Monday, March 18, 2013 8:00AM - 11:00AM –
Session A38 GIMS: Focus Session: Instrumentation and Measurement Science for a Sustainable Energy Future 347 - Eric Palm, National High Magnetic Field Laboratory, Tallahassee

8:00AM A38.00001 Our Sustainable Earth RAYMOND L ORBACH, The University of Texas at Austin — Recent evidence demonstrates that the Earth has been warming monotonically since 1980. Transient to equilibrium temperature changes take centuries to develop, as the upper levels of the ocean are slow to respond to atmospheric temperature changes. Atmospheric CO$_2$ concentrations, from ice core and observatory measurements, display consistent increases from historical averages, beginning in about 1880. They can be associated with the use of coal ecause of the spread of the industrial revolution from Great Britain to the European continent and beyond. The climactic consequence of this human-dominated increase in atmospheric CO$_2$ has been suggested to define a geologic epoch, termed the “Anthropocene.” This could be a short term, relatively minor change in global climate, or an extreme deviation that lasts for thousands of years. In order to stabilize global temperatures, sharp reductions in CO$_2$ emissions are required: an 80% reduction beginning in 2050. U.S. emissions have declined sharply recently because of market conditions leading to the substitution of natural gas for coal for electricity generation. Whether this is the best use for this resource may be questioned, but it nevertheless reduces CO$_2$ production by 67% from a coal-fired power plant, well on the way to the 80% reduction required for global temperature stabilization. Current methods for CO$_2$ capture and storage are not cost effective, and have been slow (if not absent) to introduce at scale. This paper describes research into some potentially economically feasible approaches: cost-effective capture and storage of CO$_2$ from injection of flue gas into subterranean methane-saturated aquifers at the surface; fuels from sunlight without CO$_2$ production; and large-scale electrical energy storage for intermittent (and even constant) electricity generating sources.

8:36AM A38.00002 High-Performance Electrocatalysts for Oxygen Reduction Derived from Polyaniline, Iron, and Cobalt†, PIOTR ZELENAY, Los Alamos National Laboratory — With the growing awareness that the use of platinum needs to either be greatly reduced or completely eliminated from the polymer electrolyte fuel cell (PEFC), non-precious metal catalysts for oxygen reduction reaction (ORR) have received lots of attention in recent years as a possible replacement of Pt and its alloys at the fuel cell cathode. A successful cathode catalyst must combine high ORR activity with good long-term stability — a major challenge in the strongly acidic environment of the PEFC cathode. In response to the possibly greatest challenge of the PEFC technology, we have developed a family of non-precious metal ORR catalysts capable of mimizing the performance gap to platinum-based catalysts at a cost sustainable for high-power fuel cell applications, possibly including the automotive power plant. The approach utilizes polyaniline (PANI) as a precursor of a carbon-nitrogen template for high-temperature synthesis of catalysts in the presence of transition metals (Fe and/or Co). The most active materials in the group allow for the ORR to occur within ca. 60 mV of the potential delivered by a state-of-the-art carbon-supported Pt catalyst. A distinctive combination of (i) high ORR activity, (ii) unique performance stability for non-precious metal catalysts (more than 700 hours at a fuel cell voltage of 0.4 V), and (iii) excellent four-electron selectivity (H$_2$O$_2$ yield less than 1.0%), make the leading catalyst in this group, PANI-FeCo(3:1), the best overall non-precious metal ORR catalyst studied to date. More recently, we have also focused on better understanding of the active ORR site via the use of advanced surface characterization techniques, such as nuclear resonance vibrational spectroscopy (NRVS), Monte Carlo pre-screening of possible active sites and more advanced DFT modeling of the most likely active-site structures. Combination of the experiment and theory is expected to aide in the rational design of the future ORR catalysts.

†Financial support from Los Alamos National Laboratory (LDRD Program) and US Department of Energy (Hydrogen and Fuel Cells Program) is gratefully acknowledged.

9:12AM A38.00003 Modulated photocurrent spectroscopy of thin film solar cells, BEHRANG HAMADANI, JOHN ROLLER, EL, NIST, PANAGIOTIS KOUNAVIS, University of Patras, NIKOLAI ZHITENEV, CNST, NIST, DAVID GUNDLACH, PML, NIST — We used the modulated photocurrent spectroscopy technique on sinusoidal excitation of high-powered LEDs to investigate the dynamic response of charge carrier transport in thin film solar cells based on CdTe. The impact of light bias, voltage bias and the temperature over a broad excitation frequency bandwidth were studied. The observed features of the data, including a photocurrent phase-lead and a phase-lag over different regions of the frequency spectrum, were explored in the context of an equivalent circuit model. Comparisons between the model’s predicted performance and the measured data suggest that charge carrier recombination at the cell’s back metal/semiconductor contact is the main source of photocurrent loss in the cells that were investigated by our group.

9:24AM A38.00004 Ultrasensitive spectroscopy of ultrasmall quantum dots for energy conversion and lighting applications, LLOYD DAVIS, Center for Laser Applications, University of Tennessee Space Institute, NOAH ORFIELD, SANDRA ROSENTHAL, Department of Chemistry, Vanderbilt University — Quantum dots typically have narrow spectra with a peak that tunes with their size but ultrasmall semiconductor nanocrystals of diameters less than a few nanometers have size-independent spectra and many other strikingly different properties. One especially interesting feature is that ultrasmall CdSe nanocrystals emit an almost pure white-light spectrum, which has great potential for solid-state light- ing that yields excellent color rendering. To gain understanding of the photophysical properties and mechanisms for broadband emission, we have constructed a modular fluorescence microscope for ultrasensitive spectroscopy of individual nanoparticles. Using 400-nm wide-field excitation from a frequency-doubled Ti-Sapphire laser and a high-efficiency electron-multiplying CCD, we observe that single CdSe nanocrystals exhibit blinking and abrupt photobleaching, often after detection of only a few hundred photons. Moreover, spectrally dispersed imaging shows that each particle emits the entire broadband spectrum. We discuss mechanisms for homogeneous broadband emission and ongoing experiments in which the instrument is configured for scanning, confocal, two-channel, time-resolved single photon counting for studies of photon antibunching, emission lifetimes, and correlations between spectral regions.

9:36AM A38.00005 Measuring Building Insulation*, BETH PARKS, Colgate University — Currently, the only way for homeowners to learn about the effectiveness of their home insulation is to hire an energy auditor. This difficulty deters homeowners from taking action to improve energy efficiency. In principle, measuring the temperature difference between a wall surface and the interior of a home is sufficient to determine the wall insulation, but in practice, temperature cycles from the heating system make a single measurement unreliable. I will describe a simple and inexpensive optimization method.

*Patent application 12/555371

9:48AM A38.00006 Optimized Electronic Transport Measurements in Titanium Oxide, JEFFREY LINDEMUTH, Lake Shore Cryotronics — Titanium Oxide is a material with applications in thermal electric and solar cell applications. Measurement of electronic transport properties by standard methods, for instance Hall effect are made difficult by the low mobility of the material and coupled with the thermal electric properties of the material. The measurements of the resistivity and Hall effect are optimized to reduce the thermal electric effects on the measurement. The Hall measurement is further optimized, by use of AC field Hall method, to obtain reliable mobility values and carrier type determination. Optimization of the measurement includes noise reduction and repeatability of the measurement. Both constant temperature and room temperature measurements are used in the optimization method.
10:00AM A38.00007 Neutron scattering studies of glassy Li⁺ superionics. TOM HEITMANN, University of Missouri Research Reactor, LEO ZELLA, New Mexico State University. ALI ZAIDI, Missouri State University, MUNESH RATHORE, ANSHUMAN DALVI, Birla Institute of Technology and Science, SAIBAL MITRA, Missouri State University — Two distinct neutron scattering techniques were implemented in the study of glassy superionic materials composed of a complex network of their interconnected sub-units: Li₂O, NH₂H₂PO₄, and Li₂SO₄. The use of disordered materials underlies an effort to promote Li⁺ mobility, while suppressing e⁻ conductivity, which makes them good candidates for use as electrolytes in lithium ion batteries. We present triple-axis spectrometer results of energy resolved vs. energy integrated neutron scattering that indicate the presence of a broad range of dynamic processes in the materials, rather than well-defined excitations. Additionally, we report on neutron diffraction data that demonstrates the formation of crystallites within the material upon annealing up to 450 °C. Such crystallites hinder the performance of the materials as electrolytes, which is evident in thin film devices where heating is unavoidable during fabrication.

10:12AM A38.00008 ABSTRACT WITHDRAWN

10:24AM A38.00009 Lithiation of UHV-prepared CoO Conversion Battery Materials Studied by XPS and TEM. RYAN THORPE, Rutgers, SYLVIE RANGAN, ROBERT BARTYNSKI, MAHSA SINA, FREDERIC COSANDEY, Rutgers University — Lithium-ion conversion batteries can store 2-3 times more energy than intercalation batteries by fully reducing their constituent divalent or trivalent transition metal compounds during discharge. A prototypical conversion compound is CoO, which follows the reaction 2Li⁺ + 2e⁻ + Co²⁺ → 2Li₂O + Co⁰ upon discharge. However, the cycling stability of conversion electrodes is poor, and capacity losses have prevented their implementation. To study the electronic and morphological changes that occur during the conversion reaction, we have grown 5 nm polycrystalline and epitaxial CoO films and exposed them to atomic Li in UHV to simulate cell discharge. Using XPS to monitor the valence state of Co and film stoichiometry, we find that at 25°C this reaction is inhibited by the formation of a Li₂O overlayer, which is a kinetic barrier for Li diffusion. This is alleviated by heating the film to 150°C, thereby enhancing Li diffusivity through the overlayer and enabling complete reduction of the film. Epitaxial films are reduced with less Li than is required by polycrystalline films, suggesting the presence of channels through which Li is able to diffuse. In both cases, no cobalt phases other than CoO and Co are observed.

1Work supported in part by DOE award number DE-SC0001294. RT supported through the NSF IGERT grant number 0903661.

10:36AM A38.00010 In situ Measurements of the Solid Electrolyte Interphase in Li-Ion Batteries Using Neutron Reflectometry. JOSEPH DURA, NIST - Center for Neutron Research, JEANETTE OWEJAN, Electrochemical Energy Research Laboratory, General Motors, STEVEN DECALUWE, Dept. of Mechanical Engineering, Colorado School of Mines, JON OWEJAN, Electrochemical Energy Research Laboratory, General Motors — The huge advantages of Li-ion batteries, i.e. high energy density and specific power are due not only to the low mass of Li, but also a direct result of the high operating voltage provided by the large electrochemical potential of Li. However, these advantages come at a cost, as all known electrolytes are unstable at these potentials. Li-ion batteries are only made possible by the solid electrolyte interphase, SEI, a passivation layer that forms from the decomposition products of certain electrolytes. Ideally the SEI offers sufficient electronic resistance when it has grown thick enough to stop additional electrolyte decomposition. However, slow continued SEI growth leads to capacity fade and increased cell resistance. Despite the SEI’s critical significance, currently structural characterization is incomplete because of the reactive and delicate nature of the SEI and the electrolyte system in which it forms. Here we present the first in situ neutron reflectometry measurements of the SEI layer as function of potential in a working lithium half-cell. The SEI layer after 10 and 20 CV cycles is 4.0 and 4.5 nm, respectively, growing to 8.9 nm after a series of potentiostatic holds that approximates a charge/discharge cycle. Specified data sets show uniform mixing of SEI components.

10:48AM A38.00011 Low temperature MRFM probe development and initial characterization of organic solar cells. MARK MONTI, DIMITRI ALEXSON, DORAN SMITH, U.S. Army Research Laboratory — We report on the construction of a Magnetic Resistance Force Microscope (MRFM) for organic solar cell characterization. Organic bulk-heterojunction solar cells (OSCs) consist of a blend of two organic semiconductors - an electron donating polymer and an electron accepting fullerene. The efficiency of blended OSCs is highly dependent on the phase separation between the donor and acceptor materials. MRFM offers a unique toolset to study OSCs with the potential to gain insight into the morphology of the buried heterostructure on an actual device. The MRFM probe will operate at 4K and up to 9T using force gradient detection of magnetic resonance via an ultra sensitive single crystal silicon cantilever. We plan on performing NMR spectroscopy on OSCs using a shuttling technique whereby the sample is shuttled back and forth between the two organic semiconductors - an electron donating polymer and an electron accepting fullerene. We have studied the rapid nucleation and growth at the nanoscale of crystallites from an initially amorphous metal alloy parent phase and in amorphous Ge. DTEM has also been used to study reactive multilayer films of Ni and Al that sustain a reaction front speed greater than 10 m/s. We have also investigated rapid solidification of nanoscale films of liquid Al-Cu alloys. This work performed under the auspices of the U.S. Department of Energy, Office of Basic Energy Sciences, Division of Materials Sciences and Engineering by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344.

Monday, March 18, 2013 11:15AM - 1:51PM
Session B39 DMP GIMS: Focus Session: Imaging & Modifying Materials Under Extreme Conditions of Radiation, Temperature, and at the Limits of Space and Time Resolution 348 -

11:15AM B39.00001 Quantifying transient dynamics in materials using time resolved in situ TEM. GEOFFREY CAMPBELL, Lawrence Livermore National Laboratory — The dynamic transmission electron microscope (DTLM) is a standard TEM that has been modified such that the electron beam can be operated with a single intense pulse of electrons (> 10⁸ e⁻) with a pulse duration of just 15 ns. The short pulse of electrons is created via photoemission at the microscope cathode and enables time resolved observations of in situ experiments. However, it can also be operated in thermionic emission mode for normal operation of the microscope for alignment and experimental setup. Additional modifications have also been made to the optical design of the condenser lens system. The in situ experiments currently use a second laser to initiate the dynamic response of interest in the specimen. The relative timing of the pulses from the two laser systems sets the time of the observation relative to the initiation of the event under study. The DTLM has been used to investigate a number of rapid phenomena in materials. We have studied the rapid nucleation and growth at the nanoscale of crystalline phases from an initially amorphous metal alloy parent phase and in amorphous Ge. DTEM has also been used to study reactive multilayer films of Ni and Al that sustain a reaction front speed greater than 10 m/s. We have also investigated rapid solidification of nanoscale films of liquid Al-Cu alloys. This work performed under the auspices of the U.S. Department of Energy, Office of Basic Energy Sciences, Division of Materials Sciences and Engineering by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344.
11:51AM B39.00002 Studying dynamic processes in liquids by TEM/STEM/DTEM, PATRICIA ABELLAN, JAMES E. EVANS, PNNL, TAYLOR J. WOELH, KATHERINE L. JUNGMANN, LUCAS R. PARENT, UC—Davis, ILKE ARSLAN, PNNL, WILLIAM D. RISTENPART, UC—Davis, NIGEL D. BROWNING, PNNL, MATER. SCI. GROUP TEAM, MICROSC. GROUP TEAM, CATAL. SCI. GROUP COLLABORATION, RISTENPART RES. GROUP COLLABORATION — In order to study dynamic phenomena such as corrosion or catalysis, extreme environmental conditions must be reproduced around the specimen—these include high-temperatures, high-pressures, specific oxidizing/reducing atmospheres or a liquid environment. The use of environmental stages specifically designed to fit in any transmission electron microscope (TEM) allows us to apply the distinct capabilities of each instrument to study dynamic processes. Localized gas/fluidic conditions are created around the sample and separated from the high vacuum inside the microscope using hermetically sealed windowed-cells. Advanced capabilities of these techniques include spatial resolutions of ~1 Ångstrom or better in aberration corrected instruments or temporal resolutions in the microsecond-nanosecond range in a dynamic TEM (DTEM). Here, unique qualities of the DTEM that benefit the in-situ experiments with gas/fluidic environmental cells will be discussed. We also present our results with a liquid stage allowing atomic resolution imaging of nanomaterials in a colloidal suspension, core EEL spectra acquisition, continuous flow, controlled growth of nanocrystals and systematic calibration of the effect of the electron dose on silver nuclear formation.

12:03PM B39.00003 Imaging Lead Dendrite Formation and Ion Diffusion in Aqueous Solution with Scanning Transmission Electron Microscopy1, EDWARD WHITE, SCOTT SINGER, UCLA Department of Physics and Astronomy & CNSI, VERONICA AUGUSTYN, UCLA Department of Materials Science and Engineering & CNSI, WILLIAM HUBBARD, MATTHEW MECKLEBURG, UCLA Department of Physics and Astronomy & CNSI, BRUCE DUNN, UCLA Department of Materials Science and Engineering & CNSI, B. C. REGAN, UCLA Department of Physics and Astronomy & CNSI — Using a scanning transmission electron microscope, we image the formation of lead dendrites and the local Pb\(^{2+}\) concentration in an electrochemical cell containing a saturated solution of lead(II) nitrate. We control the morphology of the lead deposits with the rate of potential change, which can result in dendrites or compact layers. The processes are reversible and can be repeated. During lead stripping and plating the local Pb\(^{2+}\) concentration can be measured as an increase or decrease in signal intensity, respectively, as ions come into and out of solution. Quantitative digital image analysis reveals excellent correlation between changes in the Pb\(^{2+}\) concentration, the rate of lead deposition, and the current passed by the electrochemical cell. Furthermore imaging the ion concentration as a function of time and distance from the electrode provides a measurement of the diffusion coefficient of the Pb\(^{2+}\) ion. Real-time electron microscopy of dendritic growth dynamics and the associated local ion concentrations can provide new insight into the functional electrochemistry of batteries and related energy storage technologies.

