Scanning Probe Microscopy Focus Topic
Room Hall D - Session SP-TuP

Scanning Probe Microscopy Poster Session

SP-TuP1 New Directions in Ultrahigh Vacuum Tip-Enhanced Raman Spectroscopy with Molecular-Resolution Scanning Tunneling Microscopy, *Z. Porach, P. Whiteman,* University of Illinois at Chicago*; N. Chiang,* Northwestern University*; **Nan Jiang**,* University of Illinois at Chicago

During the last few years, the study of ultrahigh vacuum tip-enhanced Raman spectroscopy (UHV-TERS) has been raised to an unprecedented level. While scanning probe microscopy (SPM) is commonly used to study individual molecules, its information content can be severely compromised by surface diffusion, irregular packing, or three-dimensional adsorbate geometry. Here we demonstrate the simultaneous chemical and structural analysis of single molecules on the solid surface by UHV-TERS. In situ lenses can increase the collection efficiency with large numerical aperture. The strongly enhanced Raman signal makes the detection of single molecules possible. The adsorption configurations are able to be determined at unprecedented spatial resolution (<1nm).

SP-TuP3 Temperature-dependent Nanoscale Conductance on Water-Intercalated Graphene, ***JinHeui Hwang**, H. Lee, J.Y. Park,* Institute for Basic Science (IBS) & Korea Advanced Institute of Science and Technology (KAIST), Republic of Korea

We investigated the nanoscale conductace of water-intercalated graphene using current-sensing atomic force microscopy (C-AFM). The intercalation of water between graphene and mica was enabled by transfer of chemical vapor deposition (CVD) graphene on mica substrate. Water molecules were captured in the liquid water bath during the graphene transfer process. We show that the surface conductance are significantly influenced by the presence of water layer between graphene and mica. We found that the edge of water island exhibits the lower conductance, compared to that of bare graphene. We futher showed conductance of graphene on the first water layer were fluctuated depending on the temperature. The anomalous behavior of conductance is originated by structural defects of water layer and bonding nature between edge of the water islands and mica substrate, which lead to the suppression of the local current.

SP-TuP4 Phase Coexistence in Vanadium Dioxide Crystal Probed via Scanning Probe Microscopy, ***Christina McGahan**,* Vanderbilt University*; S. Gamage,* Georgia State University*; J. Liang,* Tianjin University, China*; B.G. Cross,* Georgia State University*; R.E. Marvel, R.F. Haglund,* Vanderbilt University*; Y. Abate,* Georgia State University

For the past decade, scattering-scanning near-field optical microscopy (s-SNOM) has been employed to image the coexisting metallic and insulating domains in single-crystal nanorods and platelets of vanadium dioxide (VO_2) during the insulator-to-metal phase transition. In virtually all studies, the coexisting domains appear as alternating stripes perpendicular to the c_R (growth axis) of the nanocrystals and extending from one side of the beam to the other.

We employed s-SNOM with a laser wavelength of **λ=**10.7 µm and polarized far-field optical microscopy to examine a single VO_2 microcrystal decorated with gold (Au) plasmonic dipole antennas. Metallic and insulating domains can be easily distinguished during the thermal phase transition in VO_2 using s-SNOM due to the large dielectric contrast between metallic and insulating VO_2 at that wavelength. Plasmonic dipole antennas are positioned on the crystal, designed to be resonant at the s-SNOM probe wavelength to allow simultaneous probing of the pattern of coexisting phases of VO_2 and the nanorod plasmon.

We observe a novel herringbone pattern of phase coexistence, seen in cracked epitaxial thin films but never in single crystals, in a VO_2 single crystal which is large enough that the phase coexistence is not constrained by high aspect-ratio geometry. The herringbone pattern is altered by the presence of ferroelastic strain domains that form to relieve stress and can nucleate metallic domains. These ferroelastic domains are imaged with polarized far-field optical microscopy. Though the local dielectric environment of the crystal changes during the phase transition, as indicated via s-SNOM, the plasmon resonance frequency of Au nanoantennas atop the crystal does not change in response to the growth of metallic domains. This indicates that the metallic domains nucleate in the bulk of the single crystal, beyond the range of the plasmon field, which only penetrates tens of nanometers below the crystal surface but in range of the s-SNOM due to the penetration depth of 10.7 µm laser light. The domain pattern is insensitive to the locations and orientations of the resonant Au antennas because the field, as determined through simulations, is not high enough to induce the VO_2 phase transition. Simulations indicate that a bowtie antenna has sufficient field to locally switch VO_2 from insulating to metallic, enabling localized induction of the phase transition near the surface of the VO_2.

