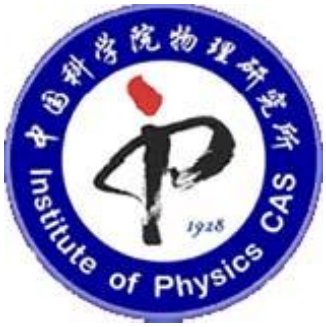
2010 International Workshop on

Nanomaterials & Nanodevices

July 1st-6th, Beijing-Guiyang, China



July 1st-3rd, 2010

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

July 4th-6th, 2010

Guizhou University, Guiyang, China

Chinese Academy of Science & State Administration of Foreign Experts Affairs

Institute of Physics, Chinese Academy of Sciences

Guizhou University

Bureau of Science and Technology, Guizhou Province

“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, 2010)

Scientific Program

July 1st, Thursday, IOP Building D 212	
8: 30－ 8：40	**Opening Ceremony and Welcome Remarks** **Jian Shen** *(Oak Ridge National Laboratory, USA)* **Hongjun Gao** *(Institute of Physics ,CAS, China)*
8：40－10：30	**Session 1** *Chair:* **Stephen Y. Chou**
8：40－9：15	**Hrvoje Petek** *(University of Pittsburgh, USA)* “Imaging the Femtosecond Time Scale Correlated Electron-Nuclear Dynamics in Surface Photodesorption”
9：15－9：50	**Karl-Heinz Ernst** *(Swiss Federal Laboratories for Materials Testing and Research (EMPA), Switzerland)* “Symmetry Aspects in two-dimensional Crystals: Enantiomorphism, Tiling and Phase Transitions”
9：50－10：25	**Orlando Auciello** *(Argonne National Laboratory, USA)* “Science and Technology of Multifunctional Thin Films and Application to Multifunctional Micro and Nano Devices”
10：25－10：3 5	Coffee Break and Photos

10：35－12：20	**Session 2** *Chair:* **Hrvoje Petek**
10：35－11：10	**Stephen Y. Chou** *(Princeton University, USA)* “Nanostructure Engineering – A Path to Discovery and Innovation ”
11：10－11：45	**Yongfeng Lu** *(University of Nebraska Lincoln, USA)* “Laser Processing of Nanomaterials with Spectral and Spatial Controllability”

11：45－12：20	**Xin Jiang** *(University Siegen, Germany)* "Effects of Catalysts on the Growth of Carbon Nanostructures"
12：20	Lunch (IOP Restaurant)

13：30－16：20	**Session 3** *Chair:* **Hongjie Dai**
13：30－14：05	**Ludwig Bartels** *(University of California, USA)* "Walking Molecules & Molecule Carriers: What Guided Molecular Motion can Teach us about Adsorbate-Adsorbate and Adsorbate-Substrate Interactions"
14：05－14：40	**Siu-Wai Chan** *(Columbia University, USA)* "Cu-CeO_2 Nanoparticles as a Water-Gas Shift Catalyst and Au-(111) Fe_3O_4 Surface for CO Oxidation and Water-Gas-Shift Reactions"
14：40－15：15	**Christian A. Bobisch** *(University of Duisburg-Essen, Germany)* "Scattering of Surface State Electrons at Defects"
15：15－15：35	**Hong Li** *(Institute of Physics, CAS, China)* "Si Anode for Li-ion Batteries: from Nano to Nano-Microcomposite"
15：35－15：55	**Zhaohua Cheng** *(Institute of Physics, CAS, China)* "Determination of Magnetic Anisotropy in Magnetic Nanowires via FMR and Monte Carlo Simulation"
15：55－16：05	Coffee Break

16：05－18：10	**Session 4** *Chair:* **Ludwing Bartels**
16：05－16：40	**Hongjie Dai** *(Stanford University, USA)* "Carbon Nanotubes and Graphene Nanoribbons"
16：40－17：15	**Min Ouyang** *(Maryland University, USA)* "Precisely Tailored Zero-Dimensional Nanostructures"
17：15－17：50	**W. A. Hofer** *(The University of Liverpool, UK)* "Manufacturing and Manipulating Molecular Devices on Metal Substrates"
17：50－18：10	**Shixuan Du** *(Institute of Physics, CAS, China)* "Diffusivity Control in Molecule-on-metal Systems Using Electric Fields"

July 2nd, Friday, IOP Building D 212	
8：30－10：35	**Session 5** *Chair:* **Stephen J. Pennycook**
8：30－9：05	**Hongkun Park** *(Harvard University, USA)* "Vertical Nanowires Arrays: a New Tool for Biology"
9：05－9：25	**Jian Shen** *(Oak Ridge National Laboratory, USA)* "Giant Magnetoresistance in Organic Spin Valves"
9：25－9：45	**Wenjun Zhang** *(City University of Hong Kong, China)* "Understanding and Controlling Nanomaterials Properties Based on a Core/shell Model"
9：45－10：05	**Shouheng Sun** *(Brown University, USA)* "Synthesis and Applications of FePt and Their Composite Nanoparticles"
10：05－10：25	**Hongqi Xu** *(Lund University, Sweden)* "Electron Transport through Semiconductor Nanowire Quantum Structures"
10：25－10：35	Coffee Break

10：35－12：10	**Session 6** *Chair:* **Hongkun Park**
10：35－11：10	**Sheng Dai** *(Oak Ridge National Laboratory, USA)* "Ionic Liquids for Controlled Synthesis of Functional Materials"
11：10－11：30	**Chonglin Chen** *(University of Texas, San Antonio, USA)* "Interface Magic in Nanostructural Metamaterials"
11：30－11：50	**Xincheng Xie** *(Oklahoma State University, USA/Institute of Physics, CAS, China)* "Some Aspects of Correlation Effect in Quantum Dots"
11：50－12：10	**Ming Liu** *(Institute of Microelectronics, CAS, China)* "Nonvolatile Storage Effect and Mechanism in Cu Doped ZrO2 Based RRAM"
12：10	Lunch (IOP Restaurant)

13：30－16：40	**Session 7** *Chair:* **Orlando Auciello**
13：30－14：05	**Stephen J. Pennycook** *(Oak Ridge National Laboratory, USA)* "Nanoscale Structure-Property Relations through Aberration-Corrected Scanning Transmission Electron Microscopy"
14：05－14：40	**Jiandi Zhang** *(Louisiana State University, USA)* "Nanoscale Domains and Domain Boundaries at the Surface of $BaFe_2As_2$: Mirroring the Bulk Spin Structure"
14：40－15：00	**Wuxia Li** *(Institute of Physics, CAS, China)* "Enhanced Superconductivity of Nanoscale Tungsten Grown by Focused-ion-beam for Maskless Device Fabrications"
15：00－15：35	**Xuan Gao** *(Case Western Reserve University, USA)* "Electron Transport Phenomena in Semiconductor and Topological Insulator Nanowires"
15：35－15：55	**Yongqing Li** *(Institute of Physics, CAS, China)* "Field Effect Devices Based on a Topological Insulator Material"
15：55－16：30	**Hongbin Yu** *(Arizona State University, USA)* "Nanoscale Materials and Structures for Transparent and Flexible Electronic and Optoelectronic Applications"
16：30－16：40	Coffee Break

16：40－18：00	**Session 8** *Chair:* **Xincheng Xie**
16：40－17：00	**Xudong Xiao** *(Chinese University of Hongkong, China)* "Size Dependent Superconductivity of Pb Islands Grown on Si (111)"
17：00－17：20	**Thomas Zac Ward** *(Oak Ridge National Laboratory, USA)* "Strain Tunable Transport in Manganites: Tailoring Emergent Electronic Phase Separation"
17：20－17：40	**Yi Shi** *(Nanjing University, China)* "Realization of Lateral Electrical Contacts on Semiconductor Nanowires"
17：40－18：00	**Haiming Guo** *(Institute of Physics, CAS, China)* "Tunable Interfacial Properties of Epitaxial Graphene on Metal Substrates"

July 3rd, Saturday, IOP Building D 212	
8：30－11：10	**Session 9** *Chair:* **Karl-Heinz Ernst**
8：30－9：05	**Andrea C. Ferrari** *(University of Cambridge, UK)* "Graphene Photonics and Optoelectronics"
9：05－9：40	**Maria Varela** *(Oak Ridge National Laboratory, USA)* "Atomic Resolution Imaging of O Positions in Perovskites by Spectrum Imaging"
9：40－9：50	Coffee Break
9：50－10：25	**Hongxing Xu** *(Institute of Physics, CAS, China)* "Controllable Propagating Plasmons on Metal Nanowire"
10：25－11：00	**Guangyu Zhang** *(Institute of Physics, CAS, China)* "Engineering of Graphene Nanostructures by Anisotropic Etching"
11：00	**Closing Remarks** **Shouheng Sun**

“中科院-国家外专局纳米材料与器件研究国际合作团队”
（贵阳部分）
International Workshop on Nanomaterials and Nanodevices

(Guiyang part, July 4th, 2010)

Scientific Program

July 4th, Sunday	
8: 30－ 9：00	**Opening Ceremony and Welcome Remarks** *Chair:* **Baoan Song** *(Vice President of Guizhou University)*
8: 30－ 8：40	**Shuping Chen** *(President of Guizhou University)* “Introduction to Guizhou University”
8: 40－ 8：50	**Jie Yu** (*Director of Bureau of Science and Technology, Guizhou Province)* “Welcome Remarks”
8: 50－ 9：00	**Wei Wei** *(Director of Colleage of Science Guizhou University)* “Introduction to Colleage of Science Guizhou University”
9：00－10：15	**Session 1** *Chair:* **W. A. Hofer**
9：00－9：25	**Hongjie Dai** *(Stanford University, USA)* “Carbon Nanotubes and Graphene Nanoribbons”
9：25－9：50	**Stephen J. Pennycook** *(Oak Ridge National Laboratory, USA)* “Imaging and Identification of Light Atoms in BN and Graphene Monolayers”
9：50－10：15	**Orlando Auciello** *(Argonne National Laboratory, USA)* “Science and Technology of Multifunctional Thin Films and Application to Multifunctional Micro and Nano Devices”
10：15－10：25	Coffee Break

10：25－12：30	**Session 2** *Chair:* **Siu-Wai Chan**
10：25－10：50	**Hongkun Park** *(Harvard University, USA)* “Optoplasmonic Engineering of Light-Matter Interactions”

10：50－11：15	**Stephen Y. Chou** *(Princeton University, USA)* "Nanostructure Engineering – A Path to Discovery and Innovation"
11：15－11：40	**Hrvoje Petek** *(University of Pittsburgh, USA)* "Ultrafast Photoemission Electron Microscopy: Imaging Nonlinear Plasmonic Phenomena on the Femto/Nano Scale"
11：40－12：05	**Christian A. Bobisch** *(University of Duisburg-Essen, Germany)* "Visualization of Molecular Switching"
12：05－12：30	**Zhao Ding** *(Guizhou University, China)* "The Study on Semiconductor, Superconductor and Devices"
12：30	Lunch

