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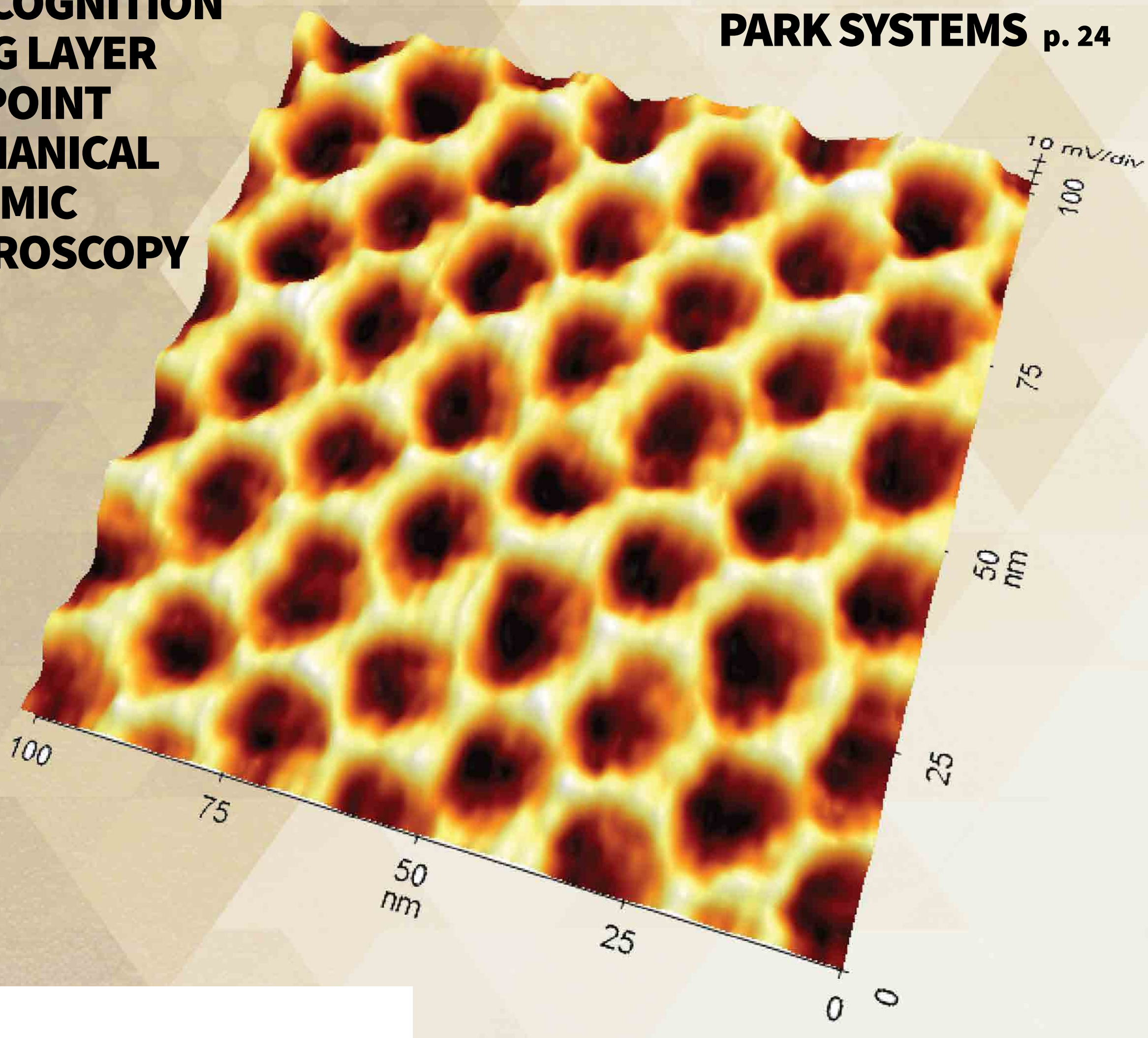

