Scope of the Symposium

You are invited to join us for the North American AFM User Meeting on May 4 - May 5. In this two-day virtual event, we will be joined by leading experts who will share their latest work in studying the nanomechanical and nanoelectrical properties of materials. From polymer mechanics and compositional mapping, electrochemical analysis, and piezoelectric materials, to the potential role of machine learning in AFM studies – a full range of exciting and cutting-edge topics will be discussed.

The event will also have six live demonstrations on the latest advances in Bruker's AFM technology, during which you will have the opportunity to meet and talk to product experts from your local Bruker AFM Team.

REGISTER

Program – Tuesday, May 4, 2021

1:00 PM – 4:00 PM EDT

1:00 – 1:05 **Welcome Address**
Steve Ziegler, Sales Account Manager, Southwest US, Bruker

1:05 – 1:25 **Mapping Nanomechanical Properties: How to Best Benefit from the Latest Innovations in PeakForce QNM**
Bede Pittenger, Ph.D., Senior Staff Development Scientist, Bruker

1:25 – 1:50 **Multidimensional Imaging of Physical Properties of Materials Using Novel Ringing Mode**
Igor Sokolov, Ph.D., Professor, Tufts University

1:50 – 2:15 **Using Machine Learning to Classify and Correlate AFM Phase Images**
Dalia Yablon, Ph.D., Founder, SurfaceChar LLC

2:15 – 2:35 **Live Demonstration featuring Ringing Mode:** Expand on the unique strengths of PeakForce QNM to provide enhanced adhesion property information that is complementary to existing mechanical and structural data.
Senli Guo, Ph.D., Application Scientist, Bruker

2:35 – 3:00 **Accessing the Viscoelasticity of Polymers at Multiple Scales: Bulk vs. AFM-nDMA**
Marius Chyasnavichyus, Ph.D., Associate Research Scientist, Dow Inc.

3:00 – 3:20 **Live Demonstration featuring nDMA:** See how the first and only AFM-based viscoelastic technique that ties directly to bulk DMA works.
John Thornton, Sr. Application Scientist, Bruker

3:20 – 3:40 **Live Demonstration featuring PeakForce Tapping:** Catch up on the latest with PeakForce Tapping techniques, see how High Accuracy QNM leverages bespoke probes and a barcode reader to improve accuracy and take the hassle out of calibration.
Ivan Yermolenko, Ph.D., Application Scientist, Bruker

3:40 – 4:00 **Question & Answer**

Program – Wednesday, May 5, 2021

1:00 PM – 4:00 PM EDT

1:00 – 1:05 **Welcome Address**
Chris Getz, Sales Account Manager, Midwest US, Bruker

1:05 – 1:25 **Review of Recent Advances in Electrical Characterization using Atomic Force Microscopy**
Peter De Wolf, Ph.D., Application Director, Bruker

1:25 – 1:50 **Advances in Understanding Electrochemical Degradation: The Power of Co-Localized KPFM**
Paul H. Davis, Ph.D., Surface Science Lab Manager, Boise State University
Corey M. Efaw, Materials Science & Engineering Ph.D. student, Boise State University
Olivia O. Maryon, Materials Science & Engineering Ph.D. student, Boise State University

1:50 – 2:15 **Understanding the Mechanism of (Photo)Electrochemical Transformations in Functional Architectures for Artificial Photosynthesis**
Francesca Maria Toma, Ph.D., CSD Staff Scientist, Lawrence Berkeley National Laboratory

2:15 – 2:35 **Live Demonstration featuring KPFM:** An overview of the many ways Bruker AFMs can perform surface potential measurements: AM/FM, tapping/ PFT, Lift Mode, or Single Pass**.**
John Thornton, Sr. Application Scientist, Bruker

2:35 – 3:00 **Quantifying Nanoscale Electromechanical Properties using Piezoresponse Force Microscopy**
Liam Collins, Ph.D., Research & Development, Center for Nanophase Materials Sciences, Oak Ridge National Laboratory

3:00 – 3:20 **Live Demonstration featuring ssPFM:** A sneak peek at the new switching spectroscopy PFM which allows to remove contact potential difference effects and quantify ferroelectric sample properties.
Senli Guo, Ph.D., Application Scientist, Bruker