1Supported by The ACS PRF 50630-ND10 and the NSF CAREER grant DMR 0748880

12:15PM B39.00004 Imaging and measuring the evolution of solid density within a thermal explosion, LAURA SMILOWITZ, LANL — Explosives have been used for millennia. All materials are energetic, but high explosives have the ability to release their stored energy in a very short period of time—nanoseconds in the case of detonations. Many explosives have an as-designed behavior that is well understood and controlled. However, the off-nominal behavior, such as would occur in an accident scenario, is typically much less understood. The subject of our research has been the energy release mechanisms for secondary high explosives heated to thermal explosion. The study of thermal explosions poses several difficulties including extreme temperature, pressure, and rate of change. In addition, thermal explosions pose the difficulty of being spontaneous dynamic events with limited ability to predict the time of the event. Typically, event durations are tens of microseconds and timing jitter is tens of seconds—essentially one in a million duty cycle. These difficulties have precluded the use of many standard laboratory diagnostics to the study of the phenomena. In the past years, we have developed diagnostics that can survive the extremes of the thermal explosion with sufficient response time and the ability to remain armed and be triggered by the onset of the spontaneous event. In addition to microsecond temporal resolution, the diagnostics need to be spatially resolved with 100 micron spatial resolution and centimeter field of view in order to capture the spatial heterogeneity of the event. Our work has focused on the important secondary high explosive PBX 9501 which is a formulation of the organic crystalline nitramine octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX). Our evolving understanding of this material has enabled us to develop a table-top x-ray imaging experiment providing millisecond time resolution with duration of minutes and sensitivity to density changes of better than 1%. This quasi-static regime provides images of material thermal expansion, phase transitions, and thermal decomposition leading to the onset of thermal ignition. A second technique provides microscale size time resolution with duration of milliseconds and contrast sensitivities of a few percent. This technique allows us to observe the propagation of ignition which determines the overall violence of the thermal explosion. In this talk, I will describe our current understanding of thermal explosions, and the evolution of the radiographic diagnostics that we have developed to study thermal explosions.

12:51PM B39.00005 Radiographic imaging of solidification in Al-Cu alloys, JASON COOLEY, AMY CLARKE, SETH IMHOFF, Brian PATTERSON, Los Alamos National Laboratory, WAH-KEAT LEE, Brookhaven National Laboratory, KAMEL FEZZAA, ALEXANDER DERIY, Argonne National Laboratory, TIM TUCKER, MARTHA BARKER, KESTER CLARKE, ROBERT CLARKE, DAN THOMA, DAVID TETER, Los Alamos National Laboratory — Until the advent of third generation synchrotrons the ability to image the microstructure of metals during solidification was non-existent. Today’s sources have sufficient energy and flux to perform real time radiographic imaging of solidification in thin samples with resolution sufficient to image dendrites, eutectic lamellae, and the density change across the solidification front. Feedback control of the solidification interface is also possible. We report on the radiographic imaging of Al-Cu eutectic alloys during solidification at the Argonne National Laboratory Advanced Photon Source. Cooling rates of up 10 degrees C/sec and, temperature gradients of up to 150 degrees C/cm were used to control the solidification. The samples were ~100 microns thick and the field of view was ~1.4 x 1.7 mm. The experimentally accessible phase space included both plane front and cellular growth regimes. The experimental resolution in the micron range was adequate to quantify cellular radii, cellular interface angles, lamellar interface angles, and lamellar spacing.

1:03PM B39.00006 Pressure-induced antiferrodistortive phase transition and phonon softening in SrTiO\(_3\), SHIH-CHANG WENG, Dept of Physics, U. of Illinois at Urbana-Champaign, RUQING XU, AYMAN SAID, Advanced Photon Source, Argonne National Lab, SHIH-LIN CHANG, National Synchrotron Radiation Research Center, TAI-CHANG CHIANG, Dept of Physics, U. of Illinois at Urbana-Champaign — SrTiO\(_3\), at room temperature, undergoes an antiferrodistortive transition under pressure with a critical pressure of \(P_c \approx 9.6\) GPa. This transition is accompanied by a cubic–to–tetragonal structural distortion, and the same distortion can be induced at ambient pressure by lowering the sample temperature below \(T_c \approx 110\) K. The temperature-induced transition is known to involve a soft phonon at the R point in the Brillouin zone based on neutron scattering, inelastic x-ray scattering, and thermal diffuse scattering studies. The same soft mode is expected for the pressure induced transition, and we report herein the first direct measurement using inelastic x-ray scattering and a diamond-anvil pressure cell. The phonon softening behavior follows a power law and is accompanied by a peak. The results are analyzed theoretically and correlated with those for temperature-induced transition.

1:15PM B39.00007 Femtosecond laser fabrication of micro/nano-channel array devices for parallelized fluorescence detection, BRIAN CANFIELD, WILLIAM HOFMEISTER, LLOYD DAVIS, University of Tennessee Space Institute — Cost-effective pharmaceutical drug discovery depends on increasing assay throughput while reducing reagent needs. Ultrasensitive, highly parallelized fluorescence-based platforms that incorporate a nano/micro-fluidic chip with an array of closely spaced channels would meet this need. We discuss the use of direct femtosecond laser machining to fabricate prototype fluidic chips with arrays of more than one hundred closely spaced channels. Traditional machining techniques involve overlapping focal spots from many laser pulses while scanning the substrate in order to create an array. However, this procedure is not only lengthy but may allow thermal effects to accumulate that degrade the quality of both the channel profile and surrounding substrate material. We are developing a different method for machining a line with just a single pulse, using a combination of cylindrical lenses and an aspheric lens to reshape a near-Gaussian beam into a tight line focus. Channels on the order of 1 micron wide, 5 microns deep, and nearly 2000 microns long may be made this way. We also address the critical issue of mitigating the high autofluorescence responses that arise from the creation of defects by fs-laser machining in fused silica.
Bond dissociation of small molecules on the silver tip under the influence of local electric field. HANYAN HE, Department of Physics and Astronomy, University of California, Irvine, CA 92697, MAYUKH BANIK, VARTKESS APKARIAN, Department of Chemistry, University of California, Irvine, CA 92697, RUQIAN WU, Department of Physics and Astronomy, University of California, Irvine, CA 92697 — The manipulation of chemical bonds at metallic nano-junctions, such as at scanning tunneling junctions, and under laser irradiation is currently of great interest, motivated by both fundamental considerations and applications in nanoelectronics, nanophotonics and nanocalysis. In this work, we systematically investigate bond formation and dissociation of small molecules (e.g., oxygen and carbon monoxide) at the junction of two silver (111) tipped surfaces, through first principles molecular dynamics simulations. The electronic structures and vibrational frequencies are a sensitive function of the gap size, and significantly modified by the local electric fields. The calculated results are compared with recent experiments. Acknowledgement. This work was supported by the National Science Foundation under CHE-0802913 and computing time at XSEDE.

The ongoing efforts to develop a reliable ultrafast electron diffraction and imaging system require a stable source of photoemitted electrons and an understanding of how the properties of the generated bunch depend on the photocathode. In order to gain more understanding of this process, we combine the three-step photoemission model with N-particle electron simulations. By using the Fast Multipole Method to treat space charge effects, we are able to follow the time evolution of pulses containing over $10^2$ electrons and investigate the role of laser fluence and extraction field on the total number of electrons that escape the surface. The results of these simulations are compared to experimental images of the photoemission process collected using the shadow imaging technique. We are able to show good quantitative agreement both for the number of electrons generated and the pulse parameters. We also see evidence of a virtual cathode limit, which gives an upper limit to the number of electrons that is possible to extract. The extension of these results to various extraction fields, laser pulse shapes and photocathode material parameters, represents a very interesting future development, allowing to better optimize the materials used in electron pulse generation.

This work was supported by the National Science Foundation under Grant No. NSF-DMR 1126343.

Tuesday, March 19, 2013 2:30PM - 5:42PM – Session J46 GIMS: Focus Session: X-ray and Neutron Instruments and Measurement Science

**3:06PM B39.00009 Understanding the ultrafast electron photoemission process, from simulation to experiment**


**3:06PM B39.00009 Understanding the ultrafast electron photoemission process, from simulation to experiment**


**3:18PM J46.00003 Development of a 10 nm spatial resolution Hard X-ray Microscope for the Nanoprobe beamline at NSLS-II**

**3:18PM J46.00003 Development of a 10 nm spatial resolution Hard X-ray Microscope for the Nanoprobe beamline at NSLS-II**

EVENGY NAZARETSKI, HANFEI YAN, JUNGDAE KIM1, KENNETH LAUER, KAZIMIERZ GOFRON, Brookhaven National Laboratory, DEMING SHU, Argonne National Laboratory, YONG CHU, Brookhaven National Laboratory — We present recent progress on the development of an x-ray microscope for the Hard X-ray Nanoprobe (HXX) beamline at NSLS-II. We discuss design approach suitable for achieving sub-10 nm spatial resolution x-ray fluorescence and diffraction measurements. Different types of focusing optics e.g. Multilayer Laue Lenses (MLL) and Zone Plates (ZP) will be implemented in the microscope yielding diverse scientific applications for the targeted spatial resolutions of 10 nm and 30 nm respectively. We discuss modular design of the microscope that enables multi-functionality and includes the possibility to regulate temperature at the sample location. The design of the microscope is greatly based on our in-depth evaluation of numerous commercially available components; detailed studies of their performance in terms of mechanical stability, resolution, and thermal characteristics. Also, our design approach greatly relies on extensive experience acquired during construction and subsequent using of a prototype scanning MLL-based microscope.

**3:30PM J46.00004 Application of ultra-small-angle X-ray scattering / X-ray photon correlation spectroscopy to relate equilibrium or non-equilibrium dynamics to microstructure**

- ANDREW ALLEN, FAN ZHANG, LYLE LEVINE, NIST, JAN ILAVSKY, Argonne National Laboratory — Ultra-small-angle X-ray scattering (USAXS) can probe microstructures over the nanometer-to-micrometer scale range. Through use of a small instrument entrance slit, X-ray photon correlation spectroscopy (XPCS) exploits the partial coherence of an X-ray synchrotron undulator beam to provide unprecedented sensitivity to the dynamics of microstructural change. In USAXS/XPCS studies, the dynamics of local structures in a scale range of 100 nm to 1000 nm can be related to an overall hierarchical microstructure extending from 1 nm to more than 1000 nm. Using a point-detection scintillator mode, the equilibrium dynamics at ambient temperature of small particles (which move more slowly than nanoparticles) in aqueous suspension have been quantified directly for the first time. Using a USAXS/XPCS scanning mode for non-equilibrium dynamics incipient processes within dental composites have been elucidated, prior to effects becoming detectable using any other technique.

**3:30PM J46.00004 Application of ultra-small-angle X-ray scattering / X-ray photon correlation spectroscopy to relate equilibrium or non-equilibrium dynamics to microstructure**

- ANDREW ALLEN, FAN ZHANG, LYLE LEVINE, NIST, JAN ILAVSKY, Argonne National Laboratory — Ultra-small-angle X-ray scattering (USAXS) can probe microstructures over the nanometer-to-micrometer scale range. Through use of a small instrument entrance slit, X-ray photon correlation spectroscopy (XPCS) exploits the partial coherence of an X-ray synchrotron undulator beam to provide unprecedented sensitivity to the dynamics of microstructural change. In USAXS/XPCS studies, the dynamics of local structures in a scale range of 100 nm to 1000 nm can be related to an overall hierarchical microstructure extending from 1 nm to more than 1000 nm. Using a point-detection scintillator mode, the equilibrium dynamics at ambient temperature of small particles (which move more slowly than nanoparticles) in aqueous suspension have been quantified directly for the first time. Using a USAXS/XPCS scanning mode for non-equilibrium dynamics incipient processes within dental composites have been elucidated, prior to effects becoming detectable using any other technique.

- Use of the Advanced Photon Source, an Office of Science User Facility operated for the United States Department of Energy (U.S. DOE) Office of Science by Argonne National Laboratory, was supported by the U.S. DOE under Contract No. DE-AC02-06CH11357.
3:42PM J46.00005 Solution measurements yield atomic scale resolution. DEREK MENDEZ, JONGMIN SUNG, Stanford Applied Physics, DANIEL RATNER, Stanford Linear Accelerator Center, CLEMENT LEVARD, MARC MICHEL, GORDON BROWN, Stanford Geology, SEBASTIAN DONIAH, Stanford Applied Physics — A conventional measure on a solution of identical non-interacting particles (e.g. a dilute solution of proteins) is the scattering averaged over all particle orientations. Such scattering results in a 1-D profile, e.g. the standard powder diffraction rings. Here, we aim to recover information that is averaged out in such a measurement. By recording many short, bright X-ray pulses one can obtain the scattering fluctuation, i.e. the 2-photon correlation function. Intensity correlations arise from double scattering events in which two photons from an incoming beam scatter off the same particle, belonging to an ensemble of randomly oriented particles. The double scattering must occur during a single exposure, and before the scatterer has undergone significant diffusion. At wide angles, such correlations have the potential to yield A-scale single-particle structural information. The problem is to extract correlated events from a background of uncorrelated single-photon scattering events. This is done by forming statistics over an ensemble of correlation measurements and comparing to correlations between uncorrelated pairs of exposures. Samples range from naturally occurring nano-minerals measured using focused synchrotron X-rays, to biomolecules measured using a free electron laser.

1Linac Coherent Light Source LCLS
2Principal Investigator

3:54PM J46.00006 Interpreting SAXS spectra of non-spherical nonaqueous nanoparticle nanodroplets using a new particle form factor factor1, ABDALLA OBEIDAT, FAWAZ HRAHSHEH, GERALD WILEMSKI, Missouri University of Science and Technology, HARSHAD PATHAK, BARBARA WYSLOUZIL, The Ohio State University — The structure of nanodroplets plays a critical role in many natural phenomena involving atmospheric nucleation and aerosol formation. Here, we review our theoretical efforts to interpret experimental measurements of small angle x-ray scattering (SAXS) from nonaqueous nanodroplets formed in supersonic nozzles. We simulated nonaqueous nanodroplets using classical molecular dynamics (MD) and found that they have a nonspherical Russian-Doll (RD) structure consisting of a roughly spherical water droplet partially wetted by a large nonane lens. We have developed an exact analytical expression for the particle form factor \( P(q) \) of a lens-on-sphere droplet with sharp interfaces and uniform lens and sphere densities for use in fitting the experimental data. The model was validated by comparing it with exact results for \( P(q) \) based on the MD simulations. Excellent agreement was found. The fits of the measured SAXS spectra generated with this model are good and generally better than those based on simpler structural models, but the resulting particle size distributions do not produce mass balance for either water or nonane. Further work is needed to resolve this discrepancy.

1Supported by NSF Grants CBET 1033887 and 1033439

4:06PM J46.00007 Radiation Induced Defect Clusters in Fe and Fe-alloys Investigated by X-Ray Diffuse Scattering Measurements and Molecular Dynamics and Monte Carlo Simulations1, BEN LARSON, Oak Ridge National Laboratory, JON TISCHLER, Argonne National Laboratory, HONGBIN BEI, ROGER STOLLER, HAIXUAN XU, Oak Ridge National Laboratory, YANWEI ZHANG, Oak Ridge National Laboratory/ Univ. TN-K — We have initiated fundamental investigations of 15 MeV Ni-ion induced defect clusters in single crystal Fe and Fe-Cr using diffuse scattering measurements near Bragg reflections combined with molecular dynamics (MD) and self-evolving atomistic kinetic Monte Carlo (SEAK-MC) simulations. Synchrotron x-ray diffuse scattering measurements performed near the (002) reflection of Fe-Cr single crystals are analyzed within the so-called asymptotic regime using scattering cross-sections based on MD simulated local lattice distortions and SEAK-MC generated interstitial and vacancy cluster configurations. Measurements for Ni-ion irradiations of Fe and Fe-Ni with doses corresponding to 0.2 and 1 displacements per atom (DPA) at ambient temperature will be presented and discussed in connection with the local Bragg scattering interpretation of defect cluster diffuse scattering in ion-irradiated Cu. Methods for calculating diffuse scattering cross sections directly from MD simulations of atomic displacements around vacancy and interstitial loops within the single defect approximation will be considered and the importance of such approaches for complex defect clusters will be addressed.