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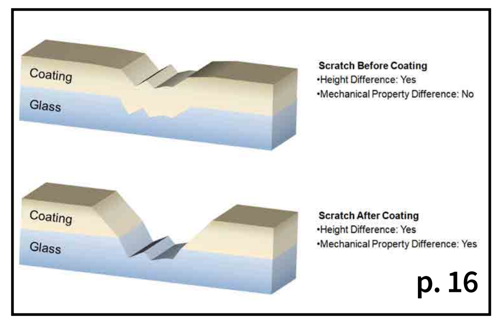

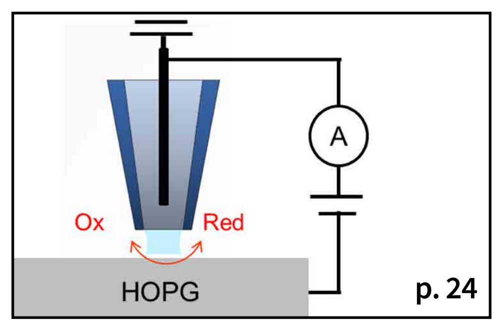

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INSET PHOTO ON COVER: Moiré superlattice periodicity in graphene on hexagonal boron nitride structures is characterized by contact resonance Piezoresponse Force Microscopy (PFM). The PFM amplitude image shows honeycomb Moiré patterns with a periodicity of 15 nm on monolayer graphene on hexagonal boron nitride (hBN). The formation of a Moiré superlattice with a 14-15 nm wavelength is the signature of aligned monolayer graphene on hBN. It shows that the contact resonance PFM is a suitable instrument for performing quality control and distinguishing the Moiré periodicity in graphene/hBN-like 2D multilayered samples.

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MESSAGE FROM EDITOR

Welcome to the 22nd edition of NanoScientific. It is with great excitement that I announce our new issue. These are indeed exciting times in nanoscience and technology, rapidly changing, expanding and improving our lives. We are happy to present articles in this issue that demonstrate the nanotechnology advances taking place in our world.

In this issue, you will find an illuminating interview with Dr. Alan Tennant from ORNL Quantum Materials Initiative discussing the quantum phase of matter and neutron scattering techniques. We are featuring a new application note in this issue on 2D Moiré Superlattice Electromechanical Characterization with Piezo-response Force Microscopy written together with Qiong Ma, Department of Physics, Boston College, USA Ilka Hermes, Applications, Park Systems Europe GmbH., Germany, Dae Yoen Won, Research & Development, Park Systems Corp., Korea. We also have articles on Defect Recognition on Coating Layer using PinPoint™ Nanomechanical Mode and on Nanoscale Electrochemistry Study using SECCM Option of Park Systems.

And for our featured product showcase, we are highlighting Park Systems Groundbreaking New Autonomous AFM which was just introduced and we have the first user review. "We are thrilled to be the first AFM user in North America to experience the Park FX40 Atomic Force Microscope," states James Hone, Professor of Mechanical Engineering at Columbia University.

"As long-time users of Park AFMs, we are excited about the new features and increased capabilities in this new generation. In particular, the breakthroughs in automation of AFMs using artificial intelligence and robotics technology will dramatically boost our productivity and drive innovation across the field of nanometrology."

In every issue, we bring you exciting nanotechnology and nanometrology applications and research. This year, we are hosting NanoScientific Symposiums worldwide again. Our successful virtual events last year brought together thousands of people from nearly 40 countries globally and awarded cash prizes for the presenters and poster exhibits. We have just begun accepting abstracts for this year's NanoScientific Symposiums, make sure to submit your abstract for a chance to be a presenter and be eligible for cash prizes.

I have watched NanoScientific evolve into a useful and interesting publication and also have enjoyed watching the successful NanoScientific Symposiums, which are hosted in 8 countries worldwide. Park Systems supports NanoScientific because it adheres to our mission of enabling scientific advances. As we share nanotechnology best practices and join together, we push the boundaries for new scientific understandings. As the Nano Revolution continues to unfold, advances in nanotechnology developments are paving the path for exciting future discoveries in science. NanoScientific will continue to do our part by sharing your research and bringing attention to new nanotechnology research.are paving the path for exciting future discoveries in science.