3:20 – 3:40 **Live Demonstration featuring DataCube PFTUNA:** The most popular electrical option is now even more useful when combined with DataCube mode. See how to characterize conductive samples in intermittent contact to preserve tip and sample.
Ivan Yermolenko, Ph.D., Application Scientist, Bruker

3:40 – 4:00 **Question & Answer**

Talk Abstracts – Tuesday, May 4, 2021

Mapping Nanomechanical Properties: How to Best Benefit from the Latest Innovations in PeakForce QNM

Bede Pittenger, Ph.D., Senior Staff Development Scientist, Bruker

The microstructure and nanoscale mechanical properties of materials are of great interest due to their influence on the function and properties of the bulk. Almost immediately after the development of the first Atomic Force Microscopes, it was realized that the sharp apex and precise force control provided by the AFM make it the ideal tool to measure and map the nanomechanics of materials.

Over the past thirty years, the nanomechanical measurements available to AFM have become more and more sophisticated, repeatable, and accurate. Evolving from single force-distance curves, to slow force volume mapping, and faster (but qualitative) TappingMode Phase imaging, nanomechanical measurements have become more and more powerful. A decade ago, PeakForce QNM was introduced to combine the quantitative mapping capabilities of FV with the speed of TappingMode, and each year improvements in algorithms, and probes have enhanced its capabilities even further.

In this talk, we will discuss the latest improvements to PeakForce QNM and how they improve the breadth of nanomechanical information available and the accuracy of the resulting property maps. We will also consider when it is of interest to examine the associated PeakForce Capture DataCubes.

Bede Pittenger is a Senior Staff Development Scientist in the AFM Unit of Bruker's Nano Surfaces Business. He received his Ph.D. in Physics from the University of Washington (Seattle, WA) in 2000, but has worked with scanning probe microscopes for 25 years, building systems, developing techniques, and studying properties of materials at the nanoscale. His work includes more than thirty publications and four patents on various techniques and applications of scanning probe microscopy. Dr. Pittenger's interests span topics from the interfacial melting of ice to the nanomechanics of soft materials, polymers, and composites.

Multidimensional Imaging of Physical Properties of Materials Using Novel Ringing Mode

Igor Sokolov, Ph.D., Professor, Tufts University

Ringing mode provides unique images of sample physical and mechanical properties, which are impossible to obtain with other techniques. It allows obtaining 8 additional imaging channels (dimensions) simultaneously. Notably, the images are highly repeatable and suitable for quantitative data analysis, including machine learning. To run Ringing mode, there is no need for extra AFM calibrations beyond the standard ones. Ringing mode is a further development of sub-resonance tapping (PeakForce QNM). Up to 14 different data channels can be acquired simultaneously when Ringing mode is combined with PeakForce QNM. It can work in both air and liquids. Technically, Ringing mode is a combination of the oscillatory sub-resonance and resonance modes. It operates with the non-resonant feedback but utilizes the signal information from the ringing of the AFM cantilever, i.e., free resonance oscillations of the cantilever, which occur after detaching the AFM probe from a sample surface. In this talk, I will describe the imaging channels of Ringing mode and overview several examples of the application of Ringing mode, including imaging of polymers, fixed biological cells, and molecular coatings on nanoparticles.

Dr. Sokolov's AFM adventure started in 1987 when he encountered the first AFM made in the Soviet Union. Being trained as a quantum field theory physicist, his early AFM works (his Ph.D. thesis) were about the search of unknown fundamental forces in nature. Using AFM force measurements, he obtained much stronger restrictions on new elementary particles than was previously found from the observation of red giant stars. Later, after suggesting ideas of lifting and tapping mode, he was awarded by E.L. Ginzton International Fellowship Award from Stanford University. His interests gradually migrated to biophysics and possible medical applications of AFM. He is now a professor at Tufts University, with 170+ referred papers, including publications in elite journals like Nature, Nature Nanotechnology, PRL, Advanced Materials, Materials Today, etc. He has 21 patents issued and pending, including 6 in the area of AFM related to medical applications of AFM, machine learning, new Ringing, and FT-NanoDMA modes. His current AFM-related interests are AFM for Heath; the goal is to introduce AFM to the medical area.

