

Thursday Evening Poster Sessions, October 24, 2019

Nanometer-scale Science and Technology Division Room Union Station AB - Session NS-ThP

Nanometer-scale Science and Technology Poster Session

NS-ThP-1 Probing Intermolecular and Molecule-Substrate Interactions at Angstrom Scale by Ultrahigh Vacuum Tip-Enhanced Raman Spectroscopy, *Sayantana Mahapatra, J Schultz, N Jiang*, University of Illinois at Chicago

Conventional spectroscopic techniques are limited by the optical diffraction limit to about half wavelength and therefore offers about 200 nm x 200 nm microscopic zone for working in the visible light range. Tip-enhanced Raman spectroscopy (TERS) emerges as an advanced analytical technique, where the plasmonically active probe is not only used to detect the tunneling current but also to interrogate the local chemical environment of surface adsorbed molecules with angstrom scale precision. In this work, we studied two regioisomers (positional isomers), *trans*- and *cis*-tetrakis(pentafluorophenyl)porphodilactone (*trans*- and *cis*-H₂F₂₀TPPDL) using scanning tunneling microscopy (STM), ultrahigh vacuum (UHV) TERS on Ag(100) with the spatial resolution down to 8 Å, which has wide range of applications in various field of surface science & nanotechnology such as regioselective catalysis reaction, chemical reactions, molecular electronics etc. We have shown, it is possible to distinguish these two structurally very similar forms with high accuracy & precision. The two-component molecular junction has been identified using high resolution two-dimensional (2D) Raman mapping. Furthermore, these new class of porphyrinoids i.e. porphodilactones (PDL) have been studied on different single crystals [Ag(100), Cu(100) and Au(100)] to probe the intermolecular and molecule-substrate interactions. This work demonstrates, STM combined with TERS is a complementary technique to characterize a system completely at angstrom scale.

NS-ThP-2 Cobalt Nanoparticles Supported on Multiwalled Carbon Nanotubes for Catalysts in Hydrogen Generation, *Brian Price*, Christopher Newport University

With the threat of fossil fuels running out in the near distant future coupled with an increased concern over the environment, a large amount of focus has been dedicated towards green forms of energy. One such source could come from hydrogen through the reduction of sodium borohydride, but this reaction is slow and needs a low cost catalyst. Using abundant metals to make nanoparticles supported by carbon nanotubes would create a globally producible catalyst. The catalytic effect of cobalt metal boride carbon nanotube composites was observed through its reaction with sodium borohydride. The metal boride carbon nanotube composites were synthesized through reduction of metal organic frameworks in the presence of carbon nanotubes. The composites were characterized through scanning electron microscope (SEM), transition electron microscope (TEM), x-ray diffraction (XRD), infrared spectroscopy (IR).

NS-ThP-3 Advanced Hybrid Metrology for Measuring Pattern Fidelity for Nano Technology—Combining Massive metrology using Full Contour based Data Extraction and Analysis, *Allen H. Rasafar*, GLOBALFOUNDRIES Inc.

Objectives:

This paper will present a new method for Pattern Fidelity assessment using an advanced holistic/hybrid metrology solution for sub 7nm technology nodes. Adopting this structured approach will enable a holistic metrology solution to close the gap on illusive yield losses and open the opportunities for a new metrology work space.

Methods:

Current state of metrology methods is not fully meeting voice of the customer. Metrology tools are not capable to deliver advanced algorithm for extraction and analysis of the data embedded in SEM images. Most of the metrology tools are collecting very basic measurement and spend more time handling and measuring the wafer. Tools are not designed to go over throughput specs. Innovation is lost in between generation based approach. An innovation in metrology was long overdue for delivering a metrology solution that is not solely based on older technology. Thus, the new metrology space sets a new standard for extracting critical pattern fidelity data for CD/OV, OPC measurement and offer unmatched analysis using high resolution wide field SEM images. The sophisticated application of advanced contour extraction methods is redefining the opportunities embedded in SEM image for better process analysis. This work will highlight

advantages of this method over OCD, and simple contour measurement techniques that is used by some SEM and eBeam tools. With this method we will pull massive amount of data related to pattern shape, size, Line edge roughness, Line width variations, and dense contact uniformity achieved by Big data analysis expertise.