NanoScientific will continue to do our part by sharing your research and bringing attention to new nanotechnology research.

Keibock Lee, Editor-in-Chief
NanoScientific

NANOSCIENTIFIC 2020

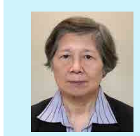

Dr. Rigoberto Advincula, Professor, Department of Macromolecular Science and Engineering at Case Western Reserve University.


Dr. Lane Baker, James L. Jackson Professor of Chemistry Indiana University


Mr. Phil Kaszuba, Global Foundries Senior Member of Technical Staff and lead engineer in their Scanning Probe Microscopy (SPM) laboratory.

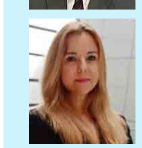

Dr. John A. Marohn, Professor & Director of Undergraduate Studies, Department of Chemistry and Chemical Biology Member, Field of Materials Science & Engineering, Cornell University.


Dr. Ye Tao, Rowland Fellow & Principle Investigator, Rowland Institute of Science at Harvard University, BA Harvard in Biochemistry, PhD MIT/ ETH Zurich Chemistry


Dr. Gwo-Ching Wang, Travelstead Institute Chair, Dept. of Physics, Applied Physics & Astronomy, Rensselaer Polytechnic Institute.


Dr. Jiahua Jack Zhu, PhD, University of Akron, Associate Professor, Department of Chemical and Biomolecular Engineering.


Dr. Yiping Zhao Professor, Department of Physics and Astronomy, Director, Nanoscale Science and Engineering Center, The University of Georgia.


Marine Le Bourer, Founder, The Nanotechnology World Association (NWA),created to help accelerate the integration of nanotechnologies in various industries.

Announcing the Park AFM 2021 Park AFM Certification Course

Sign up for the certification program: https://www.parksystems.com/medias/nano-academy/programs/certification-course

PARK SYSTEMS ANNOUNCES PARK FX40

THE AUTONOMOUS AFM WITH BUILT-IN INTELLIGENCE

– A GROUNDBREAKING NEW CLASS OF ATOMIC FORCE MICROSCOPE

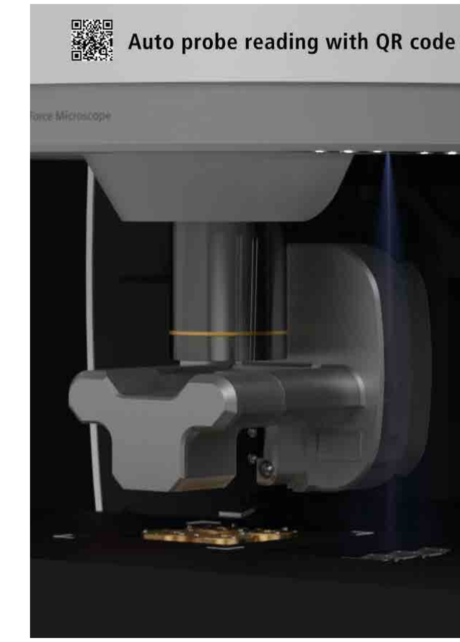
"Unlike current generations of AFM systems, Park FX40 takes care of all the set up before and during scanning: the probe exchange, probe identification, beam alignment, sample location, tip approach and imaging optimization to name a few. All the tedious and time-consuming manual processes are now a thing of the past," comments Ryan Yoo, Vice President Product Development. "Park FX40 performs all these tasks autonomously, by integrating AI intelligence into the system and incorporating robotics techniques that Park has mastered with their industry leading multimillion dollar automated AFM systems."

(June 25, 2021 Santa Clara, CA)
Park Systems, the fastest growing manufacturer of Atomic Force Microscopes (AFM) just announced Park FX40, a groundbreaking autonomous atomic force microscope, infused with innovative robotics, intelligent learning features, safety features, software and specialized add-ons. Park FX40 Atomic Force Microscope is the first AFM to automate all up-front set up and scanning processes, putting the intelligent Park FX40 in a groundbreaking new class of atomic force microscope.