Using Machine Learning to Classify and Correlate AFM Phase Images
Dalia Yablon, Ph.D., Founder, SurfaceChar LLC

Machine learning has been applied to classify and correlate AFM phase images of a variety of impact copolymers (ICP), a material composed of a polypropylene matrix with differently sized and distributed rubber domains. The various ICPs differ in their bulk mechanical properties and in their microstructure as observed in AFM phase images. A machine learning model was built using a convolutional neural net (CNN) and successfully classified the various ICPs, showing meaningful differences in microstructure between the different samples. Another CNN-based model successfully correlated the ICP AFM phase images with bulk mechanical properties. The correlation of the microstructure in the AFM image was strongest with the plastic properties of yield strength and ultimate elongation percentage.

Dalia Yablon is the founder of SurfaceChar, an AFM and nanoindentation-based measurement, consulting, and training company in the Greater Boston area since 2013. Dalia also serves as the senior advisor of TechConnect Ventures and Technical Chair of TechConnect World. In addition to editing a book on "SPM in Industrial Applications" (Wiley), Dalia's research focuses on nanomechanical characterization methods and soft material characterization. She holds an A.B. in Chemistry from Harvard University and a Ph.D. in Physical Chemistry from Columbia University.

Accessing the Viscoelasticity of Polymers at Multiple Scales: Bulk vs. AFM-nDMA

Marius Chyasnavichyus, Ph.D., Associate Research Scientist, Dow Inc.

Efficient material design relies heavily on combining several components with certain mechanical properties in a specific way to achieve desired performance. While measurements of mechanical properties of isolated material components using bulk dynamic mechanical spectroscopy (DMS) methods are well established, they do not always explain the contributions of each individual component to the overall material performance. In the DMS domain there is a gap in fundamental understanding between the bulk mechanical properties of a fully formulated system and the properties of the separate components that are involved in the formulation. AFM-nDMA can help to bridge that gap by examination of the morphology of the phases of the components constituting the system as well as observe the actual DMS performance of each of the phases in situ. In this talk we will examine performance of simplified two component model material, a layered PC-PMMA system, from the two different points of view: the bulk DMS characterization as well as AFM-nDMA. We will examine and compare mechanical properties and thermal transitions of the components of this model system observed on these two different scales to understand the efficiency of nanoscale viscoelastic property characterization using AFM-nDMA.

- *B.S./M.S., Physics, Moscow State Aviation University (2007)*
- *Ph.D. Materials Science and Engineering, Clemson University, (2012)*
- *Postdoc, Materials Science and Engineering, Georgia Institute of Technology (2012-2015)*
- *Postdoc, Center for Nanophase Materials Sciences, ORNL (2015-2016)*
- *Associate Research Scientist, Dow Inc. Joined Analytical Sciences in Midland, MI in January 2017*

Highlighted areas of interest - dynamic mechanical properties of materials on macro and microscale, structure-property relationships

Talk Abstracts – Wednesday, May 5, 2021

Review of Recent Advances in Electrical Characterization using Atomic Force Microscopy
Peter De Wolf, Ph.D., Application Director, Bruker

Today, a wide range of AFM modes is available for nano-electrical characterization of materials and devices. These modes include: EFM, KPFM, C-AFM, TUNA, SCM, SSRM, PFM, and sMIM.

This presentation will give an overview of various implementations and recent innovations of these modes with a focus on improved imaging or spectroscopy performance. This includes the correlation of multiple electrical and mechanical properties, avoiding contact mode by using PeakForce and force mapping approaches, and the acquisition of multi-dimensional data sets in which electrical spectroscopy is combined with mapping (aka DataCubes).