1Research supported by the US DOE, Basic Energy Sciences, Center for Defect Physics Energy Frontier Research Center

4:18PM J46.00008 Investigation of the experimental effects on the quality of the rapid acquisition pair distribution function (RA-PDF) data1, AHMAD S. MASADEH, Department of Physics, University of Jordan, Amman 11945, Jordan — Series of experiments have been carried out to investigate the quality of the recently developed rapid acquisition atomic pair distribution function (RA-PDF) method, which combines the uses of high energy X-rays and an image plate area detector. Image plate data for simple elements (C, Mg, Al, Si, Ni, Cu, Zn, Ag, and Pb) have been analyzed, using (RA-PDF) technique. The effect of undiscriminated Compton and fluorescence is investigated for a wide range of materials with atomic Z numbers ranging from 6(Carbon) and 82(Pb). We find the RA-PDF method is capable of obtaining high quality PDFs where quantitatively reliable structure information can be extracted.

1We would also like to acknowledge Dr. Simon Billinge group at NSLS and The University of Jordan for the support.This work was supported in part by (NSF) grant DMR-0304391.Use of the APS is supported by the U.S. DOE, Contract No. W-31-109-Eng-38.

4:30PM J46.00009 Test of the Cross Correlation Method for Efficient Single Crystal Diffuse Neutron Scattering with Elastic Discrimination1, STEPHAN ROSENKRANZ, JOHN PAUL CASTELLAN, RICH VITT, RAY-MOND OSBORN, Argonne National Laboratory, RICK RIEDEL, MARIANO RUIZ-RODRIGUEZ, LOREN FUNK, Oak Ridge National Laboratory — Single crystal diffuse scattering provides a powerful probe of the complex disorder associated with many emergent phenomena of great interest. It provides a determination not only of the local distortions around a point defect but also of the length scale and morphology of short-range order on the nanoscale. However, obtaining accurate models of the local structure usually demands measurements over large volumes of reciprocal space with sufficiently high momentum and energy resolution. In order to overcome limitations of current instrumentation, we propose to utilize the cross-correlation method at pulsed neutron sources. This concept combines the high efficiency of white-beam Laue diffraction for measuring large volumes of reciprocal space with energy discrimination produced by the use of a statistical chopper is currently being implemented in a dedicated instrument, Corelli, under construction at the Spallation Neutron Source. Here, we present our detailed investigation of the effectiveness of this method for measuring weak diffuse signals, based on full experiment simulations as well as actual measurements of the diffuse scattering from powder and single crystal samples obtained utilizing the cross correlation method on a prototype instrument.

1work supported by US DOE BES DE-AC02-06CH11357
4:42PM J46.00010 Design of Ultra Small Angle Neutron Scattering (KIST-USANS) at HANARO Cold Neutron Guide, CG4B1, MAN-HO KIM, Korea Institute of Science and Technology — The ultra small angle neutron scattering instrument can measure the lower limit of scattering vector to near Q ~ 2.0×10⁻⁵ Å⁻¹ while the upper limit can reach to an intermediate scattering vector Q ~ 10⁻² Å⁻¹ of a typical small angle neutron scattering (SANS) depending on the contrast of sample. USANS is useful when measuring objects that are micron to sub-micron in size while SANS is useful when measuring objects that are micron to nano in size. When both USANS and SANS were used together, we could measure sizes from micron to nano scale, which is useful when studying the hierarchical structures in the wide scale of Q and total cross-section, dΣ/dΩ(Q). Recently, KIST has developed the USANS (so called KIST-USANS) at HANARO cold neutron guide hall of KAERI. We will present the instrument design, performance, future plan, and some examples of measurements that cover approximately 11 orders of magnitude in the dΣ/dΩ(Q) and 4 orders in the Q.

1This work was partially supported by the KIST (202632) and the National Research Foundation of Korea(NRF) grant funded by the Korea government(MEST) (No. 2012MB2A4030220)

4:54PM J46.00011 Photon Source Capabilities of the Jefferson Lab THz to VUV FEL1, G.P. WILLIAMS, S.V. BENSON, D. DOUGLAS, P. EVTUSHENKO, F.E. HANNON, C. HERNANDEZ-GARCIA, J.M. KLOPPF, R.A. LEGG, G.R. NEIL, M.D. SHINN, C.D. TENNANT, S. ZHANG, Jefferson Lab — Jefferson Lab operates a sub-pico-second photon science R&D facility with peak and average brightness values that are many orders of magnitude higher than storage rings in the THz - VUV range. It also has multiphoton capabilities that provide unique opportunities for out of equilibrium dynamical studies at time-scales down to ~ 100 fs FWHM. The facility is based on a superconducting energy recovered linac which is operated with CW RF that powers oscillator-based IR and UV Free Electron Lasers (FELs) with diffraction limited sub-pico-second pulses with > 10¹³ photons per pulse (1.0% BW) at pulse repetition frequencies up to 75 MHz. Details of the facility and its present performance will be presented along with some example science applications. In addition we will discuss on-going upgrades to the facility that will allow 10 eV lasing in the fundamental. Finally we will present two potential upgrades including the design of an oscillator-based VUV-FEL that would produce 6×10¹² coherent (0.5% BW) 100 eV photons per pulse at multi-MHz repetition rates in the fundamental, and a dual FEL configuration that would allow simultaneous lasing at THz and UV wavelengths.

1We acknowledge support from the Commonwealth of Virginia. Jefferson Lab is supported by the U.S. DOE under Contract No. DE-AC05-84-ER40150.

5:06PM J46.00012 Picosecond Time-Resolved Strain Rosette at Atomic Length Scale, MARIA I. CAMPANA, G. JACKSON WILLIAMS1, DePaul University, SOO HEYONG LEE, Korean Research Institute of Standards and Science, DONALD WALKO, Argonne National Laboratory, ERC LANDAHL2, DePaul University — Ultrafast optical absorption in a crystalline solid generates coherent motions of strain, which propagate through the bulk at the speed of sound. Energy relaxation dynamics of the excited lattice system and the subsequent transport properties of the strains have been actively studied. Recently, these high-speed transient dynamics have been studied using laser based pump-probe techniques and time resolved x-ray diffraction (TRXD). However, the interpretation of these studies always assumes a uniaxial spatial profile for the strain (i.e. strain is exerted only along the direction of surface normal of the sample). This assumption comes from a symmetry argument originally given by Thomsen: if the illuminated area of the pump laser beam on the sample surface is much larger than the optical penetration depth, strain gradient along surface normal is expected to be much steeper than along lateral direction, and therefore, the strain generated is usually assumed to be one dimensional. While this assumption simplifies the analysis of the data, (and makes possible such applications as picosecond ultrasonics for the in-situ measurement of semiconductor heterostructure thickness), it overlooks any physical processes that take place along transverse direction. Here we report the experimental generation and detection of the transverse component of the impulsively generated strain in a single GaAs crystal using TRXD. Our analysis is based on a strain rosette applied to three non-collinear Bragg reflections.

1Present affiliation: University of California, Davis
2To whom correspondence should be addressed

5:18PM J46.00013 A high-energy x-ray precession camera at the Advanced Photon Source, A. KREYSSIG, D.K. PRATT, M. RAMAZANOGLU, G. TUCKER, Ames Laboratory, Dept. of Physics and Astronomy, Iowa State University, Ames, IA, D.S. ROBINSON, L.C. LANG, Advanced Photon Source, ANL, Argonne, IL, R.J. MCQUEEN, A.I. GOLDMAN, Ames Laboratory, Dept. of Physics and Astronomy, Iowa State University, Ames, IA — A key distinguishing feature of the APS is the capability for high-energy x-ray scattering, which has been exploited for numerous powder sample applications. The instrumentation for high-energy single-crystal diffraction measurements at the APS, however, remains underdeveloped. High-energy x-rays offer several advantages: (1) absorption effects are minimized and the entire bulk of the sample is probed and; (2) a large range of reciprocal space can be imaged when used together with a modestly sized area detector. We have developed a high-energy x-ray precession camera (HEXPC) for imaging of reciprocal-space planes. This technique is highly suited to studies of Bragg and diffuse scattering with its flexibility in dynamic range, resolution and scattering vector range. These capabilities have been demonstrated by studies of single crystals and quasicrystals.

The work at the Ames Laboratory was supported by US DOE, Office of Basic Energy Sciences, DMSE, contract DE-AC02-07CH11358.

5:30PM J46.00014 SESAME as a Model Project for Other Regions1, HERMAN WINICK2, SLAC National Accelerator Laboratory — UNESCO became the umbrella organization for SESAME at its Executive Board 164th session, May 2002. The following comments about SESAME were made by this board: “a quintessential UNESCO project combining capacity building with vital peace-building through science” and “a model project for other regions.” Now that SESAME is well underway, other regions (e.g.; Africa and Central Asia) should be made aware of this progress, and they should be welcomed to join SESAME as a first step in developing similar projects in their region. Students and scientists from other regions should be encouraged to attend SESAME Users’ meeting, schools, workshops, etc. where they can learn about synchrotron radiation sources, beamlines, and science. They should be invited to join SESAME scientists in designing and commissioning accelerators and beamlines, gaining relevant experience for their own projects and helping SESAME in the process.

1Work supported by DOE Office of Basic Energy Sciences
2I am emeritus faculty at SLAC

Tuesday, March 19, 2013 5:45PM - 6:45PM —
Session K46 GIMS: GIMS Business Meeting Hilton Baltimore Holiday Ballroom 5

5:45PM K46.00001 GIMS BUSINESS MEETING —
8:00AM M46.00001 Investigation of cell morphology for disease diagnoses via high content screening , SHYAM KHATAU, Johns Hopkins University — Ninety percent of all cancer-related deaths are caused by metastatic disease, i.e. the spreading of a subset of cells from a primary tumor in an organ to distal sites in other organs. Understanding this progression from localized to metastatic disease is essential for further developing effective therapeutic and treatment strategies. However, despite research efforts, no distinct genetic, epigenetic, or proteomic signature of cancer metastasis has been identified so far. Metastasis is a physical event: through invasion and migration through the dense, tortuous stromal matrix, intravasation, shear forces of blood flow, successful re-attachment to blood vessel walls, migration, the colonization of a distal site, and, finally, reactivation following dormancy, metastatic cells may share precise physical properties. Cell morphology is the most direct physical property that can be measured. In this work, we develop a high throughput cell phenotyping process and investigate the morphological signature of primary tumor cells and liver metastatic pancreatic cancer cells.

8:36AM M46.00002 Multiplexing nano-electroporation for simultaneous transfection of multiple cells, M. HOWDYSELL, G. VIEIRA, D. GALLEGOS-PEREZ, X. ZHAO, L. J. LEE, R. SOORYAKUMAR, The Ohio State University — Transfection of biomolecules into cells via electrophoresis across nanochannels, or nano-electroporation, is a recently developed technique shown to deliver precisely controlled dosages with low cell mortality rates. Such advantages are due to the nanochannels used for transfection, which distinguish this technique from bulk and micro-electroporation. Recent demonstrations of nano-electroporation rely on optical tweezers for cell localization, which restrict throughput to sequential electroporation of one cell at a time. In the current work, we overcome this drawback by advancing a multiplexed approach that integrates the nano-device with an array of magnetic traps remotely controlled by external magnetic fields. This setup enables multiple magnetically labeled cells to be manipulated in parallel, allowing for simultaneous electroporation of many cells with precisely controlled dosages. After transfection, the cells can be moved downstream for further analysis. Such a magnetically-actuated, remotely-controlled approach for loading of cells and subsequent removal of transfected cells has the potential to transform the current device into an automated platform for simultaneous dosage-controlled biomolecule delivery to large numbers of individual cells.

8:48AM M46.00003 Nanopore Mass Spectrometry1, JOSEPH BUSH, MIRNA MIHOVIOVIC, WILLIAM MAULBTSCH, LAYNE FRENCHETTE, WOOYOUNG MOON, COLE PRUITT, Brown University Physics Department, CARTHENE BAZEMORE-WALKER, PETER WEBER, Brown University Chemistry Department, DEREK STEIN, Brown University Physics Department — We report on the design, construction, and characterization of a nanopore-based ion source for mass spectrometry. Our goal is to field-extract ions directly from solution into the high vacuum to enable unit collection efficiency and temporal resolution of sequential ion emissions for DNA sequencing. The ion source features a capillary whose tip, measuring tens to hundreds of nanometers in inner diameter, is situated in the vacuum ∼ 1.5 cm away from an extractor electrode. The capillary was filled with conductive solution and voltage biased relative to the extractor. Applied voltages of hundreds of volts extracted tens to hundreds of nA of current from the tip. A mass analysis of the extracted ions showed primarily singly charged clusters comprising the cation or anion solvated by several solvent molecules. Our interpretation of these results, based on the works of Taylor and of de la Mora, is that the applied electric stresses distort the fluid meniscus into a Taylor cone, where electric fields reach ∼ 1V/nm and induce significant ion evaporation. Accordingly, the abundances of extracted ionic clusters resemble a Boltzmann distribution.

9:00AM M46.00004 Coupled External Cavity Photonic Crystal Enhanced Fluorescence1, ANUSHA POKHRIYAL, Department of Physics, University of Illinois at Urbana-Champaign, MENG LU, CHUN GE, BRIAN CUNNINGHAM, Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, NANO SENSORS GROUP TEAM — In this work we report a fundamentally new approach to enhance fluorescence in which surface adsorbed fluorophore-tagged biomolecules are excited on a photonic crystal surface that functions as a narrow bandwidth and tunable mirror of an external cavity laser. This scheme leads to ~10x increase in the electromagnetic enhancement factor compared to ordinary photonic crystal enhanced fluorescence. In our experiments, the cavity automatically tunes its lasing wavelength to the resonance wavelength of the photonic crystal, ensuring optimal on-resonance coupling even in the presence of variable device parameters and variations in the density of surface-adsorbed capture molecules. We achieve ~10x improvement in the limit of detection of a fluorophore-tagged protein compared to its detection on an unpatterned glass substrate. The enhanced fluorescence signal and easy optical alignment make cavity-coupled photonic crystals a viable approach for further reducing detection limits of optically-excited light emitters that are used in biological assays.

9:12AM M46.00005 Confocal absorption microscopy of biomolecules and single cells from the visible to the ultraviolet spectral range, FATHOLAH SALEHI, SANGHOON PARK, Department of Physics and College of Optics, University of Central Florida, Orlando, MICHAEL E. SIGMAN, Department of Chemistry and College of Optics, University of Central Florida, Orlando, ALFONS SCHULTE, Department of Physics and College of Optics, University of Central Florida, Orlando — We present a versatile approach for absorption spectroscopy on the micron scale that combines a broadband white light source with a confocal microscope and a multichannel detector. The attenuation of the propagating light provides a mechanism for contrast that allows spectrally resolved measurements of biomolecules in miniscule quantities and of single live cells. UV absorption spectra of aromatic amino acids, proteins, and single stranded DNA oligomers (100 bases) in solution are measured with less than 10^7 molecules in the probe volume. We discuss applications to spectroscopically identify heterogeneities at the single cell level and to the label-free detection of nucleic acids.

9:24AM M46.00006 Reflectance spectrometry of placental vessels in cases of twin-twin trans-fusion syndrome: experiments and modeling, COLLIN LINES, OLEG KIM, University of Notre Dame, JOHN MCMURDY, None, FRANCOS LUKS, Division of Pediatric Surgery and Maternal-Fetal Medicine, Alpert Medical School of Brown University, MARK ALBER, GREG CRAWFORD, University of Notre Dame — A stochastic photon transport model in multilayer skin tissue combined with reflectance spectroscopy measurements is used to study placental vessels in cases of twin-twin transfusion syndrome (TTTS). TTTS occurs in about 12% of monozygotic (identical) twin pregnancies wherein flow within placental vessels linking the twins together becomes unbalanced, leading to dual mortality. Endoscopic laser ablation can halt the syndrome by occluding the anastomoses connecting the two fetuses. The objective of this study is to develop a technique to determine hemoglobin (Hb) content through spectral analysis of diffuse reflectance spectra of placental vessels to aid in identification of the anastomoses. Previous work by researchers at Brown University has shown that the reflectance spectra of the donor twin and recipient twin are considerably different in the wavelengths for Hb absorbance. This presentation will give preliminary results for a Monte Carlo model adapted to fit the physiology of the placenta that can be used to quantitative determine the Hb levels. The reflectance spectra of the vessels are simulated for different values of Hb as well oxygenation and water concentration with the vessel and placental mass. The preliminary results will be shown to be in good approximation with the prior experimental data. The combination of modeling with spectroscopic measurement will provide a new tool for detailed prenatal study.
9:36AM M46.00007 Microwave Spectrometry for the Assessment of the Structural Integrity and Restenosis Degree of Coronary Stents, GIAMLUCA ARAUZ-CAROFALO, VICTOR LOPEZ-DOMINGUEZ, ANTONI GARCIA-SANTIAGO, JAVIER TÉJADA, Grup de Magnetisme, Departament de Física Fonamental, Facultat de Física, Universitat de Barcelona, JOAN M. O’CALLAGHAN, Department Signal Theory and Communications, Universitat Politècnica de Catalunya, ORIOL RODRIGUEZ-LEOR, ANTONI BAYES-GENIS, Servei de Cardiologia, Hospital Universitari Germans Trias i Pujol, GMAG TEAM, HUGTP TEAM, UPC TEAM — Cardiovascular disease is the main cause of death worldwide. Coronary stents are one of the most important improvements to reduce deaths from cardiovascular disorders. Stents are prosthetic tube-shaped devices which are used to rehabilitate obstructed arteries. Despite their obvious advantages, recoclusion occurs in some cases arising from restenosis or structural distortions, so stented patients require chronic monitoring (including invasive or ionizing procedures). We study microwave scattering spectra (between 2.0 - 18.0 GHz) of metallic stents in open air, showing that they behave like dipole antennas in terms of microwave scattering. They exhibit characteristic resonant frequencies in their microwave absorbance spectra that are univocally related to their length and diameter. This fact allows one to detect stent fractures or collapses. We also investigate the “dielectric shift” in the frequency of the resonances mentioned above due to the presence of different fluids along the stent lumen. This shift could give us information about the restenosis degree of implanted stents.