13：30－16：20	**Session 3** *Chair:* **Xin Jiang**
13：30－13：55	**Ludwig Bartels** *(University of California, USA)* "The Power of Confinement: Adsorbate Dynamics in Nanoscale Pores"
13：55－14：20	**W.A. Hofer** *(The University of Liverpool, UK)* "Surface Reactions on Semiconductors at the Atomic Scale"
14：20－14：45	**Jiandi Zhang** *(Louisiana State University, USA)* "Nanoscale Domains and Domain Boundaries at the Surface of $BaFe_2As_2$: Mirroring the Bulk Spin Structure"
14：45－15：10	**Maria Varela** *(Oak Ridge National Laboratory, USA)* "Electron Microscopy Observations of Ferromagnetic/Superconducting Oxide Interfaces"
15：10－15：35	**Xuan Gao** *(Case Western Reserve University, USA)* "The Disappearance of Weak Localization in a Strongly Correlated 2D Hole System"
15：35－16：00	**Weiqi Huang** *(Guizhou University, China)* "Stimulated Emission on Silicon Quantum Dots"
16：10－16：20	Coffee Break

16：20－18：00	**Session 4** *Chair:* **Christian A. Bobisch**
16：20－16：45	**Karl-Heinz Ernst** *(Swiss Federal Laboratories for Materials Testing and Research (EMPA), Switzerland)* “Tickling Single Molecules with Electrons: Inelastic Electron Tunneling Action Spectroscopy ”
16：45－17：10	**Xin Jiang** *(University Siegen, Germany)* “Effects of Catalysts on the Growth of Carbon Nanostructures”
17：10－17：35	**Hongbin Yu** *(Arizona State University, USA)* “Nanowire Surface Modification and Its Effect on Electrical Transport”
17：35－18：00	**Yeliang Wang** *(Institute of Physics, CAS, China)* “Exploring the Interfaces of Functional Molecules on Metal Surfaces”
18：00	**Closing Remarks** **Shouheng Sun**

Beijing Part

Imaging the Femtosecond Time Scale Correlated Electron-Nuclear Dynamics in Surface Photodesorption

Hrvoje Petek,

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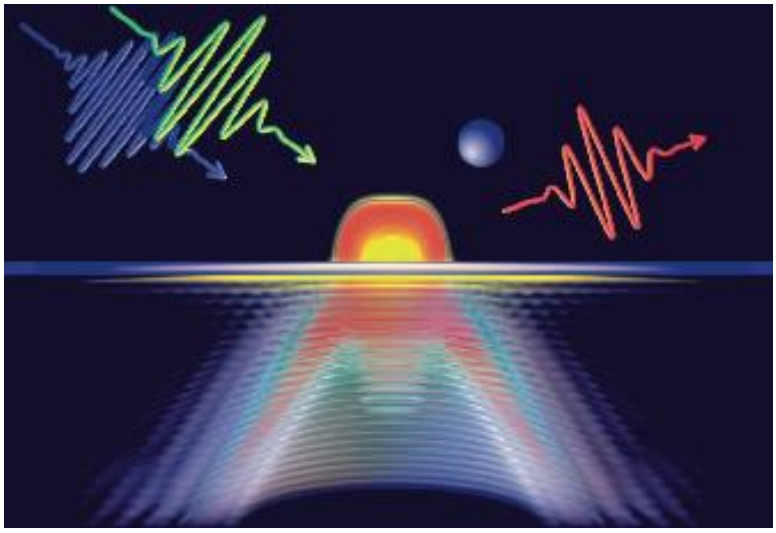
We employ time-resolved two-photon photoemission to characterize electronic structure and photoinduced dynamics of chemisorbed alkali atoms on noble metal surfaces.[1-3] Photoinduced charge transfer excitation of the lowest energy sigma resonance of Cs on Cu or Ag surfaces turns on repulsive forces between atom and surface initiating nuclear wave packet motion on a dissociative potential energy surface. Energy, momentum, and time resolved measurements of photoemission from desorbing atoms provide information on the nuclear wave packet motion and the concomitant changes in the surface electronic structure. In particular, we use time-dependent momentum imaging of photoemission from the excited state to explore the correlation between the electron and nuclear motions.

(1) Petek, H.; Weida, M. J.; Nagano, H.; Ogawa, S. *Science* **2000**, *288*, 1402-1404.
(2) Petek, H.; Ogawa, S. *Annu. Rev. Phys. Chem.* **2002**, *53*, 507-531.
(3) Zhao, J. et al.. *Phys. Rev. B* **2008**, *78*, 085419-7.



The calculated Cs 6s state electronic wave packet seen above (top) and below (bottom) metal surface.

Tickling Single Molecules with Electrons: Inelastic Electron Tunneling Action Spectroscopy

K.-H. Ernst

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Adsorbate motions are the most fundamental steps in surface chemistry. In particular when collisions with other reaction partners or reactive surface sites are required, adsorbate motions are typically the rate-determining steps of a heterogeneously catalyzed reaction. Studying the movement of adsorbates, induced by phonons, photons, or electrons, is therefore of paramount interest. We perform model studies at the ultimate lower end of the pressure range and at a temperature of 4 K only. Manipulation of single molecules at surfaces with the scanning tunneling microscope (STM) has been performed for more than a decade. However, the mechanisms of molecular excitation by electrons that inelastically tunnel through the molecule are not entirely understood. I will present results of manipulation experiments performed 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 mirror-configurations. We identified the adsorption geometry 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 the molecule at the surface. This includes hopping, rotation, interconversion of the handedness and dehydrogenation [1]. All actions are mode-selective, that is, only certain vibrations cause a certain action. The product of the single molecule chemical reaction has been identified in turn by IET-action spectroscopy, i.e., hopping was observed after excitation of a certain chemical bond in the product molecule. The microscopic mechanisms of these IET-induced molecular dynamics and the relevance for general surface chemistry and heterogeneous catalysis will be discussed.

[1] Parschau et al. Angewandte Chemie **2009**, *121*, 4125.

Science and Technology of Multifunctional Thin Films and Application to Multifunctional Micro and Nano Devices

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A review will be presented on research and development programs in the Interfacial Materials Group (Materials Science Division) and the Center for Nanoscale Materials at Argonne National Laboratory (ANL). Themes to be reviewed include:
(1) Research focused on understanding ferroelectric and high-k dielectric film growth and interface processes and scaling to fabrication of nanostructure, with the aim to applications to: a) development of next generation of high-density (Gb-TB)/ low energy consumption non-volatile ferroelectric random access memories (FeRAMs); b) new high-K dielectric layers for nanoscale CMOS gates and for super-capacitors for energy storage;
(2) Research focused on the science and technology of novel ultrananocrystalline (UNCD) thin films, developed and patented at ANL, which exhibit exceptional mechanical, tribological, chemical, electrical, and biocompatible properties, which enable application to multifunctional devices, namely: 1) coatings for mechanical pumps seals with order of magnitude longer lifetime and lower friction coefficient than other materials for seals in the market today (UNCD coated SiC mechanical pump seals have been introduced into the market in 2009 by Advanced Diamond Technology - company spun-off from ANL (O. Auciello and J.A. Carlisle (ANL scientists) and N. Kane-CEO, founders)-see ADT web site-www.thindiamond.com); 2) UNCD electrodes and membranes for efficient fuel cells; 3) field emission cathodes for field emission displays, high-frequency tubes, x-ray sources and more; 4) RF MEMS/NEMS resonators and switches for wireless communications and radar systems; 5) NEMS devices; 6) Biomedical devices (e.g., bioinert coating for encapsulation of a microchip implantable in the retina to restore sight to people blinded by retina degeneration, and UNCD tribological coating with low friction and negligible wear for prosthesis – knees, hips, heart valves); 7) biosensors; 8) UNCD as a platform for developmental biology, involving the growth of stem cells on the surface and differentiation into other human body cells; 9) UNCD as a platform for growth of multi-element/multifunctional nanowires; and 10) Science and technology of UNCD nanowires. Current and future UNCD-based products in the market from macro to nanoscale devices will be discussed, as well as the outlook for new science and development of new technologies.

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Nanostructure Engineering – A Path to Discovery and Innovation

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Advance of our ability in engineering nanostructures offers a unique path to discovery and innovation in science and technology. This is because when nanostructures become smaller than a fundamental physical length scale, conventional theory may no longer apply and new phenomena emerge. This will not only deepen our knowledge, but also lead to better or revolution products in multiple areas arranging from consumer products to medicine. Furthermore, to commercialize these new discoveries and innovations, it is essential to have low-cost high-throughput nanopatterning methods, which have been a grand challenge (and a key bottleneck) in nanotechnology. The talk will illustrate some intriguing phenomena manifested in nanostructures in the areas of electronics, optics, magnetic, biotech and materials, when the device sizes are smaller than the electron wavelength, optical wavelength, magnetic domain wall size, DNA persistent length, single-crystal critical size, and defect diffusion length.

Moreover, the talk will address the grand challenge essential to the success of nanotechnology and its commercialization: high-throughput and low-cost nanopatternings (i.e., nanomanufacturing). Two different approaches will be presented. First, nanoimprint lithography (NIL) [1], which has demonstrated the fabrication of sub-5 nm feature-size 3D patterning over large area. And second, guided self-assembly (GSA), in particular, those that have well-ordered self-assembly over an area of entire wafers, such as lithographically-induced self-assembly (LISA) and shear-force guided self-assembly.

[1] S. Y. Chou, P. R. Krauss, and P. J. Renstrom, Appl. Phys. Lett, 67 (21), 3114 (1995), and Science, 272, 85 (1996).

Laser Processing of Nanomaterials with Spectral and Spatial Controllability

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Laser material processing and characterization have demonstrated their significance in many areas such as nanoelectronics, nanophotonics, material synthesis, optical spectroscopy, and surface modification, since versatile laser sources provide flexible and unique energy sources for precise control of material processing spectrally and specially. In this presentation, the speaker will introduce their research activities in spectrally and specially controlled laser-material interactions for multi-energy processing for fast growth of diamond films and crystals in open air, self-aligned growth of carbon nanotubes for direct formation of electronic and photonic devices, nanoscale Raman spectroscopy using laser-assisted scanning probe microscope, laser-induced breakdown spectroscopy (LIBS) for analyses of trace materials using spatial confinement of plasmas and combination of Raman spectroscopy.

The speaker:

Dr. Lu is currently the Lott University Professor of Electrical Engineering at the University of Nebraska – Lincoln (UNL). He received his bachelor degree from Tsinghua University (China) in 1984, M.Sc. and PhD degrees from Osaka University (Japan) in 1988 and 1991 all in electrical engineering. From 1991 to 2002, he was a faculty in the ECE Dept at National University of Singapore. He joined the Department of Electrical Engineering at UNL in 2002. He has around 20 years experience in laser-based material processing and characterization at micro/nanoscales. His group has research projects funded by NSF, AFOSR, ONR, DoE, NRI, private companies, and other foundations in Japan, with research expenditures over 10 million dollars in past a few years. Dr. Lu has authored or co-authored over 200 journal papers and 240 conference papers. He has recently been elected to SPIE fellow and LIA fellow. He is also a board member and the treasurer of Laser Institute of America. He has served as chairs and general chairs for numerous international conferences including the general congress chair for International Congress of Applications of Lasers and Electro-Optics in 2007 and 2008.