Peter De Wolf received his Ph.D. in Electrical Engineering from the University Leuven, Belgium in 1998. His Ph.D. work focused on the development of SPM based electrical characterization methods for semiconductors at IMEC in Belgium. He is co-inventor of several SPM methods and holder of several patents. Since 1998, Peter De Wolf works at Bruker (formerly Digital Instruments & Veeco Instruments) in both Santa Barbara, USA, and Paris, France. At Bruker, he previously held positions as R&D engineer and application development scientist and contributed to the development of electrical SPM methods including SSRM, TUNA, SCM, and DataCube methods. Currently, he is the Worldwide Director of Applications – leading an international team of experts in SPM with laboratories located in Europe, USA, Asia, and Japan, covering a broad range of SPM applications and operating modes.

Advances in Understanding Electrochemical Degradation: The Power of Co-Localized KPFM

Paul H. Davis, Ph.D., Surface Science Lab Manager, Boise State University
Corey M. Efaw, Materials Science & Engineering Ph.D. student, Boise State University
Olivia O. Maryon, Materials Science & Engineering Ph.D. student, Boise State University

Kelvin Probe Force Microscopy (KPFM) is a non-destructive scanning probe microscopy (SPM) method capable of mapping the surface potential of a sample at the nanoscale by measuring the DC voltage necessary to null the tip-sample contact potential difference at each point on the surface. To convert this relative Volta potential measurement into an absolute value, the work function of the conductive KPFM probe must be calibrated. KPFM Volta potential measurements are of value in determining corrosion potentials, and can be co-localized with sub-micron precision with other materials characterization techniques such as scanning electron microscopy (SEM) or Raman microscopy to provide valuable insights into how the presence of microstructural phases and grain orientation may impact corrosion resistance and material performance. In this talk, we will highlight several recent example applications of KPFM co-located with other characterization methods to investigate the structure and performance of a variety of materials of interest, including CuSil and InCuSil brazes, novel Mg alloys, heat-treated stainless steels, zirconia, and an additively manufactured (3D printed) titanium alloy.

Paul earned a B.S. in Chemistry from the University of Tennessee (1995) and a Ph.D. in Chemical Physics from Stanford University (2001), where his thesis work centered on using ultrafast nonlinear infrared spectroscopy to study vibrational dynamics in condensed phase systems. Since 2012, he has served as the Surface Science Lab (SSL) Manager in the Micron School of Materials Science & Engineering at Boise State University, where he oversees a suite of 5 Bruker AFMs while also remaining active in ultrafast spectroscopy research, co-authoring over 20 peer-reviewed publications in that role. He is particularly excited about the newest addition to the SSL's suite of AFMs, a Bruker Anasys nanoIR3-s equipped with a tunable broadband ps/fs IR pump laser, as it combines his two areas of long-standing research interest.

Corey worked as an undergraduate research assistant in the SSL for 3 years, co-authoring 3 peer-reviewed publications (including 2 involving KPFM for corrosion applications) while pursuing a B.S. in Mechanical & Biomedical Engineering. Following graduation, he immediately put his corrosion research experience to use in industry as a QC and R&D engineer at Reflok, where he discovered the cause of a corrosion issue with one of their HVAC products and developed a solution. Corey subsequently returned to academia and is now a fifth year Ph.D. student in Materials Science & Engineering at Boise State, where he is a Department of Energy (DOE) Graduate Fellow jointly advised by Profs. Mike Hurley and Claire Xiong of Boise State and Dr. Eric Dufek of Idaho National Laboratory (INL). Corey's graduate research has utilized a wide *array of electrical AFM techniques (e.g., KPFM, CAFM/TUNA, EC-AFM, and SECM) to investigate both corrosion initiation and ion battery electrodes, which has led to a further 5 peer-reviewed and conference publications.*

Olivia worked as an undergraduate research assistant in the SSL for 3 years, co-authoring 2 peer-reviewed publications while pursuing a B.S. in Materials Science & Engineering. Her research in the SSL was primarily centered on using advanced AFM modes such as MFM, KPFM, and EC-AFM to investigate the nanoscale structure and corrosion behavior of alloys used in aerospace applications, and involved collaborations with both industry and national laboratories, including co-localization of KPFM and SEM/EBSD maps with sub-micron precision to investigate the effects of grain orientation on Volta potential. Upon graduation, Olivia eschewed several tempting aerospace industry job offers to instead enter graduate school. She is currently finishing her first year as a Ph.D. student in Materials Science & Engineering at Boise State. Advised by Prof. Mike Hurley, her graduate research is focused on corrosion initiation, propagation, and prevention, utilizing a combination of macroscale, microscale, and nanoscale electrochemical techniques including KPFM, CAFM/TUNA, EC-AFM, and SECM.