9:48AM M46.00008 Higher Resolution and Faster MRI of 31Phosphorus in Bone, MERIDETH FREY, SEAN BARRETT, Yale University, Physics Dept., ZACHARY SETHNA, Princeton University, Physics Dept., KARL INSOGNA, JOSHUA VANHOUTEN, Yale University, School of Medicine, Dept. of Internal Medicine — Probing the internal composition of bone on the sub-100 µm length scale is important to study normal features and to look for signs of disease. However, few useful non-destructive techniques are available to evaluate changes in the bone mineral chemical structure and functional micro-architecture on the interior of bones. MRI would be an excellent candidate, but bone is a particularly challenging tissue to study given the relatively low water density, wider linewidths of its solid components leading to low spatial resolution, and the long imaging time compared to conventional 1H MRI. Our lab has recently made advances in obtaining high spatial resolution (sub-400 µm) three-dimensional 31 Phosphorus MRI of bone through use of the quadratic echo line-narrowing sequence (1). In this talk, we describe our current results using proton decoupling to push this technique even further towards the factor of 1000 increase in spatial resolution imposed by fundamental limits. We also discuss our work to speed up imaging through novel, faster reconstruction algorithms that can reconstruct the desired image from very sparse data sets. (1) M. Frey, et al. PNAS 109: 5190 (2012).

10:00AM M46.00009 Accelerated Acquisition of 2D NMR Spectra using Iterative Projections, SEAN BARRETT, Yale University, Physics Dept., ZACHARY SETHNA, Princeton University, Physics Dept., MERIDETH FREY, Yale University, Physics Dept., PATRICK LORIA, Yale University, Chemistry, Dept. — Typically, in 2D NMR (or 2D MRI), only one “row” of the time-dependent (or k-dependent) signal is sampled N times per ~ T1 (spin-lattice relaxation time). Thus, filling a 2D Cartesian grid of M x N data points requires M additional experiments, for a total spectral acquisition time T_{ACQ} \approx M \times T_1. Measuring fewer “rows” than required for Fourier reconstruction decreases T_{ACQ}, but this results in a low-quality spectrum (unfortunately, computationally slower reconstruction techniques are used). Here, we show that a new approach to this problem, using iterative projections, can work on actual 2D NMR data. This approach is built upon the Fast Fourier Transform, so it can handle large data sets (2D, 3D, 4D). Moreover, this approach is expected to work even better in higher dimensions, yielding greater speedups. Finally, we will discuss how the accelerated acquisition may also improve signal-to-noise and frequency resolution.

10:12AM M46.00010 Fast Spectral Reconstruction of Noisy, Sparse Time Domain Data through Iterative Projections, ZACHARY SETHNA, Princeton University, Physics Dept., MERIDETH FREY, SEAN BARRETT, Yale University, Physics Dept., SUVRAJIT SENGUPTA, KURT ZILM, Yale University, Chemistry Dept. — We discuss here an approach for reconstructing spectra from sparse time domain data, by way of iterated projections, and more specifically by alternating projections or by use of the difference map algorithm developed by Veit Elser. This is done in a purely deterministic way, by reformulating any a priori knowledge or constraints into projections, and then iterating. This method is extremely flexible, can be applied to a variety of different signals, and is robust enough to handle real data (with noise and artifacts). In this talk we explain the motivation behind this approach, the formulation of the specific projections, and various methods for handling noise. We will demonstrate the approach using 2D NMR spectra and will compare and contrast this approach with existing methods, such as Maximum Entropy reconstruction.

10:24AM M46.00011 Tether-free endoscopic biopsy with self-assembled micro-surgical tools1, EVIN GULTEPE, EUN JI SHIN, FLORIN SELARU, ANTHONY KALLOO, DAVID GRACIAS, The Johns Hopkins University — Feynman’s futuristic vision of “swallowing the surgeon” or a truly non-invasive surgery relies on the invention and utilization of tetherless, stimul-responsive and miniaturized surgical tools. We propose a step in this direction by the use of sub-millimeter scale, untethered, self-assembled endoscopic tools by designing and deploying microgrippers (µ-grippers) for effective mucosal sampling from large surface-area organs and for tissue retrieval from hard to reach places in the body. Due to their small size, tether-free actuation, parallel fabrication and deployment, µ-grippers can be dispersed in large numbers (hundreds or thousands) to collect tissue samples and allow statistical sampling of large mucosal areas. Monte Carlo simulations showed that using large number of biopsy tools increases the sampling coverage for screening procedures and hence the chance of detecting the malignant lesions. To establish the feasibility of using µ-grippers for sampling large organs we used with ex-vivo colon and in-vivo esophagus models. Our results showed that it is possible to retrieve high quality tissue samples which are suitable for either conventional cytologic or genetic analyses by using µ-grippers.

1This work was funded in part by the NSF grant NSF CBET-1066898 and the NIH Director’s New Innovator Award Program through grant DP2-OD004346-01; in part by FAMRI grant 072119 YCSA and by a K08 Award (DK09015) from the NIH.

10:36AM M46.00012 Truly Quiet MRI: animal MRI magnetic field gradients as a test platform for acoustic noise reduction, WILLIAM EDELESTEIN, ABDEL-MONEM EL-SHARKAWY, Johns Hopkins School of Medicine — Clinical MRI acoustic noise, often substantially exceeding 100 dB, causes patient anxiety and discomfort and interferes with functional MRI (fMRI) and interventional MRI. MRI acoustic noise reduction is a long-standing and difficult technical challenge. The noise is basically caused by large Lorentz forces on gradient windings—surrounding the patient bore—situated in strong magnetic fields (1.5 T, 3 T or higher). Pulsed currents of 300 A or more are switched through the gradient windings in sub-milliseconds. Experimenting with hardware noise reduction on clinical scanners is difficult and expensive because of the large scale and weight of clinical scanner components (gradient windings ~ 1000 kg) that require special handling equipment in large engineering test facilities. Our approach is to produce a Truly Quiet (<70 dB) small-scale animal imager. Results serve as a test platform for acoustic noise reduction measures that can be implemented in clinical scanners. We have so far decreased noise in an animal scale imager from 108 dB to 71 dB, a 37 dB reduction. Our noise reduction measures include: a gradient container that can be evacuated; inflatable antivibration mounts to prevent transmission of vibrations from gradient winding to gradient container; vibration damping of wires going from gradient to the outside world via the gradient container; and a copper passive shield to prevent the generation of eddy currents in the metal cryostat inner bore, which in turn can vibrate and produce noise.
11:27 AM N46.00002 ac-Calorimetric Measurements of Transverse Thermal Conductivity\(^1\), Hao Zhang, Joseph Brill, University of Kentucky — We are developing an ac-calorimetric technique, heating one surface of a thin sample with oscillating power and measuring the temperature oscillations on the opposite surface, to measure the thermal conductivity of solids. While the temperature oscillations are inversely proportional to the heat capacity at low frequencies, at higher frequencies the response is limited by the transverse thermal diffusivity. Because of the finite response times of thermometers and the fact that the magnitude of the temperature oscillation varies inversely with frequency, this technique is most useful for materials with low thermal conductivities, such as the interlayer conductivity in layered materials. We will show results on “standard” materials (teflon, sapphire) as well as the layered organic semiconductors, rubrene and TIPS-pentacene.

\(^1\)This work is supported by NSF grants DMR-0800367 and EPS-0814194.

11:39 AM N46.00003 Thermal expansion measurement using optical grating diffraction shifts, Tran Vinh Son, Mohamed Touaibia, Alain Hache, Universite de Moncton — We demonstrate a novel optical method for accurately measuring thermal expansion in materials. When an optical grating expands or contracts, the Bragg diffraction condition is altered, and the diffracted beams undergo angular shifts. Using a diffracted laser beam, we demonstrate that this effect can be used to measure expansion coefficients as small as \(10^{-6}\) C\(^{-1}\). By patterning samples of PMA and chitosan with grating lines, we measure their thermal expansion coefficients by heating the sample by only a few degrees Celsius. The method can be generalized to opaque materials by textured the surface and measuring diffraction in reflection. A theory is presented to determine the ideal experimental conditions and the limits of accuracy.

11:51 AM N46.00004 Properties of Holmium Implanted Gold Films and a YSi\(_x\) Absorbers in TES Microcalorimeters for Holmium Neutrino Mass Experiment\(^1\), Krishna Prasai, University of Miami, Miami, FL, USA, E. Alavés, University and CNFNL, Lisbon, Portugal, D. Bagliani, University of Genoa and INFN, Genoa, Italy, N. Barradas, University and CNFNL, Lisbon, Portugal, M. Biasotti, University of Genoa and INFN, Genoa, Italy, M. Galeazzi, University of Miami, Miami, FL, USA, F. Gatti, University of Genoa and INFN, Genoa, Italy, P. Manfrinetti, M.R. Gomes, University and CNFNL, Lisbon, Portugal, Y. Upreti, S. Yanardag, University of Miami, Miami, FL, USA — The electron capture decay of Ho-163 can be used for the direct measurement of the electron neutrino mass with Transition Edge Sensor (TES) microcalorimeters. A major requirement for a microcalorimetric holmium experiment is to embed the source in the detector absorber. A logical choice would be to implant the isotope into a regular gold absorber, assuming that it does not change the absorber properties. As an alternate option, since most chemical processes to extract the Ho-163 isotope after fabrication involve yttrium based compounds, it could be possible to use a yttrium compound as absorber, rather than just as an intermediate step. We have studied the properties of gold films implanted with holmium and erbium (which is present due to source manufacturing) and Yttrium silicide (YSi) in the working temperature range of the TES microcalorimeters (90-300 mK). In this paper we present the results of our investigation

\(^1\)This work is supported by NSF.

12:03 PM N46.00005 Quasiparticle diffusion in Al film and transmission with an Al/W interface, Jeffrey Yen, Stanford University, Paul Brink, SLAC, Blas Cabrera, Matt Cherry, Stanford University, Matt Pyle, University of California, Berkeley, Peter Redl, Stanford University, Astrid Tomada, SLAC, Betty Young, Santa Clara University, CDMS COLLABORATION — The Cryogenic Dark Matter Search (CDMS) experiment uses both high-purity Si and Ge crystals to directly search for Weakly Interacting Massive Particles (WIMPs). These detectors simultaneously measure the ionization and phonon energy produced by particle interactions. This talk will focus on experiments performed with a separate set of test devices fabricated to study the fundamental physics of the CDMS phonon sensors. In our test experiments, an \(^{55}\)Fe source was used to excite a NaCl reflector, producing 2.6 keV x-rays that hit our test devices after passing through a collimator. The devices under study consisted of a 250 \(\mu\)m wide x 350 \(\mu\)m long Al absorber film (300 nm thick) coupled to two 250 \(\mu\)m x 250 \(\mu\)m (40 nm thick) W transition edge sensors (TESs), one at each end of the Al film. The impinging x-rays break Cooper pairs in the Al film, producing quasiparticles that we detect as they propagate into the W TESs. We studied the diffusion of these quasiparticles, trapping in the Al film, and their transmission probability at the Al/W interfaces. Results from our precision experiments will be presented in this talk. These results are also being used to further optimize the design of SuperCDMS detectors for a proposed 100 kg scale dark matter search.
12:15PM N46.00006 Depolarization factors in electro-optic crystals and their effects in sensing applications. ANTHONY GARZARELLA, Naval Research Laboratory — Many applications involving electric field measurements require sensors that are compact and non-intrusive. This is especially true for tests inside small cavities, where conventional antennas and metallic probes are not only too bulky, but will also perturb the very fields they measure. Electro-optic (EO) sensors are ideal in such situations, because they are small and all-dielectric. Despite this, antennas are still predominantly used due to their higher sensitivity (2-3 orders of magnitude). Therefore to make EO sensors viable, sensitivity must be improved. The customary figure of merit (FOM) is the ratio of the EO coefficient to the dielectric constant. LiNbO$_3$ and similar crystals are preferred because of their large FOMs. In these crystals, the EO tensor is such that a transverse configuration must be used where the E-field and laser path are orthogonal. In this report, we demonstrate that sensors based on longitudinal crystals (E-field and laser collinear) can have greater sensitivities, even though their FOMs are substantially lower due to depolarization effects that enhance internal fields. Explicit examples are shown, and the practical limits in making EO sensors more competitive with conventional antennas will be discussed.

12:27PM N46.00007 Stress reconfigurable tunable magnetoelectric resonators as magnetic sensors. JILLIAN KISER, PETER FINKEL, Naval Undersea Warfare Center. CHRISTOPHE DOLABDJIAN, GREYC — Magnetoelectric multiferroic materials are extremely attractive due to their potential in sensing, filtering and energy transduction applications. We report a magnetoelectric effect in doubly-clamped ferromagnetic magnetostriective Metglas resonators, as well as the magnetic field dependence of the resonance frequency as a function of uniaxial stress. Magnetostriective strain results in a resonance frequency shift when the resonator is exposed to a magnetic field. The resonance frequency can be tracked in real time as a function of magnetic field bias using a feedback loop based on the quadrature of the excited motion. This magnetically reconfigurable resonance response can be used as a simple, tunable, magnetoelectric (ME) magnetic field sensor. The effect of sample pre-tension on the field dependent magnetostrictic constant and the sensor sensitivity is examined, and the resolution of such a sensor is estimated.

12:39PM N46.00008 Disruptive Approach Towards 10nm Spatial Resolution In X-PEEM Using Diamonds. HENDRIK OHL Dag, SLAC National Accelerator Laboratory, HITOSHI ISHIWATA, Stanford University, YVES ACREMANN, ETH Zuerich, OLA V HELGWIG, Hitachi Global Storage Technologies, PETER SCHREINER, Justus-Liebig University, NICK MELOSH, ZHI-XUN SHEN, Stanford University — Diamonds are unique molecular nano-materials with diamond structure and fascinating new properties such as negative electron affinity (NEA) and short electron mean free paths. A thin layer of diamonds deposited on a cathode is able to act as an electron monochromator, reducing the energy spread of photo-emitted electrons from a surface. This property can be applied effectively to improve the spatial resolution in x-ray photoemission electron microscopy (X-PEEM), which is limited by chromatic aberration of the electron optics. In this talk we will present X-PEEM measurements reaching the technological relevant spatial resolution of 10-nm without the need of expensive and complex corrective optics. Our results provide a simple approach to image surface chemical and magnetic information at nanometer scales by employing diamondoid. [1] H. Ishiwata et al. Appl. Phys. Lett. 101, 163101 (2012)

12:51PM N46.00009 Energy Analysis in Near Field-Emission SEM. LORENZO GIUSEPPE DE PIETRO, DANILO ANDRA ZANIN, HUGO CABRERA, URS RAMSPERGER, DANILO PESCIA, MEHMET ERBU DAK, Laboratory for Solid State Physics, ETH Zurich — In Near Field-Emission Scanning Electron Microscopy (NFSEM) cold field emitted electrons from a sharp polycrystalline W-tip are the source of a primary electron beam. The applied voltage for field-emission accelerates these electrons up to some tens of eV. After having interacted with the sample, secondary and backscattered electrons are detected, while an STM controller is used to scan the tip at a constant average distance (10 to 20 nm) from the sample surface. This technique has been used for topography images in various metals and semiconductors achieving nm lateral resolution. In case of a W(110) surface covered by Fe islands a chemical contrast was observed. We recently added an energy analysis of the electrons used for imaging. The energy distribution of this electrons from the sample shows presence of both secondary and back scattered electrons. The ratio of the two groups of electrons may vary for different distances and energies. In view of including spin polarization analysis, we are currently working to optimize the secondary electron yield.