The new Park FX40 Atomic Force Microscope is more than just dozens of new features and upgrades – it's an overhaul in functionality while retaining the same basic design elements, enabling AFM's to think and perform essential functions completely on their own. This will allow untrained researchers to achieve a number of formerly training-intensive tasks, and trained researchers to focus on what they're best at in their specialized fields, while the time-consuming tasks like choosing and loading the correct probes, to automatically aligning the X, Y and Z beams along the axis, take care of themselves. Furthermore, Park FX40 has drastically upgraded many of the AFM's key aspects, including electromechanics for much reduced mechanical noise, smaller beam spot size, improved optical vision and multi snap-in sample chuck.

"Park FX 40 features significant enhancements that are completely new tech, never before seen on an AFM," adds Yoo.

Park FX built in intelligence even allows users to place several samples at the onset (of the same or different types)



and it will image them autonomously according to your requirements.

The result is better research by obtaining publishable data easily and timely and acceleration of the research cycle for ultimate scientific and engineering success. Park FX40's unique environmental sensing self-diagnostics and head crash avoidance system ensures that Park FX40 is continuously operating at its optimum performance.

In collaboration with the expert scientists at Park's growing network of nanotechnology research centers worldwide, the product marketing team diligently worked on the design of Park FX over the last year.

"Our scientists recognize the impact AFM has had on nanoscience innovation, allowing researchers to obtain scientific data never before witnessed," comments Dr. Sang-il Park , CEO and Founder of Park Systems. "Our ultimate goal with developing Park FX with autonomous features is to make the researcher's job easier as they open new doors in scientific discovery."

Known for their commanding lead in semiconductor advanced automated AFM systems and bringing AFM technology into the mainstream as the premier tool for nanoscale metrology, this latest development is part of a natural progression for Park Systems as they continue to lead the world in AFM innovation.

For more information go to www.parksystems.com/fx40.

About Park Systems

Park Systems is the fastest growing and world's leading manufacturer of atomic force microscopy (AFM) systems, with a complete range of products for researchers and engineers in the chemistry, materials, physics, life sciences, semiconductor and data storage industries. Our mission is to enable nanoscale advances for scientists and engineers solving the world's most pressing problems and pushing the boundaries of scientific discoveries and engineering innovations. Customers of Park Systems include most of the world's top 20 largest semiconductor companies and national research universities in Asia, Europe and the Americas. Park Systems is a publicly traded corporation on the Korea Stock Exchange (KOSDAQ) with corporate headquarters in Suwon, Korea, and regional headquarters in Santa Clara, California, USA, Mannheim, Germany, Beijing, China, Tokyo, Japan, Singapore, and Mexico City, Mexico. To learn more about Park Systems, please visit www.parksystems.com.

PARK SYSTEMS, GLOBAL LEADER IN ATOMIC FORCE MICROSCOPY, APPOINTS DR. STEFAN KAEMMER AS PRESIDENT, PARK SYSTEMS AMERICAS

(June 21, 2021 Santa Clara, CA) "Park Systems is experiencing unprecedented expansion, and during the coming years we expect to add significantly to the revenue growth that put us at the One Trillion Mark at Kosdaq in 2021", comments Dr. Sang-il Park, CEO & Founder of Park Systems.

Park Systems is proud to announce the appointment of Dr. Stefan Kaemmer as President of Park Systems, Americas, in alignment with its global strategy. "I am humbled by the trust that Dr. Park placed in me to lead the organization during this critical juncture for the business," comments Stefan. "We have a very motivated and capable team and customer focused products at the apex of effectiveness."