Effects of Catalysts on the Growth of Carbon Nanostructures

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Cu catalyzed carbon nanofibers are investigated by means of transmission electron microscopy. Straight and helical carbon nanofibers are observed to connect to the catalyst particles of octahedron or triangular prism in the samples prepared using the same processing conditions. Statistic analysis leads to evidence that the morphology of the nanofibers depends on the size of the catalyst particles. Small size of catalyst particles favours formation of the helical fibers, while large size of catalysts results in the straight fibers. Based on the observed results, growth and morphology formation of the carbon nanofibers are discussed in the light of diffusion distance of carbon on the surfaces of the catalyst polyhedrons.

Walking Molecules & Molecule Carriers: What Guided Molecular Motion Can Teach us about Adsorbate-Adsorbate and Adsorbate-Substrate Interactions

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The dynamics of molecules at metal surfaces can be controlled by tailoring their interaction with the substrate: bipedal molecules have been shown to perambulate linearly across a high-symmetry surface. This phenomenon can be used to explore fundamental physics, such as Microscopic Reversibility, and chemistry, such as the strength of hydrogen bonds between adsorbates. In this contribution I will show that pentacene derivatives with two and four carbonyl groups diffuse on a Cu(111) surface in a uniaxial fashion, i.e. exclusively along a substrate atomic row, despite the threefold symmetry of the substrate. In this, they resemble the behavior of dithioanthracene and anthraquinone, previously dubbed "molecular walkers", which move across Cu(111) sequentially stepping the thiol/carbonyl linkers on each side of the molecule. This poses the question of how a fourfold substituted, i.e. quadrupedal, molecule can accomplish uniaxial motion: will it move its substrate linkers on opposite ends of the molecule at the same time resembling the gait of trotting, or will it instead move both linkers on one side at the same time, resembling the gait of pacing? Density functional theory (DFT) suggests the latter. Variable temperature scanning tunneling microscopy (STM) monitoring of the molecular motion reveals a striking difference between the diffusion prefactors of the quadrupedal and bipedalspecies, with the latter being very low. Wentzel Kramers Brillouin-based modeling of the motion of the substrate linkers in the calculated diffusion barriers suggest that the origin of this discrepancy lies in the relevance of tunneling of the substrate linkers, allowing bipedal species, which only need to move one substrate linker at a time, to accomplish motion without overcoming the diffusion barrier in its entirety, whereas quadrupedal species, whose diffusion requires concerted motion of two substrate linkers, cannot move in this way, resulting in significantly higher diffusion temperatures.

Cu-CeO_2 Nanoparticles as a Water-Gas Shift Catalyst and Au-(111) Fe_3O_4 Surface for CO Oxidation and Water-Gas-Shift Reactions

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Carbon based low-dimensional graphitic materials such as fullerenes and carbon nanotubes have been provided us opportunities to explore exotic and exciting science and potential technological applications in the past decades. Recently, there is a new addition of this nanoscaled carbon forms that refresh the research community. Graphene, a single atomic layer of graphite, offers a rich lode of novel fundamental physics and practical applications based on the flat carbon form. As the pure, flawless single atom thick crystal, graphene conducts electricity faster at room temperature than any other substance. While engineers envision a range of products made of graphene, such as ultrahigh-speed transistors and flat panel display, physicists are finding the material enables them to test a theory of exotic phenomena. In this presentation I will discuss the brief history of grapheme research and their implications in science and technology.

Scattering of Surface State Electrons at Defects

Christian A. Bobisch

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The STM is a powerful tool to characterize the geometric structure as well as the electronic properties of a surface. To study the influence of local defects on electronic surfaces states we analysed a thin Bi(111) film as well as the silver induced $\sqrt{3}\times\sqrt{3}$ reconstruction of the Si(111) surface.

For the Si(111) $\sqrt{3}\times\sqrt{3}$ Ag surface we show how the electrochemical potential varies on the nanometer scale, if a lateral current is flowing along the surface. Simultaneously to scanning the surface area we mapped the electrochemical potential by the means of scanning tunneling potentiometry. By restraining an electric current to a surface state, Ohm's law can be studied in great detail. At step edges the local electrochemical potential exhibits a rather sharp monotonous transition. The major variation occurs in a very short range of about 1.2 nm corresponding roughly to 1/4 Fermi-wavelength. Our data explain how the results of previous experiments in which the electric transport was analyzed on a mesoscopic scale may be understood as the average over many elementary contributions [1].

The surface of Bi(111) offers unique electronic properties, e.g. it is known to shown a significant spin orbit coupling. In thin films the surface properties play a major role for the electronic structure of the whole film. Thus thin films can serve as a prototype system to study the influence of the surface properties to the electronic structure [2, 3]. At temperatures of 80 K scanning tunneling microscopy was used to image the local density of electronic states (LDOS) for various energies. Similar to the well known findings on (111)-oriented noble metal surfaces, a wave like pattern of the LDOS occurs in the vicinity of step edges or other defects, due to scattering of charge carriers. By analysing the distribution of the corresponding wavevectors, the participating scattering channels may be identified. Our findings will be compared to theoretical band structure calculations, i.e. constant energy contour plots. This gives more insight into transport properties in strongly correlated surface states.

References

[1] J. Homoth, M. Wenderoth, T. Druga, L. Winking, R.G. Ulbrich, C.A. Bobisch, B. Weyers, A. Bannani, E. Zubkov, A.M. Bernhart, M.R. Kaspers, R. Möller, Nano Letters 9, 1588 (2009).

[2] C. A. Bobisch, A. Bannani, Yu. M. Koroteev, G. Bihlmayer, E.V. Chulkov, and R. Möller, Phys. Rev. Lett. 102, 136807 (2009).

[3] S. Yaginuma, K. Nagaoka, T. Nagao, G. Bihlmayer, Y. M. Koroteev, E. V. Chulkov, and T. Nakayama, J. Phys. Soc. Jpn. 77, 014701 (2008).

Si Anode for Li-ion Batteries: from Nano to Nano-Microcomposite

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Silicon anodes are particularly attractive to replace carbon anode for Li-ion batteries due to its extremely high gravimetric lithium storage capacity (Li4.4Si, 4200 mAh/g), which is approximately 11 times than that of graphite anode (375 mAh/g). However, the high capacity is associated with large electrode volume changes, resulting in particle cracking and capacity fading. In order to solve this problem, great efforts have been paid on material design, such as nano-sized silicon, silicon-metal alloys, carbon-dispersed silicon composite, silicon nanowires, silicon-CNT composite, silicon-based thin-film as well as the optimization on binder, current collector and the electrolyte. In this presentation, our efforts on nanosized silicon anode for lithium ion batteries are introduced. The electrochemical agglomeration of Si nanoparticles and Si nanowires and the crack formation of micrometer sized silicon particles during lithium insertion and extraction have been observed by us previously. However, detailed information about the volume variation is not very clear. Recently, we have fabricated amorphous Si column array electrode by MEMS technique. Based on ex situ AFM investigation, the parallel and perpendicular volume variations of Si column-like electrode during lithium insertion and extraction have been investigated. The volume variation values of amorphous Li-Si alloy are closed to calculated values from the corresponding crystalline phases. The volume variation is anisotropic, perhaps due to the interfacial adherence effect. It is also found that irreversible agglomeration among Si columns occurs when the distances between neighbor Si columns are too closed. These new results provide clearer information about the volume variation. In addition, patterning, dispersing certain amount of Cu nanosized domains and covering a layer of Cu are found effectively to improve its cyclic performance. Above results indicate clearly that direct utilization of nanosized silicon powder is not feasible due to large surface area, serious electrochemical agglomeration and loss of electronic contact during cycling. Instead, nano-micro composite, in which nanosized silicon particles are dispersed within stable and conductive matrix and shell, are promising as anode for practical application, due to small surface area, high tap density and good electronic contact.

Acknowledgement

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Determination of Magnetic Anisotropy in Magnetic Nanowires via FMR and Monte Carlo Simulation

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Magnetic anisotropy plays a key role in detrermining the long range magnetic order of low dimensinal magnetic system and overcoming the superparamagnetic limit of magnetic recording media. In this talk, we will present the correlation between the magnetic anisotropy and the morphology of Fe, Co nanodots and nananowires. The magnetism and the morphology of Fe and Co nanowires on stepped Pb film of 4o miscut Si (111) substrate are investigated by means of scanning tunneling microscope (STM) and the surface magneto-optical Kerr effect (SMOKE). STM images show that the nanometer width Fe wires are formed by Fe fractal islands along the steps of Pb due to step-decoration. SMOKE data indicate that the Fe nanowires exhibit in-plane magnetic anisotropy along the step direction, which can be understand as mainly arising from step induced magnetic anisotropy and shape anisotropy. The effective in-plane uniaxial magnetic anisotropy constant was determined by means of electron spin resonance (ESR), and in-situ Magnetic Force Microscopy (MFM). Furthermore, from actual surface morphology obtained by scanning tunneling microscope (STM), the shape magnetic anisotropy constant can be also calculated in terms of height self-correlation function.

Magnetic properties of irregular Fe islands grown on Si(111) substrate with Pb buffer layer by molecular beam epitaxy (MBE) have been investigated by means of Monte Carlo(MC) simulation. During the simulation，the dipolar interaction energy among islands and the demagnetization energy of each island were accurately calculated in the Fourier space with the aid of cluster multiple labeling technique. The simulated results, i.e. the magnetic hysteresis loops and the temperature dependence of remanent magnetization, are in good agreement with the experimental ones measured by in situ surface magneto-optical Kerr effect (SMOKE).

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Carbon Nanotubes and Graphene Nanoribbons

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This talk will present our latest work on carbon nanotubes for Raman and fluorescence imaging of live cells and animals. Multiplexed sensing and imaging, nanotube based cancer imaging, drug delivery and photothermal therapy will be presented. Also, progress in grapheme nanoribbons synthesis, characterization and device will be shown.

Precisely Tailored Zero- Dimensional Nanostructures

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Nanoscience & nanotechnology offers promising for manipulating and fabricating artificial nanostructures with desired property and functionality, however, quality and precise control of nanostructures are the prerequisites for both fundamental physics exploration and technology applications. In this talk, I will focus on nanoscale materials synthesis and present a few recent progresses from my research group to highlight our efforts towards precise control of zero- dimensional nanostructures based on bottom-up chemical synthetic strategy, including control of defects, crystallinity, compositions and structures [1-3]. If time allows, application of such nanoscale precise materials control will be further discussed by presenting one example of emerging light-matter-spin interactions at the nanoscale [4].