1:03PM N46.00010 Scale invariance of a diode-like tunnel junction. HUGO CABRERA, DANILO ANDREA ZANIN, LORENZO GIUSEPPE DE PIETRO, THOMAS MICHAELS, PETER THALMANN, URS RAMSPERGER, ALESSANDRO VINDIGINI, DANILO PESCIA, ETHZ — In Near Field-Emission SEM (NFSEM), electrostatic considerations favor a diode-like tunnel junction consisting of an atomic-sized source mounted at the apex of a thin wire placed at nanometric distances from a collector. The quantum mechanical tunnel process, instead, can provide a barrier toward miniaturization. In the first place, it deteriorates the generation of electrons by introducing non-linearities within the classically forbidden zone that exponentially increase with decreasing sizes. In addition, in the direct tunneling regime, i.e. when the distance between emitter and collector $d$ approaches the subnanometer range, a characteristic length feature, making the cross-over from the (almost) scale-invariant electric-field assisted regime to the essentially different STM regime. We have observed that the experimental data relating the current $I$ to the two experimental variables $V$ (bias voltage between tip and collector) and $d$ can be made (almost) collapse onto a “scaling curve” relating $I$ to the single variable $V \cdot d^{-3/2}$, $\lambda$ being some exponent that depends solely on the geometry of the junction. This scaling property can be used to highlight non-linear aspects of the quantum mechanical tunnelling process.

1:15PM N46.00011 Particle acceleration on a chip: A laser-driven micro-accelerator for research and industry. R.B. YODER, Goucher College. TRAVIS K LUCAS, UCLA — Particle accelerators are conventionally built from radio-frequency metal cavities, but this technology limits the maximum energy available and prevents miniaturization. In the past decade, laser-powered acceleration has been intensively studied as an alternative technology promising much higher accelerating fields in a smaller footprint and taking advantage of recent advances in photonics. Among the more promising approaches are those based on dielectric field-shaping structures. These “dielectric laser accelerators” (DLAs) scale with the laser wavelength employed and can be many orders of magnitude smaller than conventional accelerators; DLAs may enable the production of high-intensity, ultra-short relativistic electron bunches in a chip-scale device. When combined with a high-$Z$ target or an optical-period undulator, these systems could produce high-brilliance x-rays from a bread-box-sized device having multiple applications in imaging, medicine, and homeland security. In our research program we have developed one such DLA, the Micro-Accelerator Platform (MAP). We describe the fundamental physics, our fabrication and testing program, and experimental results to date, along with future prospects for MAP-based light-sources and some remaining challenges.

1 Supported in part by the Defense Threat Reduction Agency and National Nuclear Security Administration.

1:27PM N46.00012 Webcam science – Can a useful transmission ion microscope be built for less than $1000? ARTHUR PALLONE, PATRICK BARNES, Norwich University — Scientists and engineers build simple, low-cost, webcam-based instruments for use in many disciplines. Analysis of the optical signal received through the three broadband color filters – red, green and blue – form the basis of many of those instruments. The CMOS sensors in webcam pixels also produces signal in response to ionizing radiations – such as alpha particles from a radioactive source. Simple alpha radiography has been demonstrated with an alpha source and a webcam modified to expose the sensors. The performance of a direct imaging transmission ion microscope built from such a modified webcam and a commercially available polonium-210 antistatic device mounted to an optics rail is analyzed. Potential uses and limitations of the microscope are also discussed.

1 Undergraduate student.
In a rotational system, the two conjugated waves possess phase difference that is proportional to the rotational velocity of the system. So by measuring the

interferometer based on degenerate four-wave mixing using evanescent field to improve the performance of fiber optic gyroscope. Degenerate four-wave mixing relies on interaction between two pump waves and evanescent fields surrounding the waveguide. By decreasing the radius of the waveguide, we can get sufficient

concentration of methanol in a 40% alcoholic ethanol-based solution. The results obtained show variations of 403 kHz in the resonant frequency for changes of 0.2% (v/v) on the concentration of methanol in a 40% alcoholic ethanol-based solution.

This project was possible thanks to the collaboration of the Department of Electrical and Electronics Engineering and the Department of Chemical Engineering of Universidad de los Andes.

Wednesday, March 20, 2013 2:30PM - 5:30PM –
Session R46 GIMS: Invited Session: Keithley Session: Enabling Sensitive Measurements Beyond the Standard Quantum Limit

2:30PM R46.00001 Josep F. Keithley Award For Advances in Measurement Science Lecture: Squeezing: the future for gravitational wave detectors, David McClelland, Australian National University — No abstract available.

3:06PM R46.00002 Joseph F. Keithley Award For Advances in Measurement Science Lecture: Beyond the quantum limit in gravitational wave detection, Nerjis Maivald, Massachusetts Institute of Technology —

3:42PM R46.00003 Exploring quantum limits with micro-mechanical membranes, Cindy Regal, JILA, University of Colorado, Boulder — The pursuit of increasingly sensitive interferometric measurement of mechanical motion has a rich history. This pursuit has resulted in the development and study of seminal ideas on quantum limits of measurement and beyond. In recent years, an interesting class of devices has been developed in which low-mass, high-frequency, and mechanically isolated objects are well-coupled to optical cavities. The large response of these mechanical objects to applied forces makes them an ideal platform to observe the effects of radiation forces, which are integral to the physics of quantum limits to interferometric measurement. Some of these nanomechanical resonators have been recently cooled with electromagnetic radiation to near their quantum mechanical ground state, illustrating the capacity for harnessing coherent optical forces. In this talk I present our recent work on a silicon nitride (SiN) membrane coupled to an optical cavity in a cryogenic environment. We use cavity coupling to significantly damp and cool membrane motion, and we demonstrate a low-absorption cavity with an efficient readout. Building on these capabilities, we observe the effect of a fluctuating radiation pressure force on the membrane resonator due to optical shot noise. Continued work will focus on further removing effects of classical noise in our devices; this will provide a path to measurement at the standard quantum limit as well as to using our optomechanical interface for applications in quantum information science. In particular, we are working on devices that will connect disparate quantum resources via SiN membrane resonators with hybrid functionalization.

4:18PM R46.00004 Approaching the Quantum Limits of Displacement Detection, John Teufel, NIST Boulder — While high quality factor mechanical resonators (such as cantilevers and membranes) are routinely used as exquisite sensors, only recently are these engineered devices encountering the fundamental limits and opportunities afforded by quantum mechanics. The standard quantum limit of displacement detection requires a balance between the measurement imprecision and momentum imparted on the object of interest. One promising measurement scheme for achieving, and possibly surpassing, these quantum limits of measurement is that of cavity optomechanics—an architecture in which a mechanical resonator modulates the frequency of a high frequency electromagnetic resonance. Ideally, the quantized nature of the measurement photons will impart backaction in the form of radiation pressure shot noise, but observation of this quantum effect in macroscopic mechanical resonators has proven experimental difficult due to the relatively weak forces of the light. We realize a microwave cavity “opto” -mechanical system by incorporating a freely-suspended membrane in a superconducting microwave resonant circuit, which simultaneously exhibits high quality factor electrical and mechanical modes [1]. The relatively large electromechanical coupling has led to experimental observation of the strong coupling regime [1] as well as sideband cooling of the mechanical mode to its quantum ground state [2]. I will present recent experiments of similar circuits in which the displacement sensitivity goes beyond that at the standard quantum limit by several orders of magnitude. These measurements also clearly show the fundamental trade-off between measurement imprecision and backaction. We observe the radiation pressure shot noise of the microwave photons and show that it can completely overwhelm the classical, thermal motion of the membrane. [1] Teufel et al., Nature 471, 204-208 (2011).

Quantum Non-Demolition Measurements between a Graphene Nanomechanical Resonator and a Diamond Nitrogen-Vacancy Center

**BRIAN D’URSO,** University of Pittsburgh — A description of the motion of microscopic particles often requires quantum mechanics, but macroscopic objects are typically observed to follow the predictions of classical mechanics. In the transition from microscopic components to a complex macroscopic system, the distinctive features of quantum mechanics can be hidden by thermal excitations and coupling to the environment. In particular, while individual spins are intrinsically quantum objects, nanomechanical resonators are usually observed as classical damped oscillators. With a careful choice of coupling, these two systems can be made to interact such that they perform quantum non-demolition (QND) measurements on each other, enabling a bridge between the quantum and classical worlds. Through this coupling, the nanomechanical resonator provides a classical readout of the spin, while the spin acts as a probe of the discrete quantum states of the resonator. We present a system consisting of a graphene nanomechanical resonator coupled to a single spin through a uniform external magnetic field. The spin originates from a nitrogen-vacancy (NV) center in a diamond nanocrystal, which is positioned on the resonator. The external magnetic field provides quadratic coupling which results in QND measurements between the spin and resonator. The strength of the quadratic coupling is enhanced by utilizing an avoided level crossing of the coupled spin-resonator system. The low mass of a graphene resonator further increases the sensitivity to the force associated with a single spin. NV centers are chosen as the source of a spin due to their exceptional spin state coherence times, large zero-field splitting, and optical addressability. We will present an analysis of the system and report on the status of experimental measurements with graphene-NV center devices.

**Thursday, March 21, 2013 8:00AM - 11:00AM —**

Session T46 GIMS: Focus Session: Advances in Scanned Probe Microscopy 1: Scanning Probe Spectroscopy & Novel Applications to C-based Systems

Hilton Baltimore Holiday Ballroom 5 - Alexander Otte, Delft University of Technology

8:00AM T46.00001 A Josephson STM with two niobium tips

**ANITA ROYCHOWDHURY,** RAMI DANA, MICHAEL DREYER, Laboratory for Physical Sciences, University of Maryland, College Park, JAMES ROBERT ANDERSON, CHRISTOPHER J. LLOB, FREDERICK C. WELSTOOD, University of Maryland, College Park — We are developing a dual-tipped scanning tunneling microscope (STM) that operates at milliKelvin temperatures. The two tips can be connected and brought into tunneling with a superconducting sample to form a SQUID loop. Our scheme involves holding one of the tips fixed while the other is scanned to image spatial variations in the gauge invariant phase difference on the superconducting surface. We have developed a novel technique to fabricate sharp Niobium tips using a reactive ion etcher. The tips have been tested at 4 K and exhibit both a superconducting gap and atomic resolution on Au(111) and Bi2Se3 samples. We will describe the experimental setup, our tip fabrication technique, and present initial results.

8:12AM T46.00002 Electron-Hole Asymmetries in the Locally Inverted α²F(ω) Spectrum of a Conventional Superconductor by STM

**FRANCIS NIESTEMSKI,** Stanford University / SLAC, STEVEN JOHNSTON, UBC, ALEX CONTRYMAN, CHARLIE CAMP, TOM DEVEREAUX, HARI MANOHARAN, Stanford University / SLAC — Utilizing scanning tunneling microscopy to create a superconductor-vacuum-superconductor junction, we invert the measured spectroscopy of the archetypal elemental superconductor Pb utilizing strong-coupling Eliashberg theory to obtain a local α²F(ω). This is the STS vacuum analogue of the pioneering McMillan and Rowell sandwich junction [W. L. McMillan and J. M. Rowell Phys. Rev. Lett. 14, 108-112 (1965)]. We find broad underlying agreement with McMillan and Rowell highlighted by previously unobserved electron-hole asymmetries and new fine structure which we discuss in terms of both conventional and unconventional superconducting bosons.

8:24AM T46.00003 Intermutation Spectroscopy applied to AFM

**DAVID HAVILAND,** DANIEL PLATZ, DANIEL FORCHHEIMER, The Royal Institute of Technology (KTH), ERIK THOLEN, Intermodulation Products AB — Measurement of surface forces at the single atom level is usually achieved by exploiting the enhanced sensitivity of a high quality factor resonator in ultrahigh vacuum, with small measurement bandwidth and therefore slow measurement speed. Frequency modulation AFM allows one to overcome this limitation, at the price of one extra feedback loop and very limited quantitative information about the interaction forces between the tip and the surface while imaging. We have introduced a multi-frequency method called Intermutation AFM (ImAFM), which can be seen as containing features of both the amplitude modulation and frequency modulation AFM methods. In this talk we describe ImAFM in its most general form, where the nonlinear tip surface interaction is seen as transferring an input drive frequency comb to an output frequency comb. These frequency combs can represent either amplitude modulated or frequency modulated signals, or both. It is demonstrated how the method optimally exploits the frequency band near resonance to extract as much information as is possible for a given measurement bandwidth. With this frequency-domain information one can reconstruct both conservative and dissipative tip-surface interactions with unprecedented accuracy and speed.

8:36AM T46.00004 Interaction imaging with amplitude-dependence force spectroscopy

**DANIEL PLATZ,** DANIEL FORCHHEIMER, Royal Institute of Technology (KTH), Stockholm, Sweden, ERIK THOLEN, Intermodulation Products AB, Solna, Sweden, DAVID HAVILAND, Royal Institute of Technology (KTH), Stockholm, Sweden — The ultimate goal in atomic force microscopy (AFM) is the combination of imaging with accurate force measurement. Dynamic AFM offers only qualitative information about the tip-surface interaction while imaging, because the cantilever resonance efficiently filters out the high frequency components of the tip-surface. Traditional force measurements are based on slow, point-wise surface approaches and are incompatible with imaging. Here, we present a method called amplitude-dependence force spectroscopy (ADFS) that enables quantitative dynamic force reconstruction at every point of an AFM image, while scanning at normal speeds. ADFS breaks with the paradigm of constant tip oscillation amplitude, as the oscillation amplitude is rapidly modulated at every image point. The measured response gives the amplitude-dependence of the Fourier component of the force at the resonant frequency, which allows for a model-free reconstruction of the tip-surface. We have made rigorous tests of ADFs using numerical simulations and have used it for a detailed study of the mechanical properties of polymer surfaces. The amplitude-dependence of the response in dynamic AFM provides a new and coherent framework for the description of conservative and dissipative tip-surface interactions.


**MEHMET Z. BAYKARA,** Bilkent University, OMUR E. DADGEVIREN, Yale University, TODD C. SCHWENDEMANN, Southern Connecticut State University, HARRY MÖNING, Westfaelische Wilhelms-Universitaet Muenster, ERIC I. ALTMAN, UDO D. SCHWARZ, Yale University — Three-dimensional atomic force microscopy (3D-AFM) is being increasingly used to measure the chemical interactions between an atomically sharp probe tip and surfaces of interest in terms of atomic-scale forces and energies in three dimensions. Since the results provided by 3D-AFM may be affected by piezo nonlinearities, thermal and electronic drift, tip asymmetries, and elastic deformation of the tip’s apex, these effects need to be considered during data interpretation. In this talk, we analyze the impact of these effects on the data, compare different methods to reconstruct the atom-resolved surface forces, and determine the approaches that suffer the least from associated artifacts. We conclude that efforts to reduce unwanted influence of tip properties on recorded data are indispensable to extract detailed information about atomic-scale properties of the surface.
9:00AM T46.00006 Virtual Scanning Tunneling Microscopy: A local spectroscopic probe of high mobility 2D electron systems , MATTHEW PELLICCIONE, JOHN BARTEL, ADAM SCIAMBI, Stanford University, LOREN PFEIFFER, KEN WEST, Princeton University, LOREN PFEIFFER, KEN WEST, Princeton University, — We present measurements on GaAs/AlGaAs bilayer two-dimensional electron systems (2DES) where the tunnel coupling between the 2DES is tunable with a gate. By designing a GaAs/AlGaAs heterostructure with a relatively low energy barrier between the 2DES, reducing the electron density with a gate lowers the effective barrier height between the 2DES and increases the tunnel coupling. We describe the fabrication process developed to realize these samples, along with measurements that take advantage of this tunable tunnel coupling to realize a novel transistor where the gate lies outside the channel region [1]. In addition, the suitability of these devices for scanning gate measurements will be discussed. [1] A. Sciambi, M. Pellccione et al., Appl. Phys. Lett. 97, 122103 (2010).

9:12AM T46.00007 Tuning 2D-2D tunneling in high mobility electron systems , JOHN BARTEL, MATTHEW PELLICCIONE, ADAM SCIAMBI, Stanford University, LOREN PFEIFFER, KEN WEST, Princeton University, — We present measurements on GaAs/AlGaAs bilayer two-dimensional electron systems (2DES) where the tunnel coupling between the 2DES is tunable with a gate. By designing a GaAs/AlGaAs heterostructure with a relatively low energy barrier between the 2DES, reducing the electron density with a gate lowers the effective barrier height between the 2DES and increases the tunnel coupling. We describe the fabrication process developed to realize these samples, along with measurements that take advantage of this tunable tunnel coupling to realize a novel transistor where the gate lies outside the channel region [1]. In addition, the suitability of these devices for scanning gate measurements will be discussed. [1] A. Sciambi, M. Pellccione et al., Appl. Phys. Lett. 97, 122103 (2010).