Conclusions:

A structured approach is demonstrated and compared to existing pattern fidelity assessment solutions in an actual sub-14nm and 7nm Fab settings. This method overlays design(physical layout)to image of pattern captured by high resolution SEM tools and collected across all dies, and wafers. A large volume of images is analyzed and comprehensive results are reported including full statistical distribution of image variations by location, image to image (die to die), distribution of overall measurements, outliers, defect distribution, and representation of weak points in physical design and OPC feedback. We invite wider adoption of this method by the industry to to enable Fabs, and engineers to achieve better process improvement, debug and enhancing design for manufacturing. The Big Data approach provides new opportunities for full stack analysis of the layers at each step, make predictions for the stacked layers at subsequent process steps. Big Data method will enable sharing data within functional team and all stakeholders in a secure server work space.

NS-ThP-4 A Nanoscopic View of Photo-induced Charge Transfer in Organic Nano-crystalline Heterojunctions, *Qian Zhang, S Cohen, B Rybtchinski*, Weizmann Institute of Science, Israel

Organic photovoltaics are promising as cost-efficient, tunable, and flexible platforms for solar energy conversion, yet their performance and stability are still far from optimal. Here we present a study of photo-induced charge transfer processes between electron donor and acceptor organic nanocrystals, as part of our path-finding effort to develop robust and efficient organic nanocrystalline materials for photovoltaic applications. We produced sub-micron to microns-long nanocrystals of perylenediimides (PDIs) as electron acceptors, and with Copper Phthalocyanine (CuPc) as the electron donor. Three different configurations of donor-acceptor heterojunctions were prepared. Charge transfer in the heterojunctions was studied with Kelvin-probe force microscopy (KPFM) under laser or white light excitation. We also conducted theoretical calculations and time-resolved photo-luminescence measurements to understand the differences in the photovoltaic processes of these organic nanocrystals. Our work demonstrates that excitonic properties can be tuned by controlling the crystal and interface structures in the nanocrystalline heterojunctions, in order to minimize photo-voltaic losses.

NS-ThP-5 Ferroic-ionic Interaction in Hybrid Organic Inorganic Perovskites, *Yongtao Liu^{1,2}, L Collins, A Ievlev, A Belianinov*, Oak Ridge National Laboratory; *M Ahmadi*, University of Tennessee Knoxville; *S Jesse, S Kalinin*, Oak Ridge National Laboratory; *B Hu*, University of Tennessee Knoxville; *O Ovchinnikova*, Oak Ridge National Laboratory

Hybrid organic-inorganic perovskites (HOIPs) such as methylammonium lead iodide (CH₃NH₃PbI₃) have attracted broad research interest due to their outstanding photovoltaic performance. However, fundamental understandings of the origin of the high performance and the anomalous current-voltage (I-V) hysteresis of HOIPs solar cells still lag. Although ferroelectricity is proposed to be a reason of the related behavior, the convincing evidence supporting ferroelectricity in HOIPs is missing because the strong ion motion in HOIPs complicates the ferroic characterization. A clear understanding of the interplay between ferroic behavior and ion motion in HOIPs will be helpful for clarifying this question.

In this work, using multi-modal functional and chemical imaging methods, we unveil a ferroic-ionic interaction in CH₃NH₃PbI₃. In piezoresponse force microscopy (PFM) experiments, we observed ferroelastic twin domain structures in CH₃NH₃PbI₃. Although PFM shows 'piezoelectric-like' contrast of the twin domains, our studies—including band excitation (BE) PFM, laser Doppler vibrometer (LDV) PFM, and BE contact resonance atomic force microscopy (BE-AFM)—unambiguously reveal the mechanical origin rather than the electromechanical origin of the 'piezoelectric-like' contrast. This ferroelastic domain was accompanied by ion segregation due to the strain-driven ion redistribution, which was observed using helium ion microscopy secondary ion mass spectrometry (HIM-SIMS) and atomic force microscopy infrared spectroscopy (AFM-IR). To further address how ion distribution affects the ferroic behavior of CH₃NH₃PbI₃, we studied the interaction of the ion distribution and the fields (elastic field and electric field)

¹ National Student Award Finalist

² NSTD Graduate Student Award Finalist

Thursday Evening Poster Sessions, October 24, 2019

distribution in $\text{CH}_3\text{NH}_3\text{PbI}_3$. It is shown that the ion redistribution is accompanied by a reversible change in lattice strain, suggesting the dependence of the elastic field on ion distribution. Furthermore, we found that the local ion distribution could manipulate the formation of ferroelastic twin domain. The electric field was studied by Kelvin probe force microscopy (KPFM), which indicates that the ion distribution affects local electric field intensity and the electric field distribution. By combining KPFM and time-of-flight secondary ion mass spectrometry (ToF-SIMS), we observed a screen effect of ion migration on the electric field in $\text{CH}_3\text{NH}_3\text{PbI}_3$. The remainder of the field is very small due to the compensation of ion migration. These results suggest that the ion motion can alter local field and hence local ferroic behavior of HOIPs. Overall, this work offers an understanding of ferroic-ionic interplay in HOIPs, providing a pathway to develop novel devices.