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Brief Biography: Min Ouyang received his B.S. (1996) and M.S. (1997) in Electronics from Peking University, M.S. (1999) and Ph.D (2010) in Chemistry from Harvard University, followed by postdoctoral research in Physics in the University of California at Santa Barbara. Min Ouyang joined the physics department of the University of Maryland in 2004. Min Ouyang has broad interest in exploring new materials chemistry, physics, and device and technology applications based on the spin and charge degrees of freedom of electrons and nuclei within ordered nano-engineered architectures. Min Ouyang has received Alfred P. Sloan Fellowship (2006), NSF CAREER award (2006), Ralph E. Powe award (2006), ONR Young Investigator award (2007), and Beckman Young Investigator award (2007), University of Maryland Discovery award (2010).

Manufacturing and Manipulating Molecular Devices on Metal Substrates.

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Due to the limitations and the high energy consumption of semiconductor electronics, the fabrication of nano-scale molecular devices for potential applications in electronics is intensively researched today. A functioning prototype of such a device, however, is still missing. In this talk we analyse some of the obstacles to an industrial fabrication and utilisation of such devices and show, where cutting-edge technology at the laboratory scale is today.

We shall focus on three systems: functionalized phthalocyanine molecules adsorbed on silver, copper, and gold surfaces [1-5], fullerene molecules on gold, cobalt, and copper [6], and quinacidrone-based molecules on silver [7]. It is shown that in all cases ordered interfaces can be produced either via surface templates or a dense packing of the molecular interfaces. In addition, we demonstrate that the molecules are very flexible in their functions, which allows for a wide range of electronic and dynamic properties. It is possible to manipulate the configuration of some molecules via electron or hole attachment, which yields a bistable switch retaining its configuration also at room temperature.

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Diffusivity Control in Molecule-on-metal Systems using Electric Fields

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Molecules adsorbed on metal surfaces have generated significant scientific interest as a possible route to the production of highly-scaled and highly-efficient electronic devices. In this talk, I will report on the results of scanning tunneling microscopy (STM) studies of the diffusion-related behavior of FePc molecules on Au (111). Using density functional theory calculations we then show that the FePc–Au interaction is dominated by the interaction of the central Fe atom with Au surface atoms. The adsorption of FePc on the Au(111) results in a charge transfer from the surface to the molecule, forming a charge dipole that can be manipulated with applied electric fields. Varying the applied field by changing the STM tip–sample bias allows tuning of both the molecule–substrate separation and binding energy. Hence, applied electric fields can be used to directly modify molecule–substrate interactions, potentially enabling field-guided dynamic patterning in molecule-on-metal systems.

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Vertical Nanowires Arrays: A New Tool for Biology

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At the heart of all investigations into cellular function lies the need to induce specific and controlled perturbations to cells. A variety of tools are now available to accomplish this in a rational and directed fashion by delivering various biological effectors (small molecules, DNAs, RNAs, peptides, and proteins). These options, however, are often limited to either particular molecules or certain cell types due to the lack of a general strategy for transporting polar or charged molecules across the plasma membrane. In this presentation, we show that vertical silicon nanowires (NWs) can serve as a universal platform for delivering virtually any type of molecule into a wide variety of cells in a format that is compatible with live-cell imaging and microarray technology. The platform's simplicity and generality stem from the direct physical access to the cells' interiors that NW penetration affords, thereby enabling efficient introduction of numerous biological effectors without chemical modification or viral packaging. Furthermore, this NW-based system is fully compatible with standard microarray printing techniques, allowing large collections of biomolecules to be co-delivered into live cells in a parallel and miniaturized fashion.

Giant Magnetoresistance in Organic Spin Valves

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Interfacial diffusion between magnetic electrodes and organic spacer layers is a serious problem in the organic spintronics which complicates attempts to understand the spin-dependent transport mechanism and hurts the achievement of a desirably high magnetoresistance (MR). We deposit nanodots instead of atoms onto the organic layer using buffer layer assist growth. Spin valves using this method exhibit a sharper interface and a giant tunneling MR of up to ~300%. Analysis of the current-voltage characteristics indicates that the spin-dependent carrier injection correlates with the observed MR.

Understanding and Controlling Nanomaterials Properties Based on a Core/shell Model

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Surface-sensitive properties of nanostructures form the basis of high-sensitivity gas, chemical and biological detectors. The large surface-to-volume ratio of nanostructures results in the dominance of surface characteristics (e.g., composition, bonding and surface states/defects) in determining the global (i.e. observed) materials properties (electrical, thermal, mechanical, catalytic, optical, etc) of nanomaterials. However, such high surface sensitivity, though beneficial for some device applications, presents a serious challenge to device fabrication as it leads to difficulty in the reproducibility and controllability of device performances. Obviously, the ability to control surface properties in nanostructures is fundamental to the development of nanostructure-based devices. In this work, using intrinsic silicon nanowires (SiNWs) as a model system, we demonstrate the role of controlling surface conditions in determining the overall electrical and transport properties of SiNWs. Tunable and reversible transition of p+-p-i-n-n+ conductance of SiNWs was achieved via simple surface charge transfer with ambient (pH value)-manipulated adsorbed aqueous layer. Critical to this study is the capability of synthesizing SiNWs with predetermined conduction type and carrier concentration from Si wafer of known properties using the metal-catalyzed chemical etching method. The distinctly different bonding characteristics and environment of the surface and the bulk of materials make nanostructures de facto a core-shell composite, which typically has remarkably different properties from the bulk counterpart. The difference becomes increasingly important with decreasing dimension in determining the ultimate materials properties. Thus far, surface-dependent effect has been grossly overlooked in common nanostructures; as they are usually perceived as “homogenous”. Such oversimplification has resulted in confusing and apparently contradictory literature reports. Full understanding and control of the materials properties of nanostructures requires the fundamental understanding of the intrinsic core-shell structure of nanostructures. The phenomenon of surface-dependent transport properties is generic to all nanoscale structures, and is significant for nano-device design for sensor and electronic applications.

Synthesis and Applications of FePt and Their Composite Nanoparticles

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I will summarize our recent efforts in synthesizing FePt alloy and their composite nanoparticles with controlled composition and structure for active/durable fuel cell catalysis and effective therapeutic applications.

Electron Transport through Semiconductor Nanowire Quantum Structures

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I will report our recent studies of electron transport through semiconductor nanowire based quantum structures. High-quality InSb nanowires were grown using metal-organic vapor phase epitaxy and were used to fabricated quantum dot devices and superconductor-semiconductor-superconductor hybrid devices by electron-beam lithography. Spin states, effective g-factors, and spin-orbit interaction energy were measured for the fabricated InSb quantum dots [1]. We also studied strong correlation phenomena in the fabricated InSb quantum dot devices and observed a new spin-correlation-induced phenomenon in the devices, namely the conductance blockade at the degeneracy of two orbital states with the same spin [2]. We attribute this conductance blockade to the effect of electron interference between two equivalent, strongly correlated, many-body states in the quantum dots. Finally, the transport properties of the InSb nanowire based superconductor-semiconductor-superconductor hybrid structures were studied, and multiple Andreev reflections and supercurrent were observed in the structures.

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Ionic Liquids for Controlled Synthesis of Functional Materials

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Conventional synthesis of functional materials relies heavily on water and organic solvents. Alternatively, the synthesis of functional materials using, or in the presence of, ionic liquids represents a burgeoning direction in materials chemistry. Use of ionic liquids in solvent extraction and organic catalysis has been extensively studied, but their use in materials synthesis has just begun. Ionic liquids are a family of non-conventional molten salts that can act as both templates and precursors to functional materials, as well as solvent. They offer many advantages, such as negligible vapor pressures, wide liquidus ranges, good thermal stability, tunable solubility of both organic and inorganic molecules, and much synthetic flexibility. The unique solvation environment of these ionic liquids provides new reaction media for controlling formation of polymeric materials and tailoring morphologies of advanced materials. Challenges and opportunities in this research area will be discussed.

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Interface Magic in Nanostructural Metamaterials

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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 multilayered layered structures of ferroelectric $BaTiO_3/SrTiO_3$, $(Ba,Sr)TiO_3/Ba(Zr,Ti)O_3$, and Mn-doping multilayered structures and found many interesting physical phenomena, such as domain locked ferroelectric phenomena from the multilayered BaTiO3/SrTiO3 superlattices, interface induced nanocolunar structures with strong anisotropic dielectric properties, etc. For instance, the high-frequency microwave (~18 GHz) dielectric measurements on $BaTiO_3/SrTiO_3$ reveal that the dielectric constant, loss tangent and Q factor of the multilayered thin films are dependent of the stacking period number and layer thickness. The best value for the loss tangent (0.02) with the dielectric constant (1319.5) and Q factor (1321.6) is achieved an optimized multilayered $BaTiO_3/SrTiO_3$ system. 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.

Nonvolatile Storage Effect and Mechanism in Cu Doped ZrO_2 Based RRAM

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Resistive switching (RS) in solid-electrolyte insulator can be dominated by the formation and rupture of nanoscale conductive filaments (CFs). The random nature of the nucleation and growth of the CFs make their formation difficult to control and limit the performance potential of solid-electrolyte-based resistive devices. The uniformity of the CF-based resistive random access memory (ReRAM) is a major obstacle to prevent them from high performance storage applications. Here, we report a novel approach to resolve this challenge through inserting a metallic nanocrystal (NC) layer between the bottom electrode and the solid-electrolyte layer. Using a Ag/ZrO_2/Cu NC/Pt structure as a prototype, we show that the inserted Cu NC layer acts to control CF nucleation and growth, thus leading to superior RS properties.