9:24AM T46.00008 Gate Map Tunneling Spectroscopy of Interactions in Graphene , JUNSEOK CHAE, Center for Nanoscale Science and Technology, NIST and Maryland NanoCenter, University of Maryland — The local electron density of states (LDOS) in semiconductors and semimetals like graphene can be adjusted with respect to the Fermi energy by using an electric field applied by a nearby gate electrode. In this way interaction physics can be turned on and off as the electron density is modulated at the Fermi level in an applied magnetic field. Interaction physics in graphene has been an interesting subject since the first isolation of single layer graphene, due the singular nature of the Dirac point in the graphene spectrum. The electronic density of states at the Dirac point vanishes and the long-range Coulomb interactions are not effectively screened, which gives rise to a rich spectrum of interaction-driven physics in magnetic fields at low temperatures. In this talk, I will present recent experimental results in graphene on boron nitride substrates using gate mapping tunneling spectroscopy [1]. Gate map tunneling spectroscopy consists of series of single tunneling spectra obtained as a back gate voltage is varied to change the carrier density at the Fermi level. The gate maps show clear variations of the tunneling spectrum as a function of carrier density. The formation of Landau levels (LLs) in magnetic fields up to 8 T is observed to form a staircase pattern in maps of the tunneling conductance in the 2-dimensional tunneling bias voltage-gate voltage plane. LLs modulate the LDOS at the Fermi level as the carrier density is varied with the gate potential. An analysis of the LL peak positions shows that the graphene energy-momentum remains linear at low energies, but that the dispersion velocity is enhanced due to interactions as the density is lowered approaching the Dirac point. Interaction effects are also strongly seen near zero density by the opening of large Coulomb gaps in the tunneling spectra, which will be discussed in terms of the competing effects of residual substrate induced disorder and interactions. [1] J. Chae et al., PRL 197, 116802 (2012)

10:00AM T46.00009 Thermoelectric microscropy for imaging disorder in epitaxial graphene , SANGHEE CHO, STEPHEN KANG, WONDONG KIM, HO-KI LYEO, Korea Research Institute of Standards and Science, EUI-SUP LEE, SUNG-JAE WOO, YONG-HYUN KIM, Korea Advanced Institute of Science and Technology, KI-JEONG KONG, Korea Research Institute of Chemical Technology, ILYOU KIM, HYEONG-DO KIM, Pohang University of Science and Technology, TONG ZHANG, JOSEPH STROSCIO, National Institute of Standards and Technology — Thermopower, an electron transport property, is a measure of thermal energy relative to the Fermi-energy $E_F$ and thus reflects the asymmetry in the density of states (DOS) with respect to $E_F$. We use thermopower as a microscopic probe of electronic properties of epitaxial graphene grown on SiC(0001), for which a scanning probe microscopy method has been developed by modifying a ultra-high-vacuum atomic force microscope. This method has a particular sensitivity to the electronic states near $E_F$. We thereby could image structural defects and strain fields that cause distortions in the electronic states near $E_F$. Such a capability allowed us to explore how the structural disorder is correlated and how the correlation evolves by responding to inherent strain in epitaxial graphene. Furthermore, striking images of atomically varying states and the finding of one-dimensional quantum confinement will be presented, demonstrating the ability to probe local DOS at the extreme scale.

10:12AM T46.00010 Noise Analysis on Graphene Devices via Scanning Noise Microscopy , DUCKHYUNG CHO, Department of Physics, Seoul Nat Univ, MOON GYU SUNG, HYUNGWOO LEE, KWANG HEO, KYUNG-EUN BYUN, TAEKYEONG KIM, DAVID H. SEO, SUNAE SEO, SEUNGHUN HONG, Seoul National University — Until now, the studies about low-frequency noises in electronic devices have mostly relied on the scaling behaviour analysis of current noise measured from multiple devices with different resistance values. However, the fabrication of such multiple devices for noise analysis is a labor-intensive and time-consuming work. Herein, we developed the scanning noise microscopy (SNM) method for nanoscale noise analysis of electronic devices, which allowed us to measure the scaling behaviour of electrical current noises in a graphene-strip-based device. In this method, a conductive atomic force microscopy probe made a direct contact on the graphene strip channel in the device to measure the noise spectra through it. The SNM method enabled the investigation of the noise scaling behaviour using only a single device. In addition, the nanoscale noise map was obtained, which allowed us to study the effect of structural defects on the noise characteristics of the graphene strip channel. Our method should be a powerful strategy for nanoscale noise analysis and play a significant role in basic research on nanoscale devices.

10:24AM T46.00011 Electronic state of carbon material surface by non-contact scanning nonlinear dielectric microscopy , SHIN-ICHIRO KOBAYASHI, YASUO CHO, Research Institute of Electrical Communication, Tohoku University — Non-contact scanning nonlinear dielectric microscopy (NC-SNDM) can detect both topography and microscopic electric dipole moment of semiconducting surfaces. Recently, we clearly observed the atomic surface of graphite and fullerene (C$_{60}$) molecule on Si(111)($7\times7$ surface)($7\times7$ surface) by using second-order amplitude in SNDM signal as a feedback signal. SNDM signal of graphite by NC-SNDM originates from the electrochemical capacitance with tunneling and is related to the density of state (DOS) of an atomic or molecular surface [1,2]. However, a linear DOS was considered to investigate the origin of SNDM signals only when considering the electronic state of graphitic surface, interface between C$_{60}$ and $7\times7$ surface and internal structure of C$_{60}$ on 7×7 surface in NC-SNDM. To resolve this problem, we introduce the general electrochemical capacitance induced by tunneling effect for analysis of NC-SNDM and discuss not only the influence of probe tip on SNDM signal and the origin of current signal but also the characteristics of SNDM signals obtained from graphite and from C$_{60}$ on $7\times7$ surface modes.

10:36AM T46.00012 Contactless Probing of the Carrier Transport in Carbon Nanotubes Using Dielectric Force Microscopy

YIZE LI, JUN GE, JIA LIU, JIE ZHANG, WEI LU, LIWEI CHEN, Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Sciences — We have developed a scanning probe microscopy (SPM) based technique which is named as dielectric force microscopy (DFM) to manipulate and probe the majority carriers in 1-dimentional nano electronic materials. We have demonstrated its success in distinguishing semiconducting single-walled carbon nanotubes (SWNTs) from metallic ones, locating semiconducting-metallic junction in SWNTs, determining the majority carrier types in SWNTs and ZnO nanowires, and detecting the electronic doping of SWNTs by gaseous ammonia. To achieve a quantitative measure of the intrinsic carrier transport, we have performed DFM measurement on individual SWNTs, fabricated field effect transistor devices with the individual SWNT serving as the channel, and carried out electrical transport experiment. The results from DFM and transport measurements are quantitatively correlated in an almost perfect fashion allowing the extraction of intrinsic carrier transport properties especially carrier mobility from DFM data without making metal contacts. Furthermore, we have successfully detected the location and behavior of local transport barriers in SWNTs utilizing the nanometer scale resolution feature of DFM.

10:48AM T46.00013 Quantitative Kelvin Probe Force Microscopy of a Single-Walled Carbon Nanotube Transistor

ELLIOT FULLER, BRAD CORSO, TOLGA GUL, PHILIP COLLINS, University of California at Irvine, UNIVERSITY OF CALIFORNIA AT IRVINE TEAM — Kelvin Probe Force Microscopy (KPFM) is well-suited to measuring the surface potentials of nanoscale devices, including organic thin film, graphene, and silicon nanowire field effect transistors (FETs). However, a primary limitation of KPFM is long-range capacitive coupling of the probe to parts of the sample that are distant from the immediate vicinity of the probe tip. This coupling complicates quantitative measurements and limits most KPFM work to qualitative observations of work function variations. Here, we address these problems to extract potentials along current-carrying, single-walled carbon nanotube (SWNT) FETs. As a low carrier density channel only 1 nm in diameter, SWNTs have extremely weak coupling to a KPFM probe tip, and therefore they provide a unique, limiting geometry that tests the resolving power of KPFM. By directly measuring this SWNT coupling and other, spatially-varying capacitative couplings to the probe tip, we have developed a robust and quantitative method for separating the desired signal, the local surface potential, from other electrostatic effects. The technique can be readily applied to other nanoscale devices to correctly extract work functions, potential gradients, and inhomogeneities in electrochemical potential.

Thursday, March 21, 2013 11:15AM - 2:15PM — Session U46 GIMS: Focus Session: Advances in Scanned Probe Microscopy 2: High Frequencies and Optical Techniques

Hilton Baltimore Holiday Ballroom S - Robert McMichael, NIST

11:15AM U46.00001 Edge mode imaging in magnetic nanodisks using ferromagnetic resonance force microscopy

FENG GUO, National Institute of Standards and Technology, University of Maryland — Edge modes are trapped spin wave modes that can form at film edges. The spontaneous localization of edge modes makes them fine probes of edge properties and test objects for magnetic resonance imaging. We use ferromagnetic resonance force microscopy (FMRFM) to study the edge modes in magnetic nanodisks with an improved resolution of less than 100 nm. In this presentation we will describe imaging and spectroscopy of the normal modes in Permalloy disks, manipulation of edge modes to characterize the disk edges, and the disk-diameter dependence of the spectrum. Micromagnetic modeling of a 500 nm diameter, 25 nm thick disk predicts a main mode that is nearly uniform across the sample and three edge modes with higher resonance fields. The spectra measured with various tip positions are consistent with the modeling results. Besides the broad center mode, three distinct edge modes are observed and appear when the tip is near the disk edge. However, in contrast to the symmetric edge behavior predicted by the modeling, the measured left and right edge modes are detected at different resonance fields, suggesting and inhomogeneity of the edge properties. By rotating the applied field, we are able to move the localized edge mode along the edge of a single structure and thus probe the inhomogeneity in edge properties. The fundamental edge mode with the highest resonance field is most sensitive to the edge inhomogeneity while the center mode is relatively isotropic. The disk size dependence of the edge mode is also investigated for disk diameters ranging from 100 nm to 750 nm. The number of trapped edge modes reduces with decreasing disk size in agreement with micromagnetic modeling.

11:51AM U46.00002 Magnetic imaging with shallow spins in nitrogen delta-doped diamond

BRYAN A. MYERS, JENS BOSS, Physics Department, University of California, Santa Barbara, KENICHI OHNO, Materials Department, University of California, Santa Barbara, PREETI OVARTCHAIYAPONG, DAVID D. AWSCHALOM, ANIA C. BLESZYNSKI JAYICH, Physics Department, University of California, Santa Barbara — Nitrogen-vacancy (NV) electronic spins in diamond are atomic-size sensors of magnetism at the nanoscale. Shallow NVs with long spin coherence times (T2) are desirable for ultrasensitive magnetometry. However, T2 tends to decrease for shallow NVs, which couple most strongly to external spins. To optimize magnetic sensitivity, it was recently shown that delta-doping nitrogen during chemical vapor deposition of single-crystal diamond (SCD) can produce films with a <5 nm thick layer of NVs that retain long T2 [1]. Here, using a magnetic field gradient produced by a scanning probe, we investigate optically-detected magnetic resonance measurement protocols to simultaneously determine the relative and absolute depths of the NVs in SCD films containing multiple doped layers separated by a few nm. A consistent comparison of NV properties, such as T2 versus depth is important for engineering spin placement. Furthermore, this magnetic field gradient technique enables sub-diffraction imaging of NV centers, which itself will be explored for high resolution NV-based magnetometry. [1] K. Ohno et al., Appl. Phys. Lett. 101, 082413 (2012).

This work was supported by DARPA Quasar, AFOSR YIP, and the ASEE NDSEG fellowship.

12:03PM U46.00003 Nanoscale Fourier-transform magnetic resonance imaging

JOHN NICHOL, TYLER NAIBERT, WILLIAM ROSE, University of Illinois at Urbana-Champaign, ERIC HEMESATH, LINCOLN LAHON, Northwestern University, RAFFI BUDAKIAN, University of Illinois at Urbana-Champaign — Magnetic resonance force microscopy is a promising technique for nanoscale magnetic resonance imaging, but the detection sensitivity must still be improved to reach the single proton level. Multiplexed imaging schemes, such as Fourier encoding, are used in clinical magnetic resonance imaging for sensitivity enhancement. Here, we report a method for Fourier encoding nanoscale samples, where statistical fluctuations dominate the spin polarization. The protocol uses periodic encoding pulses to create correlations in the spin fluctuations. We demonstrate this technique using a silicon nanowire mechanical oscillator as a force sensor to image 1H spins in a polystyrene sample. The sample is encoded using pulsed magnetic field gradients generated by a nanoscale current-carrying wire. We reconstruct a 2-dimensional projection of the proton density in the sample with 10 nm resolution.
12:15PM U46.00004 On infrared and terahertz imaging of surface plasmons in high-Tc superconductors, H.T. STINSON, Z. FEI, University of California - San Diego, A.S. RODIN, Boston University, A.S. MCLEOD, M.M. FOGLER, D.N. BASOV, University of California - San Diego — Recent scattering-mode scanning near-field optical microscopy (s-SNOM) experiments have imaged surface plasmons in graphene at infrared frequencies. The scanning probe launches surface plasmons and detects their standing-wave interference pattern upon reflection from the sample edge. The surface plasmon dispersion relation directly relates the standing wave fringe separation and amplitude decay to the optical constants of the sample. We have modeled surface plasmon s-SNOM imaging for high-Tc superconductor (HTSC) thin films. Our results indicate that surface plasmons can be imaged in HTSCs at frequencies near or below the superconducting gap. This would allow for a direct measurement of HTSC optical constants below the gap. For known HTSCs such as YBCO, this is in the far-IR or terahertz range. Our simulations show that this method can also distinguish between superconducting and normal states at the nanoscale.


12:27PM U46.00005 Quantifying the Stochastic Dynamics of the Elastic Probe used in Cavity Optomechanical Force Microscopy, STEPHEN EPSTEIN, MARK PAUL, Virginia Tech — Atomic force microscopy has revolutionized surface science and is now as essential tool for micro and nanoscale studies in science and engineering. Cavity optomechanical force microscopy consists of an atomic force microscopy probe that is placed in close proximity to a microfabricated optical cavity. The interaction between the probe and the optical cavity is used to quantify the probe dynamics. Cavity optomechanical force microscopy extends conventional atomic force microscopy by being more sensitive with increased frequency resolution. In many situations of interest the probe operates while immersed in a viscous fluid which can strongly affect the probe dynamics. In this talk we quantify the stochastic dynamics of the elastic probe when driven by Brownian motion where the dominant source of dissipation is the surrounding viscous fluid. We use deterministic finite-element numerical simulations with the fluctuation-dissipation theorem to quantify the stochastic dynamics of the probe for the precise conditions and geometries used in current experiments.

12:39PM U46.00006 Enhanced Electroluminescence from a Nanocavity Due to Dynamical Coupling of Plasmonic and Molecular Emissions, Z. Fei et al., Nature, 82 (2012).

12:51PM U46.00007 Measurement of optical force in plasmonic resonant cavities using dynamic mode AFM, DONGSHI GUAN, ZHIHONG HANG, Department of Physics, The Hong Kong University of Science and Technology (HKUST), ZSOLT MARCET, Department of Physics, University of Florida, HUI LIU, Department of Physics, Nanjing University, IVAN KRAVCHENKO, Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, CHETING CHAN, HOUBIN CHAN, PENGGER TONG, Department of Physics, HKUST — We report an experimental study of the optical force induced by a plasmonic resonance mode in metallic cavities using dynamic mode atomic force microscopy (AFM). The plasmonic cavity is made of a (upper) gold coated glass sphere and a (lower) quartz substrate patterned with an array of gold disks, whose diameter \(d\) varies from 250 to 750 nm. The gold coated sphere is glued to an AFM cantilever, by which we measure the optical force acted on the sphere using AFM (AFM). The plasmonic and molecular emissions, and identify conditions for enhanced electroluminescence. We discuss these results in comparison with experiments.

Supported by NSF and MOST of China

1:03PM U46.00008 Nano-FTIR: infrared spectroscopic chemical identification of materials at the nanoscale, FLORIAN HUTH, Neaspec GmbH, Martinsried, Germany, ALEXANDER GOYVADINOV, CIC Nanogune Consolider, Donostia-San Sebastian, Spain, SERGIU AMARIE, Neaspec GmbH, Martinsried, Germany, WIWAT NUANSING, CIC Nanogune Consolider, Donostia-San Sebastian, Spain, B. RASCHKE, University of Colorado, Boulder, MICHAEL C. MARTIN, Lawrence Berkeley National Laboratory — Scattering-scanning near-field optical microscopy (s-SNOM) is capable of providing chemical contrast with deep sub-wavelength spatial resolution of a few 10’s of nanometers. Unfortunately, the wide applicability of the technique has been hindered by the lack of suitable broadly-tunable or broadband IR sources that can provide the necessary high spectral irradiance. Here, we demonstrate broadband, Fourier-transform infrared spectroscopic s-SNOM using infrared synchrotron radiation from the Advanced Light Source (ALS). We show near-field spectra spanning the full mid-infrared, including the fingerprint absorption region (700 cm\(^{-1}\) — 4000 cm\(^{-1}\)) and spectroscopic multi-modal imaging in combination with laser-based IR sources. We discuss the potential of the approach for a wide range of soft and hard matter nanoscale spectroscopic applications.