Understanding the Mechanism of (Photo)Electrochemical Transformations in Functional Architectures for Artificial Photosynthesis

Francesca Maria Toma, Ph.D., CSD Staff Scientist, Lawrence Berkeley National Laboratory

Stable and efficient catalytic architectures are a prerequisite for artificial photosynthesis. In order to achieve sustainable energy conversion and storage into chemical bonds, it is instrumental to understand the chemical transformation of these catalytic architectures under operating conditions. Our group uses different strategies to understand how the performance of a (photo)electrode is impacted by chemical transformations during operation. Specifically, we look at how functional, chemical, and structural heterogeneity over different length scales influences macroscopic performance and stability. Here, we will show how we combine photoelectrochemical measurements with atomic force microscopy-based techniques and scanning transmission X-ray microscopy to gain a complete understanding of different material systems, such as bismuth vanadate, copper oxide, and gallium nitride, for their application in artificial photosynthesis.

Francesca got her M.S. in Pharmaceutical Chemistry at the University of Padua, and her Ph.D. in Biophysics at the International School of Advanced Studies in Trieste (Italy) in 2009. She joined UC Santa Barbara as a Marie Curie Researcher in 2011, and was a Postdoctoral Scholar for a brief time in the Chemistry Department at UC Berkeley, before joining the Berkeley Lab in 2013. Francesca focuses on the synthesis, characterization, integration, and understanding of catalysts, and light absorbers for an energy-efficient, sustainable future. Francesca has more than 80 papers and has received numerous recognitions including the 2021 WCC Rising Star Award from ACS.

Quantifying Nanoscale Electromechanical Properties using Piezoresponse Force Microscopy

Liam Collins, Ph.D., Research & Development, Center for Nanophase Materials Sciences, Oak Ridge National Laboratory

Electromechanical coupling underlies a broad range of diverse applications from data storage and computing, to energy harvesting and biotechnology. Voltage modulated (VM) AFM techniques, including piezoresponse force microscopy (PFM) and related electrochemical strain microscopy (ESM), are uniquely positioned to probe electromechanical properties with spatial resolution from micrometers to nanometers. As with all AFM techniques, the goal of any PFM/ESM measurement should be towards quantification of the local material properties. Unfortunately, quantification of these methods remains a significant challenge. Furthermore, with the growing popularity of PFM there has been a congruent rise in reports of nanoscale electromechanical functionality, including hysteresis, in materials that should be incapable of exhibiting piezo- or ferroelectricity. Worryingly, VM AFM methods are highly susceptible to numerous forms of crosstalk, and, despite efforts within the AFM community, a global approach for eliminating this has remained elusive. This presentation will go over the fundamentals of PFM, including identification and avoidance of unwanted background signals and electrostatic crosstalk. Simple approaches to flag false hysteresis/ferroelectricity along with best practices for quantification of material properties on the nanoscale will be discussed. Throughout the presentation examples of quantitative measurements on various ferroelectric thin films, polymers, and hybrid organic-inorganic perovskites will be described.

This research was conducted at the Center for Nanophase Materials Sciences, which is a DOE Office of Science User Facility.

Liam Collins received his Ph.D. in Physics from the University College Dublin (Ireland) in 2015. He is currently an R&D staff in the Center for Nanophase Materials Sciences at Oak Ridge National Laboratory. He has over a decade of experience in material science with a specialization in the development of AFM techniques for characterizing structure-function properties on the nanoscale. He is particularly interested in developing force based electro-mechanical/chemical methods for in-situ characterization of solid-liquid interfaces. He is co-inventor of several AFM methods for nanoscale characterization of electrostatic, electrochemical, and electromechanical effects, which he utilizes to investigate diverse functional materials including ferroelectric, bio- and energy materials.

Please don't hesitate to contact us at productinfo@bruker.com if you have any questions.