Nanoscale Structure-Property Relations through Aberration-Corrected Scanning Transmission Electron Microscopy

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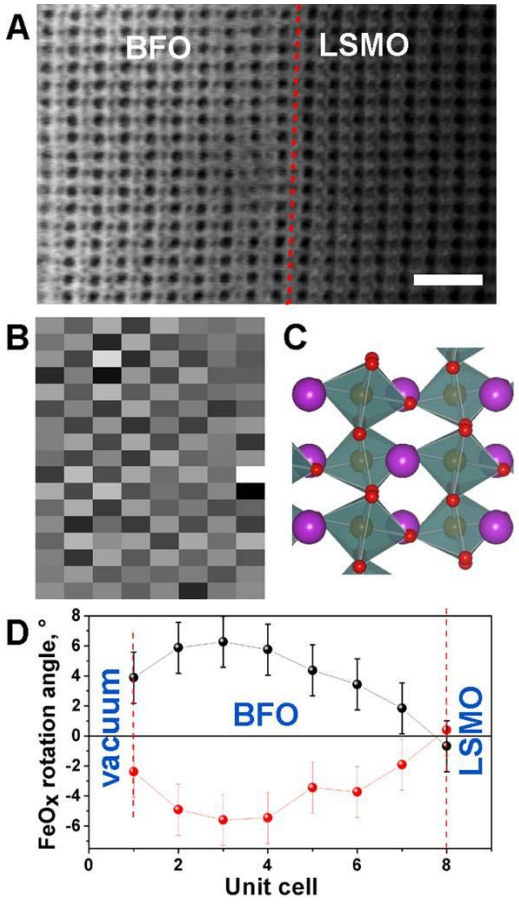
Complex oxide interfaces present perhaps the most challenging nanoscale systems, due to their many possible structural distortions and mixed valence electronic systems. With an aberration-corrected STEM, a range of different signals is available to allow quantitative measurement of column locations, including light elements. Figure 1A shows a bright field image of a $BiFeO_3$-$La_{0.7}Sr_{0.3}MnO_3$ (BFO/LSMO) interface obtained with a VG Microscopes HB603U STEM. Light O columns can be seen as small dark spots between the larger dark spots of the cation columns [1]. An accurate map of octahedral tilts can be extracted, as shown in Fig. 1B, and displays a checkerboard pattern, as expected from the bulk structure shown schematically in Fig. 1C. The magnitude of the tilts is progressively suppressed near the interface with LSMO, as shown in Fig. 1D, which is expected to influence local electronic properties. Indeed, the interface region shows up in electron energy loss spectroscopy as having electronic properties different from either BFO or LSMO. Quantitative measure of lattice parameter is also possible directly from the Z-contrast image, and the same region shows an anomalous lattice expansion normal to the substrate. Results will be compared with density functional calculations that show changes due to the suppression of octahedral tilts, and Ginsburg-Landau-Devonshire theory to derive the polarization, electric field, charge and potential across these ferroelectric-oxide interfaces. In such manner it is now possible to obtain detailed insight into the microscopic origins of the unique properties of nanostructured oxides.



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[2] This work was supported by DOE Basic Energy Sciences, Division of Materials Science and Engineering, and by appointment to the ORNL Postdoctoral Research Program administered jointly by ORNL and ORISE (HJC).

Fig. 1: (A) Bright field image of a BFO/LSMO thin film. (B) 2D map of in-plane octahedral tilt angles in BFO showing checkerboard order. (C) BFO structure in rhombohedral (001) orientation showing the expected tilt pattern of oxygen (red). (D) Line profile obtained from the map in (B); error bars are set to the standard deviation of local Bi-Bi angles. Reproduced from [1].

Spintronics with Hybrid Nanostructures

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Studies of exchange interactions and spin transport in heterogeneous materials have evoked long-standing interest in condensed matter physics for both fundamental and technological reasons. For instance, exchange-biased spin valves and magnetic tunnel junctions that incorporate ferromagnetic (and antiferromagnetic) metals with conventional metals (and insulators) form the backbone of mainstream spintronics technology. On the other hand, the juxtaposition of ferromagnets with superconductors has been driven by more fundamental questions, ranging from the precise measurement of spin polarization to the search for new phenomena created by competing order parameters. In this general context, we have been exploring spin-dependent phenomena in a variety of hybrid magnetic/semiconductor [1-3] and magnetic/superconductor nanostructures [4]. This talk provides a thematic motivation for such a program with key glimpses from recent results involving mesoscale magnetic/ semiconductor devices [1] and then focuses on emerging opportunities in "nanospintronics" driven by the synthesis of axially- and radially-modulated magnetic/semiconductor nanowires [2,3] and by the observation of long-ranged proximity effects in superconductor/ferromagnet nanostructures [4].

This work was carried out with B. J. Cooley, N. Dellas, J. Liang, P. Mitra, C. Shi, J. Wang, M. J. Wilson, M. Zhu, M. Tian, S. Crooker, H. Htoon, E. Dickey, S. Mohney, T. Mallouk, J. Jain and M. H. W. Chan. The work is supported by the NSF Center for Nanoscale Science at Penn State, the NSF NNIN program and by ONR.

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Enhanced Superconductivity of Nanoscale Tungsten Grown by Focused-ion-beam for Maskless Device Fabrications

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The superconductivity of a nanowire exhibits quasi-one-dimensional behavior when the thickness of the superconducting nanowire is reduced smaller than the Ginsburg-Landau phase coherence length (ξ) and the magnetic penetration depth (λ). Below or near the superconducting transition temperature (Tc), the resistance of a 1D wire is no longer zero. The nonzero dissipation is due to the thermally activated phase slip (TAPS) or quantum phase slip (QPS) process. A quick approach to probe such phenomenon is to examine the feature of the temperature dependent resistance (R-T) and transport (I-V) properties near and below Tc. In addition, focused-ion-beam induced chemical vapour deposition (FIB-CVD) allows the formation of complex true nanoscale features in a user-defined area in a single processing step. Tungsten grown by FIB-CVD is one of the most commonly used materials in nanodevice fabrication.

Here we present superconductivity of FIB grown tungsten thin films, lateral nanowires and freestanding nanostructures. Compared with the bulk counterpart, it has been proved to have a significantly enhanced Tc larger than 5 K, a value technologically useful above 4.2 K. Such materials are BCS superconductors with tunable Tc. The variation of Tc can be correlated with how far the films are from the metal-insulator transition, showing a non-monotonic dependence that is well described by the heuristic model of Osofsky et al. (Phys. Rev. Lett. 87 197004). The transition width of nanowire was found to be closely wire cross-sectional area dependent and the logarithm plot of the residual resistance show two distinct slopes which might be attributed to phase slip processes occurring during the transition. Thus the FIB-CVD of tungsten opens up the possibility to fabricate novel superconducting devices, e.g., single photon detector, without mask and other conventional microfabrication techniques; it also may serve as a growth approach to study the superconducting suppression in nanoscale materials.

Electron Transport Phenomena in Semiconductor and Topological Insulator Nanowires

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Semiconductor nanowires are believed to be promising materials for novel nanoelectronic, optoelectronic and biosensor applications. With the small length scale and a variety of material choices, nanowires are also a versatile platform to explore rich mesoscopic physics. I will discuss our recent magneto-transport studies of InAs and Bi_2Se_3 nanowires. In InAs nanowires with small diameters, we found that quantum interference leads to one-dimensional localization of electrons. For nanowires/ribbons of Bi_2Se_3, a topological insulator, our magneto-transport experiments revealed a linear quantum magneto-resistance that is consistent with the existence of Dirac electrons on sample surface.

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Field Effect Devices Based on a Topological Insulator Material

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We will report that bismuth selenide thin films can be epitaxially grown on strontium titanate substrates, which forms a basis for field effect devices. Very large tunablity in carrier density can be obtained by applying back-gate voltages. The observed low field magnetoconductivity due to weak anti-localization has a very weak gate-voltage dependence unless the electron density is reduced to very low values. Our results suggest much suppressed bulk conductivity at large negative biases and a possible role of the surface states in the weak anti-localization phenomena. This work may pave a way for realizing three-dimensional topological insulators at ambient conditions.

This work was in collaboration with Kehui Wu, Li Lu, Junren Shi, Xin Cheng Xie,Jun Chen, and Huajun Qin et al. We are grateful to the financial support from NSF-China, Chinese Academy of Science, and Ministry of Science & Technology of China. A part of the work has been presented in manuscript arXiv 1003.1534.

Nanoscale Materials and Structures for Transparent and Flexible Electronic and Optoelectronic Applications

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Nanoscale materials have many unique electronic, electrical and optical properties as a result of their large surface to volume ratio as compared to their bulk counterparts. Their small sizes also offer mechanical flexibility that could be utilized for many potential applications. Here we demonstrate two such examples.

In the first example, a UV detector fabricated on transparent and flexible substrate will be described. Photodetectors, especially in the UV spectral range, are typically fabricated on substrates that are both rigid and opaque due especially to processing convenience. The production of UV detectors on transparent substrates, such as polymer, with both transparent active material and transparent contact materials would, however, enable many novel applications. An "all-visible" transparent UV detector, as described, could be attached to windows, or on top of other devices which need exposure to visible light. These devices ultimately further the goal of transparent thin-film electronics but more immediately can support solar cells or act as controls for automated window blinds. As a result, Zinc Oxide (ZnO) has been explored as a choice active material because of its large band-edge emission (356 nm) falling in the UV spectral range. Furthermore, ZnO nanowires (NW) are described as a transparent and mechanically flexible and their single dimensional structure lends itself free to line or planar defects. This, in turn, reduces the likelihood of extraneous trap-state emissions, most notoriously the green band from ZnO thin films. Furthermore, the use of ZnO NWs for UV detection has previously been studied and the desorption of oxygen acts as a sufficient mechanism for ZnO to alter the conductivity of the NW and therefore serve as a good material for detection. The fabrication and characterization of such UV detectors based on nanoscale materials will be described.

In the second example, we describe a tunable optical grating based on buckled nanoscale thin film with periodic sinusoidal patterns on a transparent elastomeric substrate. Submicron scale sinusoidal gratings have been fabricated with nanometer thin film coated on 30% pretensioned polydimethylsiloxane substrates. Due to competition between the soft elastomeric substrates and relatively stiff films, periodic wavy profiles are created upon releasing the pretension. The buckling profiles can be easily tuned by mechanically stretching or compressing. Optical transmittance diffraction testing has been conducted, and 85 nm peak wavelength shifts of the first order diffraction have been achieved by stretching the grating up to 30% of its original length. Such unique and versatile structures enable many novel applications such as strain sensors on curved or irregular surfaces, and will be elaborated in more details.

Size Dependent Superconductivity of Pb Islands Grown on Si (111)

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The superconductivity of nano-sized Pb islands grown on Si (111) with different size at 9 monolayer thickness was studied by low temperature scanning tunneling spectroscopy. By measuring the zero bias conductance as a function of temperature, for larger islands we observed a transition between pseudogap state at high temperature and superconductivity state at low temperature through two distinct slopes, where the superconductivity transition temperature (Tc) of the island can be determined. For islands less than 150 nm2, no superconducting state was observed down to the measurable temperature of 4.5 K. By properly subtracting the background and pseudogap effect, information on the temperature dependent superconductivity gap can be obtained. The ratio of $\frac{2\Delta_0}{k_B T_c}$ decreased from 4.5 to 3.3 with the reduction of island size while their Tc only decreased by ~ 5%, showing that the electron-phonon coupling becomes weaker as the size decreases.