The Advanced Light Source is supported by the Director, Office of Science, Office of Basic Energy Sciences, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.
The Lightning Rod Model: a Genesis for Quantitative Near-Field Spectroscopy
ALEXANDER MCLEOD, University of California San Diego, GREGORY ANDREEV, Bruker Nano Surfaces Division, GERARDO DOMINGUEZ, California State University San Marcos, MARK THIEMENS, MICHAEL FOGLER, D.N. BASOV, University of California San Diego — Near-field infrared spectroscopy has the proven ability to resolve optical contrasts in materials at deeply sub-wavelength scales across a broad range of infrared frequencies. In principle, the technique enables sub-diffractional optical identification of chemical compositions within nanostructured and naturally homogeneous samples. However, current models of probe-sample optical interaction, while qualitatively descriptive, cannot quantitatively explain infrared near-field spectra, especially for strongly resonant sample materials. We present a universal first-principles model of near-field interactions with infrared near-field spectra measured for thin films of silicon dioxide and the strongly phonon-resonant material silicon carbide. Using this model we reveal the role of probe geometry and surface mode dispersion in shaping the measured near-field spectrum, establishing its quantitative relationship with the dielectric properties of the sample. This treatment offers a route to the quantitative determination of optical constants at the nano-scale.

Interferometric Scanning Microwave Microscope for Nanotechnology Application
NICOLAS CLEMENT, THOMAS DARGENT, IEMN-CNRS (France), HASSAN TANBAKUCHI, Agilent Santa Rosa (US), KATSUHIKO NISHIGUCHI, NTT Basic Research Labs (Japan), RAGAVENDRAN SIVAKUMARASAMY, FEI WANG, IEMN-CNRS (France), AKIRA FUJIWARA, NTT Basic Research Labs (Japan), DAMIEN DUCATTEAU, GILLES DAMBRINE, DOMINIQUE VUILLAUME, BERNARD LEGRAND, DIDIER THERON, IEMN-CNRS (France) — Scanning probe microscopes (SPMs) allow scientists to image, characterize and even manipulate material structures at exceedingly small scales including features of atomic dimensions. Although most microelectronics devices operate at high frequency, SPMs have mainly been used with electrical excitation at DC (Conducting Atomic Force Microscope) or kHz (Electric Force Microscope, Kelvin Force Microscope). The main reason is that at GHz frequency, nanoscale objects are far from the standard impedance of 50ohms and almost all the signal is reflected. Here we show, using an interferometer to enable extraction and amplification of the signal of interest, that Scanning Microwave Microscopes (SMM) are ideal tools for tiny capacitances imaging. We demonstrate applications in several fields of nanotechnology with capacitance evaluation down to fF of nanoscale integrated capacitors, biased nanotransistors, molecular junctions and biomolecule flow in a nanofluidic channel. The frequency range of excitation varied from 2 GHz to 20 GHz. With a finite element analysis, we discuss the limits of such microscope.

Highly enhanced green emission of ZnO via plasmonic resonance of a tungsten tip
HUIQI GONG, XIAODONG GOU, LI DONG, Beijing National Laboratory for Condensed-Matter Physics and Institute of Physics, Chinese Academy of Sciences, NAN XIE, Photonics Center, College of Physics Science, Nankai University, SHICHAO YAN, XINYAN SHAN, YANG GUO, JIMIN ZHAO, Beijing National Laboratory for Condensed-Matter Physics and Institute of Physics, Chinese Academy of Sciences, QIAN SUN, Photonics Center, College of Physics Science, Nankai University, XINGHUA LU, Beijing National Laboratory for Condensed-Matter Physics and Institute of Physics, Chinese Academy of Sciences — We present a systematic investigation of the photoluminescence of a single crystal ZnO with the aid of a metallic tungsten tip in a pulse laser assisted scanning tunneling microscope. When excited with 740nm laser pulses and as the tip approaches ZnO surface up to the tunneling region (~1nm), an enhancement in green emission (centered at 560nm), up to a factor of 70, is observed. The photoluminescence is a two-photon excitation process, which is evident by the observation of the second-harmonic peak of excitation light and the up-converted luminescence. By measuring the green emission intensity as a function of incidence power, wavelength, and tip-sample distance, we illustrate the critical role of plasmonic resonance of the tungsten tip for the enhanced green emission. The observed broad plasmonic response (680nm to 1080nm) implies possible applications in designing novel solar cells with the aid of tungsten plasmon.

2:03PM U46.00013 Single & Multiprobe Apertureless Thermal Imaging of Electromagnetic Excitation Over A Wide Range of Wavelengths
RIMMA DEKHTER, Nanonics Imaging Ltd., AARON LEWIS, Hebrew University of Jerusalem, Dept of Applied Physics & Benin School of Engineering & Computer Science, SOPHIA KOKOTOV, PATRICIA HAMRA, BOAZ FLEISCHMAN, HESHAM TAHA, Nanonics Imaging Ltd. — Near-field optical effects have generally been detected using photodetectors. There are no reports on the use of the temperature changes caused by electromagnetic radiation using thermal sensing probes for scanned probe microscopy. In this paper we apply our development of such probes to monitor the effects of electromagnetic radiation at a number of different wavelengths using the heating caused in a sample by specific wavelengths and their propagation. The paper will catalogue effects over a wide spectrum of wavelengths from the near to mid infrared. The thermal sensing probes are based on glass nanopipettes that have metal wires that make a contact at the very tip of a tapered glass structure. These probes are cantilevered and use normal force tuning fork methodology to bring them either into contact or near-contact since this feedback method has no jump to contact instability associated with it. Data will be shown that defines the resolution of such thermal sensing to at least the 32 nm level. In addition the probes have the important attribute of having a highly exposed tip that allows for either optical sensing methodologies with a lens either from directly above or below or heat sensing with a single or additional probe in a multiprobe scanning probe system.

Thursday, March 21, 2013 2:30PM - 5:42PM — Session W46 GIMS: Focus Session: Advances in Scanned Probe Microscopy III: Novel Approaches and Ultrasensitive Detection
Hilton Baltimore Holiday Ballroom 5 - Eric Hudson, Pennsylvania State University

2:30PM W46.00001 Probing single molecules with the STM in the frequency and time domains
HIKARI KIMURA, Department of Physics and Astronomy, University of California, Irvine, WEICAI CAO, Department of Chemical Engineering and Materials Science, University of California, Irvine, CALVIN PATEL, Department of Physics and Astronomy, University of California, Irvine, WILSON HO, Department of Physics and Astronomy, University of California, Irvine — We have constructed a scanning tunneling microscope (STM) and combined it with a tunable femtosecond laser (210 nm to 1040 nm) to probe single molecules with simultaneous spatial and temporal resolutions. Employing the RF lock-in amplifier to measure the laser-induced tunneling current that is directly synchronized with the high repetition rate of the laser (~80 MHz), time resolved measurement of single molecules with atomic scale resolution can be achieved by varying the time delay between pairs of laser pulses in the two-pulse correlation or two-color pump-probe configuration. A femtosecond laser system with widely tunable wavelength enables resonant excitation of single molecules based on glass nanopipettes that have metal wires that make a contact at the very tip of a tapered glass structure. These probes are cantilevered and use normal force tuning fork methodology to bring them either into contact or near-contact since this feedback method has no jump to contact instability associated with it. Data will be shown that defines the resolution of such thermal sensing to at least the 32 nm level. In addition the probes have the important attribute of having a highly exposed tip that allows for either optical sensing methodologies with a lens either from directly above or below or heat sensing with a single or additional probe in a multiprobe scanning probe system.

2:42PM W46.00002 High Resolution Single Molecule Vibrational Spectroscopy with the STM
CHEN XU, CHILUN JIANG, YANNING ZHANG, RUQIAN WU, WILSON HO, Department of Physics and Astronomy, University of California, Irvine — Inelastic electron tunneling spectroscopy (IETS) with the scanning tunneling microscope (STM) has been regarded as the ultimate tool to identify and characterize single molecules adsorbed on solid surfaces with atomic spatial resolution. With the improvement of energy resolution obtained at ~ 600 mK, STM-IETS is able to resolve the lowest vibrational energies and reveal subtle interactions between the molecule and its environment which were previously not possible at higher temperatures. Here we demonstrate the capability of sub-Kelvin STM on detecting the influence of the tip as well as the anisotropy of the reconstructed Au(110) surface on the low energy hindered vibrational motions of single adsorbed CO molecule. Single molecule vibrational spectroscopy at ~ 600 mK with atomic scale spatial resolution opens new possibilities to probe molecular interactions with high spectral sub-THz resolution.
2:54PM W46.00003 Measuring infrared absorption of molecular adsorbates at the submonolayer level by scanning tunneling microscopy-based IR spectroscopy (IR-STM) , IVAN V. PECHENEZHSKIY, GIANG D. NGUYEN, XIAOPING HONG, Department of Physics, University of California at Berkeley, Berkeley, California 94720 — Here we present a simple, effective technique whereby a scanning tunneling microscope (STM) can achieve vibrational spectroscopy of molecular adsorbates at the submonolayer level through the use of a tunable infrared (IR) laser source. By using the STM as a detector to probe the IR molecular response, the technique takes advantage of the high spectral resolution inherent to IR measurements while avoiding the typical difficulties related to optical detection. This technique also allows sub-nm scale spatial mapping of surface structure under the same experimental conditions that the STM-IR absorption spectra are acquired (sub-nm spatial resolution for specific IR spectral features has not yet been achieved). Using this technique we have obtained IR absorption spectra of higher diamondoid molecules, specifically [121]tetramantane and [123]tetramantane, deposited on a Au(111) surface. The significant differences between the IR-STM spectra obtained for these two molecular isomers show the power of this new technique to differentiate chemical structures.

3:06PM W46.00004 Imaging the Electron-Phonon Interaction on the Atomic Scale1 , IGOR ALTFEDER, Air Force Research Laboratory, KONSTANTIN MATVEEV, Argonne National Laboratory, ANDREY VOEVODIN, Air Force Research Laboratory — New STM-based spectroscopic imaging technique, direct real-space imaging of electron-phonon interaction parameter \( \lambda \), was demonstrated using the combination of STM and inelastic electron tunneling spectroscopy (IETS) for thin Pb islands epitaxially grown on 7x7 reconstructed Si(111). We found that \( \lambda \) increases when the electron scattering at the Pb/Si(111) interface is diffuse and decreases when the electron scattering becomes specular. We show that the effect is driven by transverse redistribution of the electron density inside a quantum well. Reference: Igor Altfeder, K. A. Matveev, A. A. Voevodin, “Imaging the Electron-Phonon Interaction on the Atomic Scale”, Physical Review Letters 109, 166402 (2012).

3:18PM W46.00005 Vibrational and electronic properties of small molecules on metal surfaces , YANNING ZHANG, CHEN XU, CHI-LUN JIANG, WILSON HO, RUQIAN WU, Department of Physics and Astronomy, University of California, Irvine, CA 92697 — Research of manipulating chemical bonds in a single molecule has been extremely active in recent years. Using a newly built milli-Kelvin scanning tunneling microscope, we can now resolve vibrational spectroscopic features down to a few tenths meV. Synergistic density functional calculations allow correct interpretation for each vibrational mode and provide links between experimental observations to the change of individual chemical bonds. In particular, we explored the effect of tunneling gap distance on different vibrational energies, by moving the tip toward the molecules, so as to shed some light for selective bond dissociation and formation. Here we discuss our results of the atomic structure, vibrational and electronic properties of several small molecules such as CO on the anisotropic Au(110) surface and C2H2 on the Cu(001) square lattice. Calculated vibrational frequencies, using the generalized gradient approximation or the non-local van der Waals density functional, are in good agreement with experimental results. Acknowledgement. Work was supported by the National Science Foundation under CHE-0802913 and computing time at XSEDE.

3:30PM W46.00006 Design and Implementation of a 4K Cryocooler-Based Scanning Tunneling Microscope1 , RAMYA VISHNUBHOTLA, NEAL HARRINGTON, BILL DUSCH, CARRIE GENG, RIJU BANNERJEE, LAVISH PABBI, ERIC W. HUDSON, Pennsylvania State University — Low temperature, ultra-high vacuum scanning tunneling microscopes (STMs) have proved to be excellent tools for the study of electronic properties of complex materials. Unfortunately, with the continuing increase in liquid helium prices, already a dominant cost for operating these systems, their use is becoming exceedingly expensive. Here we describe the design and implementation of a STM cooled by a Cryomech PT407 Remote Motor Cryorefrigerator, allowing us to reach helium temperatures using a closed thermodynamic cycle with zero cryogen waste. Unfortunately, this refrigeration technique is not ultra-high vacuum (UHV) compatible and introduces vibrations. To tackle these problems, we separately house the cryocooler in a high-vacuum (HV) chamber. This provides both a UHV environment for the STM and mechanical isolation to minimize vibrations reaching the instrument. However, it makes for more challenging thermal connections. This last difficulty we solve by introducing a novel coaxial thermal feedthrough between the HV and UHV chambers.

3:42PM W46.00007 Spin dynamics of atoms and magnetic nanostructures on surfaces , ANDREAS HEINRICH, IBM Research — Scanning tunneling microscopy is a powerful tool for studying the electronic and magnetic properties of magnetic nanostructures on surfaces. Over the last decade, inelastic tunneling spectroscopy has been used to probe discrete energy levels of quantum spin systems. These states can often be described as solutions of simple spin Hamiltonians. In spin excitation spectroscopy, a spin system is kicked from the ground into excited spin states at discrete energy increments. In this talk we will focus on the dynamics of quantum spin systems on surfaces. STM can measure tunnel currents in the range of pico amps with millisecond time resolution. This time resolution is well matched to observing transition between spin states of artificial magnetic nanostructures on surfaces that can be built and measured with STM. We will highlight an example of extended, artificial antiferromagnets on a Cu2N surface (Science 2012). Smaller magnetic clusters relax much faster but their dynamics can be measured with pump probe techniques. A pump voltage pulse drives the spin system into excited states and a subsequent probe pulse measures the resulting population of spin states. An exponential decay back to the ground state is observed when averaging over many pump-probe cycles (Science 2010). We will show results down to nanosecond time resolution with an ultimate limit set by modern electronics at about 100 pico seconds. Individual atoms on Cu2N relax their spin states even faster. Hence, another technique is employed to determine spin relaxation times. Small tunnel currents always leave the spin system in the ground state while high currents can create non-equilibrium distributions of spin states. This approach relies on some modeling but allows time domain measurements down to about 1 pico second (Nature Physics 2010). Transition metal atoms on metal surfaces relax even faster, on time scales of about 100 femtoseconds. This fast relaxation manifests itself as a measurable lifetime broadening of spin excitation spectra. Combining these approaches allows measurements of spin relaxation times over about 16 orders of magnitude for spins on surfaces – while maintaining the atomic scale spatial resolution of STM!

4:18PM W46.00008 A versatile variable field module for Asylum Cypher scanning probe system1 , HONGXUE LIU, RYAN COMES, JIWEI LU, STUART WOLF, Department of Materials Science and Engineering, University of Virginia, Charlottesville, VA 22904, JIM HODGSON, MAARTEN RUTTERS, Asylum Research, Santa Barbara, CA 93117 — Atomic force microscopy (AFM) has become one of the most widely used techniques for measuring and manipulating various characteristics of materials at the nanoscale. However, there are very limited options for the characterization of field dependence properties. In this work, we demonstrate a versatile variable field module (VFM) with magnetic field up to 1800 Oe for the Asylum Cypher Research system. The magnetic field is changed by adjusting the distance between a rare earth magnet and the AFM probe. A built-in Hall sensor makes it possible to perform in-situ measurements of the field. Rotating the magnet makes it possible to do angular field dependent measurements. The capability of the VFM system is demonstrated clearly show the evolution of magnetic density structures. A completely reversible magnetic force microscopy (MFM) phase contrast is observed when the magnetic field is rotated by 180°. Further demonstration of successful magnetic switching of CoFe2O4 pillars in CoFe2O4 BiFeO3 nanocomposites will be presented and field dependent MFM and piezoresponse force microscopy (PFM) will be discussed.

1The work at University of Virginia was supported by DARPA under contract no. HR-0011-10-1-0072.
4:30PM W46.00009 Magnetoelectric Force Microscopy for visualizing cross-coupled domains. YANAN GENG, WEIDA WU, Department of Physics and Astronomy, Rutgers University, Piscataway, NJ 08854 — Intensive studies have been focused on magnetoelectric (ME) effect ever since Dzyaloshinskii and Astrov’s seminal works on linear ME effect in Cr$_2$O$_3$. The measurements of the components of ME tensor are of great importance in technical applications and in fundamental science (e.g. determining magnetic point groups). For bulk ME measurements, it is necessary to obtain a single domain state by the ME annealing (i.e. applying magnetic and electric fields simultaneously) of the specimen through its transition temperature. However, the ME domain structure has never been directly observed due to the weakness of the ME effect in most magnetoelectrics.