NS-ThP-6 Processing of Nanoscale Lamellae in Bulk Al-Cu Eutectic Samples Through Selective Laser Melting, Jonathan Skelton, J Floro, J Fitz-Gerald, University of Virginia

Eutectic alloys with nanoscale lamellar spacing may have a wide range of applications in functional materials such as thermoelectrics and photovoltaics, as well as in enhanced mechanical properties. This is due to an intimate interleaving of two or more phases where the length scales are controlled in part by the solidification rate. Utilization of nanoscale eutectics remains limited as a result of the lack of methods available to readily produce them in bulk materials. Rapid solidification through laser irradiation has been shown to create these structures on the surface of model eutectic materials, such as Al-Cu, with an interphase spacing dependent on the scanning velocity of the laser, but the limited absorption depth of the laser frustrates formation of bulk nanostructured samples. Selective laser melting (SLM) presents an innovative solution to this problem by building 3D samples via a layer-by-layer method, where each pass is rapidly cooled by the bulk material. In this research, the relationship between the SLM processing parameters and the resulting microstructure of bulk Al-Cu eutectic samples is investigated, with a focus on controlling the interphase spacing and directionality of the lamellar microstructure. An SLM Solutions GmbH 125 system was used to process the samples in this study, operating at scan velocities ranging from 50 to 150 mm/s at a CW laser power of 100 W. Cross-sections of samples exhibited lamellar spacing of 40 to 100 nm within narrow eutectic colonies of approximately 3 μm width that extended the height of the individual scan layers (50 μm). The solidification mechanism that produced these colonies is investigated, and the fine lamellar spacing is analyzed in accordance to the Jackson-Hunt theory. Samples in this study were characterized by scanning electron microscopy (SEM), focused ion beam (FIB), and energy dispersive X-ray spectroscopy (EDS). Support for this research from the National Science Foundation grant #CMMI-1663085 is gratefully acknowledged.

NS-ThP-7 Precision Nanometer-scale Scanning Probe Microscopy Data Recalculation for Diamond Tool Cutting Edge Structures, J Su, Nian-Nan Chu, C Hsiao, Taiwan Instrument Research Institute, National Applied Research Laboratories, Taiwan, Republic of China

Ultra-high precision diamond tool machining demands for high resolution three-dimensional inspection. Scanning Probe Microscopy (SPM) fulfills these needs through high resolution 3D measurements, non-destructive examination and a variety of probes for specific structural measurements. Moreover, recalculation of SPM data in respect to probe effect will improve data accuracy, especially for small angle structures. Here we present an algorithm method to evaluate probe effect and improve the resulted accuracy based on the scanning probe mechanism. This work is valuable to ultra-high precision diamond tool machining where other methods are incompatible.

Author Index

Bold page numbers indicate presenter

— A —

Ahmadi, M: NS-ThP-5, **1**

— B —

Belianinov, A: NS-ThP-5, **1**

— C —

Chu, N: NS-ThP-7, **2**

Cohen, S: NS-ThP-4, **1**

Collins, L: NS-ThP-5, **1**

— F —

Fitz-Gerald, J: NS-ThP-6, **2**

Floro, J: NS-ThP-6, **2**

— H —

Hsiao, C: NS-ThP-7, **2**

Hu, B: NS-ThP-5, **1**

— I —

Ievlev, A: NS-ThP-5, **1**

— J —

Jesse, S: NS-ThP-5, **1**

Jiang, N: NS-ThP-1, **1**

— K —

Kalinin, S: NS-ThP-5, **1**

— L —

Liu, Y: NS-ThP-5, **1**

— M —

Mahapatra, S: NS-ThP-1, **1**

— O —

Ovchinnikova, O: NS-ThP-5, **1**

— P —

Price, B: NS-ThP-2, **1**

— R —

Rasafar, A: NS-ThP-3, **1**

Rybtchinski, B: NS-ThP-4, **1**

— S —

Schultz, J: NS-ThP-1, **1**

Skelton, J: NS-ThP-6, **2**

Su, J: NS-ThP-7, **2**

— Z —

Zhang, Q: NS-ThP-4, **1**