Strain Tunable Transport in Manganites: Tailoring Emergent Electronic Phase Separation

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Emergent electronic phase separation has been linked to many exciting behaviors such as the metal-insulator transition, colossal magnetoresistance, and high TC superconductivity. The intricate energy overlaps of spin-charge-lattice-orbital interactions in complex materials that lead to electronic phase separation have made a fundamental understanding of the phenomena very difficult to study. By selectively tuning the elastic energy in manganite films and wires, we have uncovered never before seen transport properties that shed new light on the fundamental role of electronic phase separation in complex materials. Using $La_{5/8-x}Pr_xCa_{3/8}MnO_3$ (LPCMO) as a model system, we have found that it is possible to selectively induce shifts to the metal-insulator transition (MIT) temperature and magnitude of magnetoresistnace. Specifically, we will discuss results showing that it is possible to create a low-temperature reemergent MIT through careful balancing of chemical pressure and substrate induced lattice strain; and examine some recent findings in which we induce anisotropic electronic domain formation along the in-plane axes of a pseudocubic single crystal LPCMO thin film by epitaxially locking it to an orthorhombic substrate. These findings show that emergent electronic phase domain formation can be selectively tuned over long distances which gives us a fuller understanding of the balanced energetics that drive emergent behaviors in complex materials while opening the door to new device engineering.

Realization of Lateral Electrical Contacts on Semiconductor Nanowires

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Semiconductor nanowires (NWs) would offer novel and powerful approach for assembling highly integrated photonic devices with the potential to co-assemble diverse materials on a common platform to produce detectors and lasers that can cover the entire optical spectrum ranging from the UV to the infrared. In this talk, we will mainly discuss on realization of electrical contacts over whole NWs array, and the applications to optoelectronic devices, including selective epitaxy on nano patterned templates and selective anodic oxidation for individual NWs. As the first part, we report on InGaN NWs fabricated by selective area growth using metalorganic chemical vapor deposition (MOCVD) on a patterned GaN/sapphire substrate. Structural investigation indicates that crystalline nanowire aligned with GaN [11-20] direction has a large length up to hundreds of microns and a special cross sectional structure with two smooth {1-101} sidewall facets. Further analysis reveals that selective growth of InGaN NWs in the inverted trapezoidal wire-trench patterns formed on GaN substrate can effectively reduces total threading dislocations and improves crystalline quality of nanowire. Meanwhile, Optical characterization indicates that intense ultra-violet luminescence happens around 434nm, corresponding to the near-band-edge emission of InGaN NWs. Finally, the light-emitting diodes based on InGaN NWs has been obtained. Secondly, we present the realization of lateral electrical contacts over individual ZnO NWs, a quasi-sandwich structure was launched on Al film enveloping ZnO NWs with one lateral surface of the NWs exposed. The alumina film as insulating layer between top and bottom electrical contacts was obtained by utilizing anodic oxidation technique. The non-oxided part of the Al film with enveloping nanowres acted as the bottom electrical contacts. UV response was investigated under ambient condition. By adjusting various surface treatments and metallic top-contacts, a high UV sensitivity of on/off ratio up to 104, and fast response and recovery time have been achieved.

Tunable Interfacial Properties of Epitaxial Graphene on Metal Substrates

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Graphene has attracted much recent attention due to its novel physical properties and potential applications. As a basis of further intensive research, the reliable methods to produce high quality and large scale graphene are of crucial significance. Epitaxial graphene grown on metal surface is an important approach. And understanding how epitaxial graphene interacts with the underlying substrates is highly desirable to realize controlling their interfacial and thus the physical properties of the graphene-based systems. In this presentation, I will talk growth of high quality graphene overlayers through thermal decomposing of hydrocarbon on transition metals [1, 2]. A comparative study was performed to reveal a dependence of interfacial interaction and thermoelectric potential properties by using different model systems of epitaxial graphene on Ni(111), Ru(0001) and Pt(111) [2]. It demonstrated that the interfacial properties can be tuned between graphene and different kinds of metal substrates. Further scanning tunneling microscopy (STM) results show hexagonal Moiré patterns and different amounts of surface corrugation due to the different lattice mismatch and strength of interfacial interaction. For graphene on Ru (0001) surface, we revealed the electron scattering and periodic quantum wells properties in the unit cell of Moiré patterns at the interface using the scanning tunneling spectroscopy (STS). This ordered Moiré pattern and tunable interfacial structures of graphene can be used as templates for site-specific molecular adsorption and formation of ordered molecular superstructures.

* In collaboration with H. G. Zhang [a], H. Hu [a], Y. Pan [a], M. Gao [a], J. H. Mao [a], W. D. Xiao [a], Y.L. Wang [a], S. X. Du [a], F. Liu [b], and H.-J. Gao [a]
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Graphene Photonics and Optoelectronics

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The richness of optical and electronic properties of graphene attracts enormous interest. Graphene has high mobility and optical transparency, in addition to flexibility, robustness and environmental stability. So far, the main focus has been on fundamental physics and electronic devices. However, we believe its true potential to be in photonics and optoelectronics, where the combination of its unique optical and electronic properties can be fully exploited, the absence of a bandgap can be beneficial, and the linear dispersion of the Dirac electrons enables ultra-wide-band tunability. The rise of graphene in photonics and optoelectronics is shown by several recent results, ranging from solar cells and light emitting devices, to touch screens, photodetectors and ultrafast lasers. Despite being a single atom thick, graphene can be optically visualized [1]. Its transmittance can be expressed in terms of the fine structure constant [2]. Raman spectroscopy allows a full characterisation of the material, in terms of number of layers, doping, disorder and defects [3], and is a direct probe of electron-phonon and electron-electron interactions [4,5]. The linear dispersion of the Dirac electrons enables broadband applications. Saturable absorption is observed as a consequence of Pauli blocking[6,7]. Chemical and physical treatments enable luminescence [8]. Broadband luminescence is also observed upon ultrafast laser irradiation. Graphene-polymer composites prepared using wet chemistry techniques [6-7] can be integrated in a fiber laser cavity to generate pulse durations as short as 200fs, combined with broadband tunability [6,7].

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Atomic Resolution Imaging of O Positions in Perovskites by Spectrum Imaging

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Direct imaging of light atoms, such as O, in the electron microscope has only been achieved through the successful correction of spherical aberration. Here, we apply atomic resolution electron energy loss spectroscopy spectrum imaging in the aberration corrected scanning transmission electron microscope, combined with density functional theory and dynamical simulations, to the imaging of O atoms in complex oxides with perovskite structure. These materials exhibit exciting new physics: from high Tc superconductivity to colossal magnetoresistance, ferroelectricity, etc. These properties depend directly on the bonding between transition metals and the O atoms in octahedral configuration around them. Hence, being able to directly image and quantify their positions is a necessary ingredient to understand their physical properties. Other interesting effects such as non-locality or dechanneling giving rise to volcano-like contrast will also be discussed, together with the possibility of distinguishing inequivalent O species in Jahn-Teller distorted perovskites such as LaMnO3. We will apply these techniques to imaging subtle O displacements and measure their effects on the local electronic properties of complex oxide interfaces. These results will be discussed and combined with density functional theory to explain the microscopic origin of bulk magneto transport properties.

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Controllable Propagating Plasmons on Metal Nanowire

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The control of light propagation at the nanometer scale is critical for the development of nanophotonic chips and novel sensors. Nanoplasmonics is a rapidly emerging branch of photonics, which offers variable means to manipulate light using plasmon excitations on metal nanostructures. Here we report our recent studies about propagation properties of plasmons on metal nanostructures.

We achieved remote-excitation surface-enhanced Raman scattering (SERS) at the single molecule level with nanowire-nanoparticle coupled system. The novel technique of remote excitation source has remarkable advantages compared with direct optical excitation. Remote-excitation can achieve the illumination within nanometer area, and thus improve the signal to noise ratio and decrease the damage to the samples. Interestingly, we also found that propagating surface plasmons can excite excitons, which results in quantum dot emission. In this process, the energy is directly transferred from the propagating plasmons to the excitons without converting to photons, and vice versa.

We also observed that light from the end of a silver nanowire, following excitation of plasmons at the other end of the wire, is emitted in a cone of angles peaking at nominally 45-60 ° from the nanowire axis, with virtually no light emitted along the direction of the nanowire. This surprising characteristic can be explained by a simple picture invoking Fabry-Pérot resonances of the forward- and back-propagating plasmons on the nanowire. This strongly angular-dependent emission is a critical property that must be considered when designing coupled nanowire-based photonic devices and systems.

The polarization is a big issue that influence plasmon propagating. We investigated the correlation between the incident and emission polarization in plasmonic Ag nanowire waveguides. We find that the polarization change depends only slightly on the diameter and length of the wire, but sensitively on the shape of the wire terminations. The polarization and intensity of the nanowire emission can be manipulated by modifying the shape of the nanowire termination. A polarization controllable nanoscale plasmonic waveguide may be useful in applications in nanophotonics, such as chip-to-chip interconnects, or in specific applications, such as quantum cryptography.

Using polarization dependent scattering spectroscopy, we investigate plasmon propagation on branched silver nanowires as well. 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.

Engineering of Graphene Nanostructures by Anisotropic Etching

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Graphene shows great potential for future electronics due to its extraordinary electrical properties and structure-engineerable nature. Controlling the edge morphology is crucial during graphene fabrication process as the electric and magnetic properties of graphene depend on its edge structure, especially for confined structures. However, the identification of graphene crystallographic orientation and smooth edges has been difficult to achieve, one has to deal with graphene nanostructures with unknown crystallographic orientation and irregular edges. Anisotropic etching has been proposed as a key technique for controllable graphene edge fabrication with atomic precision. Here we present a dry anisotropic etching method for graphite/graphene. We are able to control the etching from edges by tuning the etching parameters such as plasma intensity, temperature and time duration. The etching process is attributed to hydrogenation and gasification of carbon atoms with etching dynamics consistent with methane formation. This simple, clean, controllable and scalable technique is compatible with existing semiconductor processing technology.

Guiyang Part

Carbon Nanotubes and Graphene Nanoribbons

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This talk will present our latest work on carbon nanotubes for Raman and fluorescence imaging of live cells and animals. Multiplexed sensing and imaging, nanotube based cancer imaging, drug delivery and photothermal therapy will be presented. Also, progress in grapheme nanoribbons synthesis, characterization and device will be shown.

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Imaging and Identification of Light Atoms in BN and Graphene Monolayers

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Individual light atoms have been imaged and identified in an aberration corrected scanning transmission electron microscope (STEM) [1]. Figure 1a shows a raw image from monolayer BN imaged using a Nion UltraSTEM [2] operating at 60 kV, below the 78kV threshold for knock-on damage in the perfect lattice. The individual B and N atoms are clearly distinguishable based on their intensity. In bright field imaging the scattering factors of B and N are very similar and the lattice polarity has so far only been extracted by averaging many B-N pairs [3]. Figure 1b shows a processed image and Fig. 1c shows two line traces in which some peaks are visible with intensity in between that of the B and N atoms, while others are seen with a higher intensity. The intensities are well fitted by a power law dependence on atomic number, and substitutional carbon and oxygen atoms can be identified directly from their image intensity. Carbon atoms only substitute in pairs, replacing a B-N pair, while O atoms substitute only for N atoms. Density functional calculations confirm the stability and coordinates observed, including the distortion visible in the ring of 6 carbon atoms.