Stefan comes to Park with extensive experience in the AFM industry and most recently as Director of Sales, Americas, where he made a dramatic impact on the growth of sales and business development. Stefan first applied Scanning Probe Microscopy during his graduate work at the University of Braunschweig/Germany . Since then, he has had various executive positions in the SPM industry, including at Hitachi, Japan and Bruker, U.S, leading a range of functions, from science, to engineering, to sales to technology innovations. As the first General Manager for JPK Instruments, he led initiatives to deliver unique solutions to the U.S. market.

"Stefan's combination of can-do attitude and critical thinking are just as valuable as his vast technical knowledge and experience," comments a collaborator of Stefan during the joint development of two Scanning Probe Microscopes. Park Systems welcomes Dr. Kaemmer as the new President of Park Americas and looks forward to his success in this new role.

"STEFAN'S ADDITION AS PARK SYSTEMS AMERICAS PRESIDENT STRENGTHENS OUR POSITION IN THE GLOBAL AFM MARKET," STATES DR. SANG-IL PARK, FOUNDER AND CEO OF PARK SYSTEMS. "WE ARE CONFIDENT IN HIS ABILITY TO LEAD PARK SYSTEMS INTO THE FUTURE AS THE PREMIERE AFM SUPPLIER TO BOTH THE INDUSTRIAL AND RESEARCH MARKETS."

About Park Systems
Park Systems is the fastest growing and world's leading manufacturer of atomic force microscopy (AFM) systems, with a complete range of products for researchers and engineers in the chemistry, materials, physics, life sciences, semiconductor and data storage industries. Our mission is to enable nanoscale advances for scientists and engineers solving the world's most pressing problems and pushing the boundaries of scientific discoveries and engineering innovations. Customers of Park Systems include most of the world's top 20 largest semiconductor companies and national research universities in Asia, Europe and the Americas. Park Systems is a publicly traded corporation on the Korea Stock Exchange (KOSDAQ) with corporate headquarters in Suwon, Korea, and regional headquarters in Santa Clara, California, USA, Mannheim, Germany, Beijing, China, Tokyo, Japan, Singapore, and Mexico City, Mexico.

To learn more about Park Systems, please visit www.parksystems.com.

Park FX40 is coming June 25. Watch our Video.

APPLICATION NOTE

2D MOIRÉ SUPERLATTICE ELECTROMECHANICAL CHARACTERIZATION WITH PIEZO-RESPONSE FORCE MICROSCOPY

Park SYSTEMS

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Dae Yoen Won, Research & Development, Park Systems Corp., Korea

Introduction

Stacking two-dimensional (2D) materials within the van der Waals interaction distance of each other can generate long-range wavelength ordering called Moiré superlattice periodicity. In the case of graphene on hexagonal boron nitride (hBN), for example, this effect would appear on the top layer of graphene and cause the energy bandgap of graphene to open [1-3]. By regulating the lattice orientation between graphene and boron nitride, one can vary the Moiré periodicity's wavelength, thus tuning the graphene energy bandgap. The energy bandgap range impacts graphene's device functionalities and performance [4]. Therefore, it is useful for researchers to have a simple way of deciphering the Moiré shape and periodicity, especially when designing 2D graphene/BN-like heterostructured materials and devices.

Piezo-response Force Microscopy (PFM) is a contact Atomic Force Microscopy (AFM)-based imaging technique. It is widely used for electromechanical mapping of a sample with nanoscale lateral resolution and has shown promise in detecting local strain gradients and piezoelectricity in various 2D heterostructured material systems, including graphene/hBN [5]. In this paper, we use contact resonance PFM to characterize the Moiré shape and periodicity–the superlattice wavelength. Using two types of graphene-on-hBN stacked systems, we correlate these variables to describe lattice misalignment and rotation.