SP-TuP5 Single Virus Particle Spectroscopic Nano-Imaging, ***Brendan Cross**, S. Gamage, M. Howard, J.R. Terrell, M. Luo, Y. Abate,* Georgia State University

We present the spectroscopic nano-imaging of single influenza virus particles in the mid infrared spectral region. The X-31 strain of Influenza A is an enveloped virus, which has a lipid and protein layer that contains the nucleocapsid. Virions are drop cast on silicon substrates for near-field imaging. High-resolution near-field microscopy is used to map the amide and phosphate bands of the envelope proteins on a single virion. We have also investigated the evolution of the virus as a function of time, acid treatment and laser radiation.

SP-TuP6 Spectroscopic Nano-Imaging Patterned InGaN Nanolayers, ***Alireza Fali**, S. Gamage, D. Seidlitz, I. Kankanamge, N. Dietz,* Georgia State University*; Y. Abate,* Georgia state university

Ternary InGaN compound semiconductors are of interest for many device applications such as light-emitting diodes, laser diodes, solar cells, etc., because they cover a broad spectral range from deep ultraviolet to near infrared as a function of the composition. This study focuses on nanoscopy of patterned structures of InGaN compound. To achieve this goal, InGaN film has been grown on top of the InN substrate. Scattering-type scanning near-field optical microscopy was used for nano-spectroscopic studies in the mid infrared spectral region of various thickness and composition of $In_{1-x}Ga_xN$ nanolayers grown on InN substrates.

SP-TuP7 Nanoscopy of Black Phosphorus Degradation, ***Sampath Gamage**,* Georgia State University*; L. Zhen,* University of Southern California*; V.E. Babicheva, M. Javani, V.S. Yakovlev,* Georgia State University*; H. Wang, S. Cronin,* University of Southern California*; Y. Abate,* Georgia State University

Black phosphorus (BP) is a promising layered material for optoelectronics applications due to its outstanding physical properties. Importantly, the thickness-dependent tunable direct bandgap of BP excited material scientists over graphene that lacks a natural bandgap. Similar to graphene, BP can be prepared commonly and simply by mechanical exfoliation. However, the major impediment of the BP based research is its surface degradation when exposed to atmospheric water and oxygen. In order to develop BP as a material for aforementioned applications, it is essential to understand degradation process at nanoscale chemical resolved resolution. In this poster contribution, we present our findings of the nanoscale spectroscopy degradation study of BP using scattering type scanning near-field optical microscopic (s-SNOM) technique at several mid infrared wavelengths. We have experimentally investigated the thickness dependence and substrate influence of a set of uncoated and Al_2O_3 coated samples and theoretically modeled the degradation evolution.

SP-TuP8 Periodically-pulsed Laser-Assisted Tunneling May Generate Terahertz Radiation, ***Mark Hagmann**,* University of Utah

Background: Periodic excitation of the tunneling junction in a scanning tunneling microscope by a mode-locked ultrafast laser superimposes a frequency comb at harmonics of the pulse repetition frequency on the DC tunneling current.[1] The power measured at the first 200 harmonics (74.254 MHz to 14.85 GHz) varies inversely with the square of the frequency—decaying only due to shunting by the stray capacitance.

Hypothesis: The tunneling junction is much smaller than the laser wavelength so effectively the laser superimposes a time-dependent voltage on the DC bias. Quasi-static conditions cause the time-dependent tunneling current to be related to the time-dependent voltage by a cubic polynomial as in the DC case. Thus, the waveform of the current in the tunneling junction is similar to the envelope of the laser radiation.

Analysis: The time-dependent voltage is modeled as a random process including pulse-jitter and finite coherence length of the laser. The current in the tunneling junction is shown to be a wide-sense stationary random process. For a laser with a pulse-width of 15 fs and pulse repetition frequency of 74.254 MHz the power spectral density in the tunneling junction has an intrinsic decay of 3 dB at the 2.4 x10^{5}th harmonic of 18 THz. The power measured at the first harmonic corresponds to a peak current of 5.7 nA. But the frequency of this harmonic is low enough that the decay caused by stray capacitance is negligible so this value, adjusted for the intrinsic decay, is the peak current at each harmonic in the tunneling junction.

Results and conclusions: Under the conditions for our measurements of the frequency comb we predict that in the tunneling junction the peak current for each pulse is approximately 690 mA. This value would be higher with a laser having greater coherence length or lower timing-jitter. It appears that the finest spatial resolution so far achieved in terahertz imaging is 40 nm by the near-field confinement of plane-wave illumination at a conical metal tip.[2] Our simulations suggest it may be possible to achieve atomic resolution by using the terahertz radiation at the tunneling junction in periodically-pulsed laser-assisted scanning tunneling microscopy. Much higher power is expected in periodically-pulsed laser-assisted field emission because of the greater current and much lower stray capacitance.

References

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[2]A. J. Huber, F. Keilmann, J. Wittborn, J. Alzpurua, and R. Hillenbrand, Nano Lett. 8, 3766-3770 (2008).

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