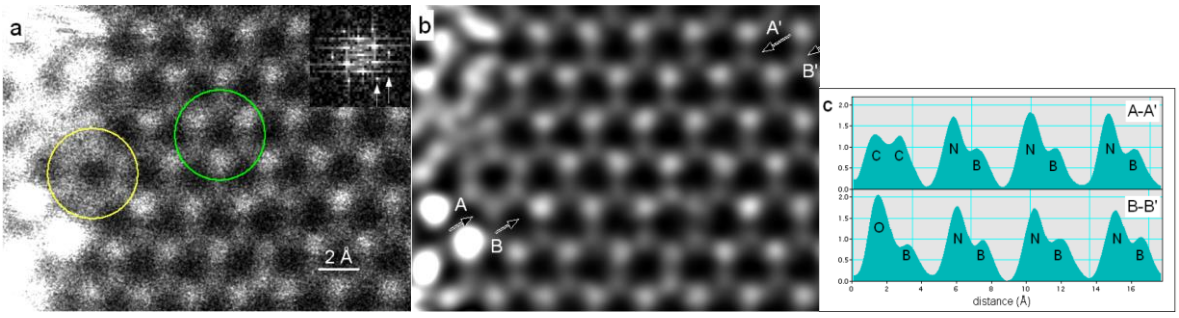

Figure 1. (a) Raw ADF image of monolayer BN obtained with a Nion UltraSTEM. Centre circle shows a ring of 6 atoms with alternating intensity corresponding to individual B and N atoms, circle on the left shows a ring of 6 equal intensity C atoms. (b) Image corrected for distortion, smoothed, and deconvolved to remove probe tail contributions to nearest neighbours. (c) Line profiles through (b) distinguishing C and O atoms from B and N atoms.

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Science and Technology of Multifunctional Thin Films and Application to Multifunctional Micro and Nano Devices

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A review will be presented on research and development programs in the Interfacial Materials Group (Materials Science Division) and the Center for Nanoscale Materials at Argonne National Laboratory (ANL). Themes to be reviewed include:
(1) Research focused on understanding ferroelectric and high-k dielectric film growth and interface processes and scaling to fabrication of nanostructure, with the aim to applications to: a) development of next generation of high-density (Gb-TB)/ low energy consumption non-volatile ferroelectric random access memories (FeRAMs); b) new high-K dielectric layers for nanoscale CMOS gates and for super-capacitors for energy storage;
(2) Research focused on the science and technology of novel ultrananocrystalline (UNCD) thin films, developed and patented at ANL, which exhibit exceptional mechanical, tribological, chemical, electrical, and biocompatible properties, which enable application to multifunctional devices, namely: 1) coatings for mechanical pumps seals with order of magnitude longer lifetime and lower friction coefficient than other materials for seals in the market today (UNCD coated SiC mechanical pump seals have been introduced into the market in 2009 by Advanced Diamond Technology - company spun-off from ANL (O. Auciello and J.A. Carlisle (ANL scientists) and N. Kane-CEO, founders)-see ADT web site-www.thindiamond.com); 2) UNCD electrodes and membranes for efficient fuel cells; 3) field emission cathodes for field emission displays, high-frequency tubes, x-ray sources and more; 4) RF MEMS/NEMS resonators and switches for wireless communications and radar systems; 5) NEMS devices; 6) Biomedical devices (e.g., bioinert coating for encapsulation of a microchip implantable in the retina to restore sight to people blinded by retina degeneration, and UNCD tribological coating with low friction and negligible wear for prosthesis – knees, hips, heart valves); 7) biosensors; 8) UNCD as a platform for developmental biology, involving the growth of stem cells on the surface and differentiation into other human body cells; 9) UNCD as a platform for growth of multi-element/multifunctional nanowires; and 10) Science and technology of UNCD nanowires. Current and future UNCD-based products in the market from macro to nanoscale devices will be discussed, as well as the outlook for new science and development of new technologies.

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Optoplasmonic Engineering of Light-Matter Interactions

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Manipulating light-matter interactions at the nanoscale has broad implications for many research areas, ranging from spectroscopy and sensing to communications and quantum information processing. In this presentation, I will discuss our research efforts to develop a general strategy for engineering light-matter interaction using nanoscale plasmonic and optoelectronic interfaces. Topics that will be discussed include (1) a cavity-free, broadband approach for engineering photon-emitter interactions via sub-wavelength plasmon confinement in metallic nanowires, (2) the realization of "dark" optoplasmonic circuit elements that are based on near-field electrical generation and detection of optical plasmons, and (3) the deterministic coupling between quantum emitters and photonic and plasmonic crystal cavities.

Nanostructure Engineering – A Path to Discovery and Innovation

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Advance of our ability in engineering nanostructures offers a unique path to discovery and innovation in science and technology. This is because when nanostructures become smaller than a fundamental physical length scale, conventional theory may no longer apply and new phenomena emerge. This will not only deepen our knowledge, but also lead to better or revolution products in multiple areas arranging from consumer products to medicine. Furthermore, to commercialize these new discoveries and innovations, it is essential to have low-cost high-throughput nanopatterning methods, which have been a grand challenge (and a key bottleneck) in nanotechnology. The talk will illustrate some intriguing phenomena manifested in nanostructures in the areas of electronics, optics, magnetic, biotech and materials, when the device sizes are smaller than the electron wavelength, optical wavelength, magnetic domain wall size, DNA persistent length, single-crystal critical size, and defect diffusion length.

Moreover, the talk will address the grand challenge essential to the success of nanotechnology and its commercialization: high-throughput and low-cost nanopatternings (i.e., nanomanufacturing). Two different approaches will be presented. First, nanoimprint lithography (NIL) [1], which has demonstrated the fabrication of sub-5 nm feature-size 3D patterning over large area. And second, guided self-assembly (GSA), in particular, those that have well-ordered self-assembly over an area of entire wafers, such as lithographically-induced self-assembly (LISA) and shear-force guided self-assembly.

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Ultrafast Photoemission Electron Microscopy: Imaging Nonlinear Plasmonic Phenomena on the Femto/Nano Scale

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Light interacting with a metal surface can excite both single-particle (e-h pair) and collective (plasmon) excitations. By photoemission electron microscopy, we investigate the coherent ultrafast dynamical processes in interaction of light with silver metal surfaces.[1-2] To establish the physics of nonlinear multiphoton photoemission, we model the fundamental response of silver to intense optical excitation through its known dielectric properties and momentum resolved band structure. Furthermore, we employ the two photon photoemission process to image plasmonic phenomena in Ag metal films. Using interferometric time-resolved photoemission electron microscopy, we create spatial maps of two-photon photoemission excited in nanostructured Ag films. We fabricate specific nanoscale structures for the coupling of surface plasmon polaritons (SPP), the electromagnetic modes of a metal/dielectric interface, and we image their effect on the coupling, propagation, interference, and focusing of SPP waves. By advancing the delay between identical and collinear pump and probe pulses with interferometric precision, we record movies of SPP wave propagation, and nonlinear interactions with ~50 nm spatial resolution and 330 attosecond/frame temporal rate. Based on simple theoretical models, we discuss the imaging process, the optics of SPP wave packets, and the prospects of ultrafast microscopy of plasmonic phenomena.

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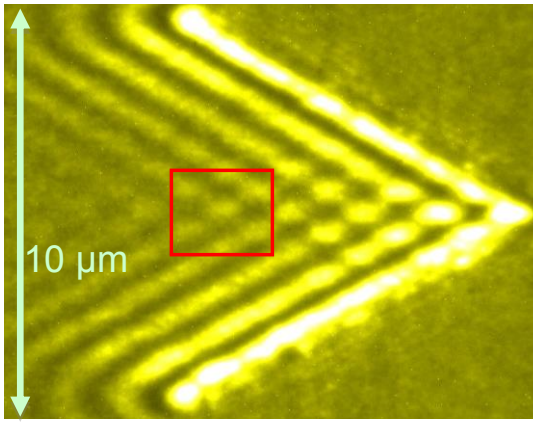

Photoemission electron microscope image of of SPP interference generated by a nanofabricated interferometer that is imaged for 22.7 fs pump-probe delay.

Visualization of Molecular Switching

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Recent studies show that the scanning tunneling microscope (STM) is a versatile tool for studying molecular switching processes [1, 2, 3]. In the case of Copper-Phthalocyanine (CuPc) deposited onto a Cu(111) surface two of the benzene rings of isolated molecules seem to show an unexpected motion at low temperatures.

The four fold symmetry of the gas phase molecule is reduced to a two fold symmetry when adsorbed on the hexagonal Cu(111) surface. A closer look at the low temperature STM images of single CuPc molecules reveals a random telegraph noise in the tunneling current if the STM tip is placed over one of the benzene rings that appears dimmer in the intramolecular STM contrast [4]. To evaluate these switching processes in more detail we designed analogue electronics to fully characterize the signal by its switching frequency (up and down), its amplitude and the ratio between the residence time in the "ON" and the "OFF" state, respectively. These parameters of molecular switching could be mapped simultaneously with topography and reveal a variety of molecular information, e.g. the frequency distribution within a single molecule and the difference between the two molecular states were obtained with submolecular spatial resolution. Furthermore, the spectroscopic analysis of the noise signal yields complementary information to scanning tunneling spectroscopy (STS).

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The Study on Semiconductor, Superconductor and Devices

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We report the researches on nano-materials and devices in Guizhou University in several aspects. 1) The study on III-V compound- semiconductors and future work on quantum dots and its application in spintronics: Our current work focuses on the molecular beam epitaxy growth of GaAs and InGaAs/GaAs and scanning tunneling microscopy study on the surface morphology of epitaxial films. 2) The study on ecologically friendly materials: The experimental study focuses on the magnetron sputtering of metal silicides such as FeSi2, Ca_2Si, Mg_2Si etc; on the other hand, the theoretical study focuses on the electron structures and optical properties of metal silicides. The application of metal silicides in opto-electronics will focus on solar cells and light emitting diode. 3) The study on superconductor MgB_2 and its applications: The research work focuses on chemical vapor deposition of magnesium diboride film and MgB_2-B-MgB_2 multi-films; also, the research studies on the application of MgB_2-B-MgB_2 in Josephson junction. 4) The study on functional materials.

The Power of Confinement: Adsorbate Dynamics in Nanoscale Pores

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Metal nanoparticles exhibit catalytic properties that sensitively depend on the particle size. In this study we explore how the behavior of adsorbates on small facets differs from that on extended terraces. We use low temperature scanning tunneling microscopy to investigate the diffusion and arrangement of CO molecules adsorbed on Cu(111) facets of ~4 nm diameter formed by self-assembly of a honeycomb network of anthraquinone molecules. CO molecules and adlayers exhibit properties under such nanoscale confinement that markedly depart from those of extended adlayers: a) the confinement stabilizes dislocation lines (anti-phase domain boundaries) in the adlayer that affect roughly ¼ of the adsorbed molecules; b) confinement prevents the formation of dense islands of adsorbed molecules, depending on coverage either causing dispersion of vacancies in the adlayer or preventing the growth of molecular islands; c) at a coverage of just a few molecules on the facet, we observe that a molecular shell structure is formed, resembling in its underlying mathematics the atomic model. Confined structures are an ideal test bed for measurement of the coverage dependence of molecular diffusion and in this study we find a reduction of the diffusion barrier at a slope of 57%/ML.