Experiment and Result

a. Monolayer graphene on hexagonal boron nitride

The sample is a monolayer graphene epitaxially grown on a hexagonal boron nitride. PFM setup uses a Park NX10 AFM

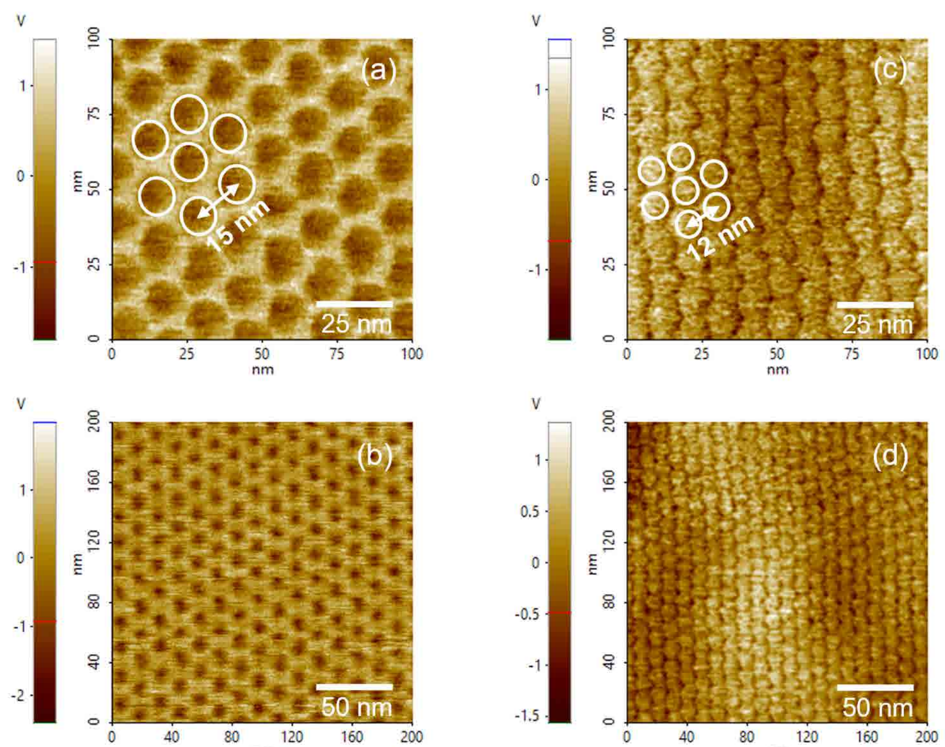

Figure 1. PFM amplitude images. Honeycomb Moiré patterns with periodicity 15 nm on monolayer graphene/hBN (a) and (b), and with periodicity 12 nm on twisted bilayer graphene/hBN (c) and (d).

system coupled with a Zurich Instruments HF2 lock-in amplifier [6]. The PFM cantilever probe (PPP-EFM) used is a ~3 N/m Si cantilever probe, PtIr-coated, with an air resonance ~75 kHz. The AC voltage applied is 2 V, and the contact resonance frequency used is ~330 kHz. The AFM loading force applied during PFM scanning is 40 nN, and the PFM scan rate is 1-1.5 Hz. The 100 nm x 100 nm and 200 nm x 200 nm scan size data were acquired. To perform the contact resonance PFM on the graphene sample, we followed the procedure outlined by Hermes et al., who used PFM to image ferroelectric domains in Bismuth Ferrite (BFO) [6], with the following exception. In the reported PFM study on BFO, surface pits prevented the contact resonance frequency from staying within acceptable levels during scanning. Thus, it was necessary to enable "Double Frequency Resonance Tracking" (DFRT)'s PID control during scanning to compensate for shifts in contact resonant frequency. However, in this report, the topography of graphene/hBN in the scanning area is atomically flat and virtually featureless. Thus, there is a negligible contact resonance frequency shift during the PFM operation, which allows for high-resolution PFM data without enabling DFRT's PID control.