To address this critical issue, we have developed a nanoscale imaging technique, namely, the Magnetoelectric Force Microscopy (MeFM), to directly detect local response based on magnetoelectric force microscopy with in-situ high voltages. Preliminary results of visualizing ME domains will be presented to demonstrate the feasibility of the MeFM technique.

5:06PM W46.00012 Massively Multiplexed Cantilever-Free Scanning Probe Lithography. KEITH A. BROWN, DANIEL J. EICHELSDOERFER, Northwestern University Department of Chemistry and International Institute for Nanotechnology, WOOYOUNG SHIM, Northwestern University Department of Materials Science and Engineering, RADHA BOYA, ABRIN L. SCHMUCKER, GUOLIANG LIU, Northwestern University Department of Chemistry and International Institute for Nanotechnology, CHAD A. MIRKIN, Northwestern University Department of Chemistry, Department of Materials Science and Engineering, and International Institute for Nanotechnology — Cantilever-free scanning probe lithography has emerged as a low-cost technique for rapidly patterning nanoscale materials. In this architecture, an array of probes is fabricated on a soft backing layer that provides mechanical compliance to each probe while an underlying hard surface maintains the structural integrity of the array. One drawback of this technique is that each probe in the array acts simultaneously and thus generates a copy of the same pattern. Here, we discuss recent efforts to incorporate heaters into these probe arrays so that when a given heater is activated, the thermal expansion of the elastomer actuates a single tip. We find thermal actuation to be powerful enough to actuate individual tips over 4 μm with minimal crosstalk, fast enough to actuate on relevant time scales (20 ms), and scalable by virtue of being electrically addressable. Furthermore, turning the individual heaters allows for variability in the arrays to be compensated for precisely, resulting in high quality nanofabrication. The addition of tunable actuators transforms cantilever-free scanning probe lithography into a technique capable of true desktop nanofabrication.

5:18PM W46.00013 Tuning the Spring Constant of Cantilever-Free Probe Arrays. DANIEL J. EICHELSDOERFER, KEITH A. BROWN, ABRIN L. SCHMUCKER, NWU Department of Chemistry and International Institute for Nanotechnology, WOOYOUNG SHIM, Northwestern University Department of Materials Science and Engineering, CHAD A. MIRKIN, Northwestern University Department of Chemistry, Department of Materials Science and Engineering, and International Institute for Nanotechnology — The versatility of atomic force microscope (AFM) based techniques such as scanning probe lithography is due in part to the utilization of a cantilever that can be fabricated to match a desired application. In contrast, cantilever-free scanning probe lithography utilizes a low cost array of probes on a compliant backing layer that allows for high throughput nanofabrication but lacks the tailoring afforded by the cantilever in traditional AFM. Here, we present a method to measure and tune the spring constant of probes in a cantilever-free array by adjusting the mechanical properties of the underlying elastic layer. Using this technique, we are able to fabricate large-area silicon probe arrays with spring constants that can be tuned in the range from 7 to 150 N/m. This technique offers an advantage in that the spring constant depends directly on the geometry of the probe, which is in contrast to traditional cantilever-based lithography where the spring constant varies as the cube of the beam width and thickness. To illustrate the benefit of utilizing a probe array with a lower spring constant, we pattern a block copolymer on a delicate 50 nm thick silicon nitride window.

5:30PM W46.00014 Debye screening length of electrolytic solutions from capacitive force measurements using atomic force microscopy. BHARAT KUMAR, SCOTT R. CRITTENDEN, Department of Physics and Astronomy, University of South Carolina, Columbia, SC 29208 — We present a method to obtain the Debye screening length of a dilute electrolytic solution by measuring the capacitive force using atomic force microscopy (AFM). A small AC bias voltage of frequency ω was applied between an AFM cantilever and conducting substrate in an electrolytic solution and the resulting capacitive force between them was measured from the cantilever oscillations. The ω component of the oscillating force was used to obtain the capacitance gradient between the AFM cantilever tip and substrate as a function of tip-sample distance z. An analytic expression relating tip-sample distance z and capacitance gradient between AFM tip and conducting substrate in an electrolytic solution was derived using the solution of the linearized Poisson-Boltzmann equation. We find that the analytic expression fits well with the experimental data for dilute KCl-water solutions. The fit parameters were further used to calculate the Debye screening length of the electrolytic solution.

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1 This work is supported by DOE grant DE-SC0008147.

2 This work is supported by NSF DMR grant 0844807.

3 This research is funded by Army Research Office under grant # W911NF-11-1-0251.
By mapping the external field dependence of the measured resonance frequency, we determined the nuclear gyromagnetic ratio to be 239

we have a flexible and capable spectroscopy facility that provides unique insight into the electronic structure of transuranic materials.

source. By combining the above photoemission tools with a variety of surface preparation capabilities including cleaving, laser ablation, and thermal desorption, hybridization for transuranic materials. By adding temperature-dependent (10 - 350K) photoemission to the suite of tools, we may cross over phase transition contributions to the valence electronic structure. Between ARPES and tunable photoemission, one may construct a fairly detailed picture of the bonding and intermediate valence to mechanical and fundamental bonding behavior in these materials.

1 Work was supported by the Office of Science, Office of Basic Energy Sciences, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

9:12AM Y10.00003 Observation of 239 Pu NMR in PuO2. A new frontier for the physics and chemistry of plutonium compounds1, YASUOKA HIROSHI, Los Alamos National Laboratory — In actinide science, in general, NMR studies have been forced to limit their scope to nuclei associated with ligand atoms. The only exception of direct observation of NMR in actinide nuclei is that of 235 U NMR in UO2. There have been extensive efforts to realize NMR in actinide compounds since the electronic properties of these materials are predominantly governed by the actinide nucleus itself. We report the first observation of Nuclear Magnetic Resonance (NMR) on the 239Pu nucleus in any material. Our 239Pu NMR measurements were performed on plutonium dioxide, PuO2, for a wide range of external magnetic field values (Ho=3–8T) at a temperature of T=4K. By mapping the external field dependence of the measured resonance frequency, we determined the nuclear gyromagnetic ratio to be 239γPu(239Pu)=2.856 ± .001 MHz/T. Assuming a free ion value for the Pu4+ hyperfine coupling constant, we estimated a bare value of 239γn,239Pu=2.97MHz/T for the 239Pu nucleus, hence a nuclear magnetic moment of μn=15.1μN (where μN is the nuclear magneton). Our findings put an end to a fifty-year long search for Pu NMR and open potentially a new horizon for the solid state physics, nuclear materials science and complex chemistry in Pu compounds.

Work done in collaboration with G. Koutroulakis, S. Richmond, K. Veirs, E. D. Bauer, J. D. Thompson, G. Jarvinen, and D. L. Clark, Los Alamos National Laboratory, Los Alamos, NM.

1This work was supported by the Chemical Sciences, Geosciences, and Biosciences Division and by the Materials Sciences and Engineering Division, Office of Basic Energy Sciences, U.S. Department of Energy (DOE).

9:48AM Y10.00004 An instrument for the investigation of actinides with spin resolved photoelectron spectroscopy and bremsstrahlung isochromat spectroscopy2, JAMES TOBIN, Lawrence Livermore National Laboratory — A new system [1] for spin resolved photoelectron spectroscopy [2,3] and bremsstrahlung isochromat spectroscopy [4] has been built and commissioned at Lawrence Livermore National Laboratory for the investigation of the electronic structure of the actinides. Actinide materials are very toxic and radioactive and therefore cannot be brought to most general user facilities for spectroscopic studies. The technical details of the new system and preliminary data obtained therein will be presented and discussed. Lawrence Livermore National Laboratory is operated by Lawrence Livermore National Security, LLC, for the U.S. Department of Energy (DOE), National Nuclear Security Administration under Contract DE-AC52-07NA27344. This work was supported by the U.S. Department of Energy, Office of Basic Energy Science, Division of Materials Sciences and Engineering.


10:24AM Y10.00005 Transuranic Photoemission Using a Unique Light Source1, JOHN JOYCE, Los Alamos National Laboratory — There has been a remarkable advance in the understanding of electronic structure for complex materials in recent years. Much of this advance in understanding has been realized through advanced spectroscopy capabilities available at public synchrotron facilities. While the vast majority of materials can take advantage of facilities at public synchrotrons, transuranic materials are excluded from these facilities when multiple containment barriers are incompatible with the chosen spectroscopy. We have developed an advanced spectroscopy capability at Los Alamos for photoemission on transuranic materials including Pu. Using several different variants of photoemission we have explored a wide range of Pu materials which has lead to a significant improvement in our understanding of transuranic electronic structure. Examples of these success will be given along with details of the unique facility. Using the unique capabilities of our transuranic photoemission system we exploit opportunities in angle-resolved photoemission (ARPES) providing insight into the details of both the energy and crystal momentum for a material. Additional information is obtained using tunable photons which may be used to isolate the 5f electron contribution to the valence electronic structure. Between ARPES and tunable photoemission, one may construct a fairly detailed picture of the bonding and hybridization for transuranic materials. By adding temperature-dependent (10 - 350K) photoemission to the suite of tools, we may cross over phase transition boundaries as well as quantify electron-phonon coupling. We also have the capability for 1.5 and 3 KeV core-level spectroscopy using a monochromatized x-ray source. By combining the above photoemission tools with a variety of surface preparation capabilities including cleaving, laser ablation, and thermal desorption, we have a flexible and capable spectroscopy facility that provides unique insight into the electronic structure of transuranic materials.

1Work supported by DOE, BES, DMSE; Science Campaign 2; and the LANL LDRD program.
11:15AM Z1.00001 Ultrafast Optical Excitation of a Persistent Surface-State Population in the Topological Insulator Bi$_2$Se$_3$  
JONATHAN SOBOTA, Stanford University — Bi$_2$Se$_3$ is a material which has gained great attention since it was recognized to be a topological insulator. Due to their topologically-protected spin-textured Dirac surface states, topological insulators have been recognized for their potential in device applications, particularly for spintronics. Thus, much of the experimental focus has been on ways to electronically or optically couple to the surface spin-texture. Using time- and angle-resolved photoemission spectroscopy (TR-ARPES), we optically excite p-type Bi$_2$Se$_3$ and study the dynamical response of its electronic structure on a femtosecond timescale. The strength of this technique is that its energy- and angle-resolution allows us to study these dynamics directly within the electronic band structure, so that surface and bulk contributions can be separately resolved. We find that optical excitation produces a metastable population of bulk carriers due to the presence of the bandgap. We discuss the coupling of these carriers to the Dirac surface state, which results in a long-lived nonequilibrium surface carrier distribution. This spin-textured population may present a channel in which to drive transient spin-polarized currents.

11:51AM Z1.00002 Ultrafast momentum-dependent quasiparticle dynamics in high-$T_c$ superconductors1. UWE BOVENSIEPEN, University Duisburg-Essen — Femtosecond time- and angle-resolved photoelectron spectroscopy trARPES facilitates insight into electronic relaxation and electronic structure of non-equilibrium states of matter [1]. Hot electrons and holes relax in metals on ultrafast timescales due to the screened Coulomb interaction [2]. In superconductors the relaxation rates of quasiparticles at energies close to the superconducting gap edge are reduced because of the loss of quasiparticle states near $E_F$. Since in the superconducting state the relaxation of optically excited carriers proceeds partly by Cooper pair reformation, the study of the quasiparticle dynamics bears the potential to analyze the interaction responsible for Cooper pair formation. Results of trARPES will be discussed for optimally doped Bi$_2$Sr$_2$CaCu$_2$O$_{8+4}$ in the superconducting state [2] and on EuFe$_2$As$_2$ in the antiferromagnetic state [3]. In the cuprate system we find a predominant excitation of quasiparticles at momenta near the antinode. We show furthermore, that at excitation densities of several $10^{15}$ cm$^{-2}$ quasiparticle relaxation is dominated by Cooper pair reformation, which again proceeds near the antinode. In the Fe-pnictide material we monitor a difference in the relaxation rate for electrons and holes near the Fermi momentum, which disappears above the Neel temperature. We conclude that this anisotropic relaxation of electrons and holes is a consequence of the optical modification of the antiferromagnetic order. Analysis of energy transfer from electrons to phonons allows to determine the momentum averaged electron-phonon coupling constant $\lambda$. We find values below 0.25 for Bi$_2$Sr$_2$CaCu$_2$O$_{8+4}$ [5] and below 0.15 for EuFe$_2$As$_2$ [4].

References

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12:27PM Z1.00003 Measurement of intrinsic Dirac fermion cooling of a topological insulator with time- and angle-resolved photoemission spectroscopy  
YIHUA WANG, MIT — Three-dimensional topological insulator (TI) is a new phase of matter with exotic surface electronic properties. Even though the bulk states have a bandgap, the surface electrons possess a linear energy-momentum dispersion that is protected by the nontrivial topology of TI to cross the Fermi level. These properties provide a promising platform for new physics and applications in future electronics and computers including high-speed quantum information processing, whose performance depends critically on the dynamics of hot carriers. Unlike the case in graphene, helical Dirac fermions in a TI interact not only with phonons but also with an underlying bulk reservoir of electrons. In this talk, we will present our recent results of time- and angle-resolved photoemission spectroscopy (TR-ARPES) study of a prototypical TI Bi$_2$Se$_3$. We show that TR-ARPES is a powerful tool to distinguish the coupled dynamics between these different degrees of freedom. With the combined sub-picosecond time resolution and energy-momentum resolution, we have directly visualized the coupling between surface and bulk electrons through phonons. At low temperature, such coupling is suppressed and the unique cooling of surface Dirac fermions by acoustonic phonons is revealed through the power law cooling rate depending on doping. The effect on the TR-ARPES spectra from varying excitation photon energy will also be discussed.

1:03PM Z1.00004 Time-resolved ARPES and f-electron coherence1, TOMASZ DURAKIEWICZ, Los Alamos National Laboratory, MPA-CMMS Group, Los Alamos, NM 87544, USA — The coherence temperature, $T^*$, sets an important energy scale in correlated f-electron systems. In this scale the hybridization gap opens at or in the vicinity of the Fermi level and the gap magnitude scales with effective quasiparticle mass. The new quasiparticle bands are heavy, as demonstrated by their small dispersion, and the quasiparticle lifetime is long, as seen by the narrow width of the peaks. Unless magnetic ordering suppresses the gap or mass enhancement is observed due to, e.g., magnetic excitations, the gap scales with effective mass in a universal manner across the heavy fermion systems. Possible deviations from this pattern, e.g. a small finite gap persisting at high temperatures above $T^*$ require models beyond a mean-field approach, and may be understood within e.g. the model of periodic array of Anderson impurities with correlations described by coupling to specific boson modes.

Self-energy approach is commonly used in ARPES of correlated systems. The coherent part of the self-energy corresponding to the gap formation is reduced at high temperatures, and the incoherent part corresponds to quasiparticle scattering. The coherent term in the self-energy expresses the mixing of f and d bands and is directly responsible for repulsion, producing the hybridization gap. This theoretical framework provides a direction towards understanding quasiparticle dynamics in correlated electron systems through ultrafast self-energy measurements and modeling. Here we show examples of time-resolved ARPES measurements of f-electron systems, providing valuable information about the evolution of coherence and the dynamics of the related quasiparticle states.

References

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Ultrafast quasiparticle dynamics and pair recombination in cuprate high-temperature superconductors, CHRIS JOZWIAK, Lawrence Berkeley National Lab — Understanding how superconductivity emerges from other competing phases and how this balance evolves through the phase diagram is one of the biggest challenges in the field of high-$T_c$ superconductors. By using high resolution time- and angle-resolved photoemission spectroscopy (tr-ARPES) we are able to directly probe the effects of optical excitation on the electronic structure of cuprate superconductors, and study the resulting quasiparticle, superconducting gap, and Cooper pair formation dynamics near their natural time scales. In particular, we observed a pump-induced meltdown of quasiparticles, which occurs only within the energy scale defined by a particular boson mode. This meltdown was observed only below $T_c$, suggesting a link between superconductivity and quasiparticles in momentum space where the superconducting gap is zero. We observed that the excited quasiparticle decay dynamics were strongly pump-fluence dependent and consistent with the picture that the observed dynamics reflect actual Cooper pair formation. Further, these quasiparticle recombination dynamics were strongly momentum dependent, increasing away from the superconducting nodes. Direct measurements of momentum dependent superconducting gap dynamics and the evolution of other non-equilibrium spectral phenomena through the phase diagram further illustrate the power of this unique time- and momentum-resolved spectroscopy. These results reveal new windows into the nature of the pairing interaction in high-$T_c$ superconductors.