Surface Reactions on Semiconductors at the Atomic Scale

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With the advances in scanning probe microscopy it becomes possible to study reactions of single molecules in situ. While the time resolution of the most advanced instruments and their resolution is now sufficient to, for example, observe the formation of surface oxides and their role in oxidation processes, the detailed electronic and vibrational processes leading to reactions are still much in need of theoretical analysis.

In the first part of the talk I shall focus on the reaction of polar molecules on silicon [1,2]. Here, we find that the rupture of halogen carbon bonds allows to imprint halogen atoms at the surface even perpendicular to the dimer rows, which is a necessary prerequisite for the construction of silicon hybrid devices from design. It is shown that theoretical methods accurately describe the reaction process and that they are providing results which are often unobtainable by chemical intuition.

In the second part of the talk I shall focus on TiO_2 [3-7], which is probably the most important system for photocatalytic and photovoltaic applications. Here I shall talk about the identification of defects via scanning tunnelling microscopes, the role of hydrogen, and the role of charging in surface reactions of oxygen and hydrogen leading to the desorption of water into the gas phase. One may conclude from the present state-of-the-art that the system is finally understood enough to aim at a rational design of a high-performance catalyst.

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Surface Reactions on Semiconductors at the Atomic Scale Understanding and Controlling Nanomaterials Properties Based on a Core/shell Model

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Surface-sensitive properties of nanostructures form the basis of high-sensitivity gas, chemical and biological detectors. The large surface-to-volume ratio of nanostructures results in the dominance of surface characteristics (e.g., composition, bonding and surface states/defects) in determining the global (i.e. observed) materials properties (electrical, thermal, mechanical, catalytic, optical, etc) of nanomaterials. However, such high surface sensitivity, though beneficial for some device applications, presents a serious challenge to device fabrication as it leads to difficulty in the reproducibility and controllability of device performances. Obviously, the ability to control surface properties in nanostructures is fundamental to the development of nanostructure-based devices. In this work, using intrinsic silicon nanowires (SiNWs) as a model system, we demonstrate the role of controlling surface conditions in determining the overall electrical and transport properties of SiNWs. Tunable and reversible transition of p+-p-i-n-n+ conductance of SiNWs was achieved via simple surface charge transfer with ambient (pH value)-manipulated adsorbed aqueous layer. Critical to this study is the capability of synthesizing SiNWs with predetermined conduction type and carrier concentration from Si wafer of known properties using the metal-catalyzed chemical etching method. The distinctly different bonding characteristics and environment of the surface and the bulk of materials make nanostructures de facto a core-shell composite, which typically has remarkably different properties from the bulk counterpart. The difference becomes increasingly important with decreasing dimension in determining the ultimate materials properties. Thus far, surface-dependent effect has been grossly overlooked in common nanostructures; as they are usually perceived as “homogenous”. Such oversimplification has resulted in confusing and apparently contradictory literature reports. Full understanding and control of the materials properties of nanostructures requires the fundamental understanding of the intrinsic core-shell structure of nanostructures. The phenomenon of surface-dependent transport properties is generic to all nanoscale structures, and is significant for nano-device design for sensor and electronic applications.

Electron Microscopy Observations of Ferromagnetic/Superconducting Oxide Interfaces

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Aberration corrected electron microscopy and spectroscopy have proven to be very effective to improve our understanding of complex oxide materials. Probe sizes in aberration-corrected scanning transmission electron microscopes have been reduced below 1 Ångström, while post-specimen optics allow highly efficient electron energy loss spectroscopy. The new instrumentation has made it possible to image near edge spectral features with atomic resolution and single atom sensitivity. Atomic resolution spectrum images of complex oxides can be used to map the different elemental lattices. Additionally, in perovskites the O 2p bands and the transition metal 3d bands are very close to the Fermi level so the electronic properties can be probed by studying the fine structure on the O K edge and the transition metal L edge. Here we will use these techniques to map the electronic properties of superconductors at the atomic scale. Mapping of the distribution of holes and the electronic state of Cu in $YBa_2Cu_3O_{7-x}$ can be achieved by placing the electron beam on different planes of the structure. In ferromagnetic/superconducting interfaces such as cuprate/manganite $YBa_2Cu_3O_{7-x}$ / $La_{0.7}Ca_{0.3}MnO_3$, EELS measurements show that there is significant transfer of electrons from the ferromagnet into the superconductor, which radically changes the physical properties of both ultrathin oxide layers. Superconductivity is suppressed in the superconductor, and the magnetization in the ferromagnet interface layer is depressed. Such transfer of charge can even be used to induce superconductivity in $LaFeO_3/Sm_2CuO_4$ heterostructures where an antiferromagnet is combined with the non superconducting parent compound of an electron doped cuprate, which has been predicted theoretically [1], but not experimentally reported.

[1] S. Yunoki et al., Physical Review B 76 (2007) 064532.

[2] Research sponsored by the US Department of Energy Division of Materials Sciences and Engineering.

The Disappearance of Weak Localization in a Strongly Correlated 2D Hole System

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The origin of Metal-Insulator Transition (MIT) in strongly correlated two-dimensional (2D) electrons or holes in semiconductors has long been of great interest. We will present the low temperature (down to 0.05K) transport properties of 10nm GaAs quantum wells with metallic hole densities near the critical point of the 2D MIT (critical density $p_c \approx 0.7 \times 1010 cm^{-2}$). We found that 2D holes exhibit a negative magneto-resistance in small perpendicular magnetic fields, which has been attributed to weak localization in the literature. On the other hand, the magnitude of this negative magneto-resistance is much smaller than conventional 2D weak localization. What is more surprising is that the weak localization induced negative magneto-resistance peak around B=0 becomes weaker at lower temperature, suggesting there is a mechanism causing quasiparticles to lose coherence as temperature decreases.

Stimulated Emission on Silicon Quantum Dots

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The low-dimensional nanostructures on silicon and SiGe alloy can be fabricated by irradiation of a pulse laser. The physical mechanism forming the net-hole structure and the quantum dots structure of silicon could be explained with the theory of the harmonic standing wave of plasma formed by a pulse laser. The enhancement of the photoluminescence (PL) on the low-dimensional nanostructures was discovered. A stimulated emission at 700 nm was observed on the quantum dots structure of silicon whose peak has a Lorentzian shape with a full width at half maximum of 0.5–0.6 nm. This stimulated emission comes from the nanostructures on silicon oxidized fabricated by irradiation and annealing treatment. Controlling the time of annealing can produce a good coherent emission. A model has been proposed for explaining the stimulated emission in which the trap states of the interface between oxide of silicon and nanocrystal play an important role. Calculation shows that trap electronic states appear in the energy gap of the smaller nanocrystal when Si=O bonds or Si–O–Si bonds are formed. In the theoretical model, the most important factor in the enhancement and pinning effect of PL emission is the relative position between the level of the trap states and the level of the photo-excitation in the silicon nanocrystal.

Symmetry Aspects in Two-dimensional Crystals: Enantiomorphism, Tiling and Phase Transitions

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Crystallization of organic compounds is one of the most important means in chemical and pharmaceutical industry to obtain products. However, not much is understood about important phenomena like polymorphism and optical resolution, i.e., separation of chiral compounds into their left- and right-handed forms. A promising approach is to study these two-dimensional (2D) crystallization phenomena on well-defined substrates with scanning tunneling microscopy (STM) and other surface sensitive techniques. Understanding self-assembly phenomena of organic molecules at metal surfaces is also important for new materials systems for photovoltaic and organic electronics. The interplay of handedness in chiral monolayers shows new cooperative effects like amplification of enantiomorphism or suppression of long-range order by chiral impurities. Symmetry mismatch effects in crystallization, by 2D tiling with fivefold-symmetric corannulene derivatives, so-called buckybowls. STM reveals interesting strategies to achieve close-packing where the symmetry actually does not allow perfect tiling. The role of molecular vibrations for polymorphism will be addressed.

Effects of Catalysts on the Growth of Carbon Nanostructures

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Cu catalyzed carbon nanofibers are investigated by means of transmission electron microscopy. Straight and helical carbon nanofibers are observed to connect to the catalyst particles of octahedron or triangular prism in the samples prepared using the same processing conditions. Statistic analysis leads to evidence that the morphology of the nanofibers depends on the size of the catalyst particles. Small size of catalyst particles favours formation of the helical fibers, while large size of catalysts results in the straight fibers. Based on the observed results, growth and morphology formation of the carbon nanofibers are discussed in the light of diffusion distance of carbon on the surfaces of the catalyst polyhedrons.

Nanowire Surface Modification and Its Effect on Electrical Transport

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Semiconducting nanowires have attracted considerable recent interest due to their unique properties, including their highly anisotropic geometry, large surface-to-volume ratio, and carrier and photon confinement. At present, tremendous efforts are devoted to the rational synthesis of advanced nanowire heterostructures. Yet, if functional devices are to be made from these materials, not only the precise control over their composition, structure, morphology, and dopant concentration must be achieved, their fundamental properties must also be carefully investigated since the presence of a large surface and interfacial area in nanowires can profoundly alter their performance.

In this presentation, surface modification of several semiconducting nanowire and its effect on their carrier transport will be discussed. In the case of thin CdSe nanowire, hydrazine functionalized nanowire device demonstrate improved conductivity as well as its response to the photons, and this behavior can be interpreted in the context of surface trap density modification. For ZnO nanowire devices, the choice of different molecular modification of the surfaces could lead to either increase or decrease in the conductivity.

Exploring the Interfaces of Functional Molecules on Metal Surfaces

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The interface structures and self-assembled behavior of a quinacridone derivative with alkyl chains of 16 carbon atoms (QA16C), an organic semiconductor material, on metal surfaces were investigated by scanning tunneling microscopy (STM). On Cu(110) surface, QA16C molecules prefer to assemble at 150 K into short homochiral molecular lines with two enantiomorphous orientations, in which the lateral alkyl chains exhibit partial disorder. With increasing sample temperatures, the QA16C lines form larger homochiral domains. As a reason for the homochiral recognition, we identify a rigid alignment of the molecule due to the interaction with the substrate. With QA16C molecules on Ag(110) surface, we show how the length and arrangement of carbon ligands of QA16C molecules affect the properties of self-assembled structures in a very subtle manner. It is establish that the involvement of different bond hierarchies, from strong covalent bonding of the backbones to weak van der Waals bonds, results in eight different well-ordered superstructures in the monolayer regime. These superstructures coexist with increasing substrate coverage due to a double functionality of the alkyl chains during the growth process. The detailed insight emerging from this analysis will lead to a much better control in the fabrication of hybrid devices with interfaces between metals and organic molecules.