Figure 1(a) is a contact-resonance PFM amplitude image that shows a honeycomb Moiré periodicity. The periodic superlattice spacing is 15 nm, two orders of magnitude larger than the atomic lattice constants of graphene and hBN. For aligned graphene on boron nitride, a Moiré periodicity ~14-15 nm is expected [2,3]. Our results are consistent with this value. When zoomed out to 200 nm x 200 nm and scanned again, the sample shows a consistent 15 nm periodicity and a coherent piezo-response signal, as shown in Fig. 1(b).

b. Twisted bilayer graphene on hexagonal boron nitride

The sample was prepared by employing an exfoliation technique and purposely misaligning the upper graphene bilayer graphene by 1.15 degrees to the underlying hBN substrate. The surface of the exfoliated bilayer graphene was studied with noncontact AFM survey imaging, and a residue film with a nanometer-scale thickness, likely leftover from the exfoliation process, was covering the exfoliated sample surface. First, a PPP-EFM probe scanned the sample in contact mode AFM (applying up to ~500 nN loading force) to sweep aside the residue. Next, a new PPP-EFM probe performed PFM measurements on the cleaned bilayer graphene surface. The PFM setup and imaging procedures used for the twisted bilayer graphene characterization are the same as that of the monolayer graphene PFM study, except for the following parameters. The AC voltage applied is 6 V, and the contact resonance frequency used is 354 kHz. The AFM loading force applied during PFM scanning is 500 nN, and the PFM scan rate is 2-3 Hz.

Figure 1(c) is a 100 nm x 100 nm scan contact-resonance PFM amplitude image. One can outline a hexagonal pattern and determine the twisted bilayer's superlattice periodicity to be 12 nm. There is a 20% difference in Moiré periodicity between bilayer graphene and monolayer graphene, with the latter being larger. The 12 nm wavelength periodicity should correspond to the bilayer graphene's configuration misaligned by the 1.15-degree twist on BN. Monolayer graphene with 15 nm periodicity represents monolayer graphene on hBN without misorientation between two layers. This observation agrees with the general understanding that the Moiré periodicity, i.e., the superlattice wavelength, is reduced further as the top adlayer is increasingly misaligned to the underlying layer [7]. Fig 1(d) is the PFM amplitude data of the same area after zooming out to the 200 nm x 200 nm scan area. The individual component that makes up the honeycomb array is discernable everywhere with the same periodicity in the zoomed-in and zoomed-out scan images of Figs 1(c) and (d).

Summary

Moiré superlattice periodicity in two types of graphene on hexagonal boron nitride structures is characterized by contact resonance PFM. Bilayer graphene misoriented with a 1.15-degree twist on hBN showed a 12 nm Moiré wavelength periodicity, which is 20 % smaller than the 15 nm lattice periodicity for monolayer graphene on hBN. The formation of a Moiré superlattice with a wavelength of 14-15 nm is the signature of aligned monolayer graphene on hBN. Therefore, contact resonance PFM is a suitable instrument for performing quality control and distinguishing the Moiré periodicity in graphene/hBN-like 2D multilayered samples.

Acknowledgment

The authors thank Prof. David Goldhaber-Gordon's group from Stanford University for providing the epitaxially-grown monolayer graphene/hBN sample.

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AN INTERVIEW WITH DR. ALAN TENNANT, LEAD OF THE QUANTUM MATERIALS INITIATIVE

at Oak Ridge National Laboratory and Joint Faculty Professor in the Dept. of Physics and Astronomy at the University of Tennessee

"The ORNL quantum materials initiative has really been focused on jump starting some new quantum research at the laboratory and helped prepare the ground for the Quantum Science Center, one of five new national quantum centers established though the National Quantum Initiative Act."

Dr. Alan Tennant giving a lecture on the vision for a Second Target Station to Oak Ridge National Laboratory. This project is now approved by DOE and designing and building this new flagship neutron facility for the nation is underway.

Director, Dr. Alan Tennant

Alan Tennant is the Lead of the Quantum Materials Initiative at Oak Ridge National Laboratory, and Joint Faculty Professor in the Department of Physics and Astronomy at the University of Tennessee. Before conducting postdoctoral research at ORNL in the late 1990s, Tennant studied physics at the University of Edinburgh, Scotland, and earned his PhD at the University of Oxford. He served as a professor at the Technical University, Berlin, and institute director in the field of magnetism at the Helmholtz Center Berlin. During nine years in Berlin, he was science director of the Berlin Neutron Scattering Center and undertook research on exotic states of matter, including the observation of "nature's ultimate symmetry," the E8 symmetry, in a material using neutrons. He received the Euro physics Prize for the experimental observation of magnetic monopoles in spin ice in 2012. Tennant returned to ORNL in November 2013 as Chief Scientist in the Neutron Sciences Directorate.

