutes. He has served as international advisory board members in various international conferences, chair and/or co-chair in several international and national symposiums such as the American Ceramics Society, Materials Science and Engineering, and others. His current researches are supported by NSF-NIRT and CMS programs, Department of Energy, Army Research Office, Texas Advanced Research Program, the State of Texas through the TcSUH, government labs, etc.