As the lead at the lab wide quantum materials initiative at ORNL, Dr. Tennant is principal investigator on an initiative to develop capabilities for measuring quantum properties in materials. Other activities include developing machine learning/AI approaches for understanding quantum and topological materials and the prediction and synthesis of new quantum materials for energy and quantum information science. Dr. Tennant has over 25 years of experience in quantum condensed matter and magnetism research and 15 years of experience in science management and has directed major international scientific user facilities and renowned research institutes. He has extensive expertise in national research planning and international collaborations and has held academic positions in the UK and Germany as well as positions in national laboratories in the UK, US, and Germany. He has authored over 100 scientific papers and received prestigious research awards including the 2012 European Physics Prize for Condensed Matter. His main research areas are application of neutrons and photons to understanding quantum materials and the use of advanced modelling and analysis including machine learning/AI to quantum and topological materials.

Above picture shows inside the experimental hall of the First Target Station at the Spallation Neutron Source. Dr. Alan Tennant pictured with John Galambos from the accelerator division (left), Bill Stirling from the ORNL Neutron Advisory Board and ex director of ESRF and ILL facilities in Grenoble (second from left), and Paul Langan (right) who was the Associate Laboratory Director for Neutrons at ORNL

Q&A with Dr. Alan Tennant

1) Neutron Scattering is an emerging branch of Physics which you have been involved in since the beginning. Can you explain why Neutrons are so important in quantum materials?

Neutron scattering dates back to the 1940s using the first reactors built for the Manhattan Project but has really exploded in terms of application to quantum properties of materials in the last two decades. This is because of the new sources and instrumentation that make the measurements possible. Neutrons are quite an amazing probe of quantum states because of the way they "see" the atomic spins. Magnetism comes about because of the Pauli exclusion principle; electrons can't be in the same state at the same time so become correlated, adopting shared configurations in space and time. Neutrons scatter off these states and reveal what you can think of as a kind of "quantum dance".

2) How significant are new supercomputers to understand more about quantum science?

I think they are very significant. The reason is they offer a new level of understanding, particularly when combined with new algorithms and artificial intelligence in the way complex materials can be simulated. Many of the materials challenges we face, the experimental data, and quantum states are challenging. Having tools that can address this is important for progress.

3) How does the development of topological semimetals discovered by Quantum Physics affect the ability to advance Quantum computing?

Topological semimetals are part of a wider class of topological materials that include superconductors and insulators. Some topological semimetals such as Weyl semimetals are of interest in low power electronics due to their fast dissipationless transport. However, for quantum computing people are particularly interested in so called non-Abelian anyons found in other types of materials. These are quasiparticles that can be used to do quantum operations. You can potentially get them in topological superconductors and quantum spin liquids. There is still so much still to be discovered and understood in topological materials that I feel we are still at the start.

4) You said in our interview that "A lot is happening in quantum materials that will have an incredible influence on physics". Can you elaborate on that?

I think that from the explorations that have been happening to date, which have often been on the simple model systems we think we can understand, there have been enough surprising new findings and insights that we can speculate that there is a lot of undiscovered physics out there. As our experiments and theory get better and better, more and more science is coming into range and these discoveries will change the way we look at materials and quantum states. There are a lot of connections between the models we use in condensed matter and those in other branches of physics like high energy physics so a synergy is happening between disciplines including new ideas coming from quantum information science itself.

5) You mentioned that "Quantum brings a signature of the quantum state, when observing quantum systems, you cannot see everything". Is the research ORNL Quantum Materials Initiative

"I think that from the explorations that have been happening to date, which have often been on the simple model systems we think we can understand, there have been enough surprising new findings and insights that we can speculate that there is a lot of undiscovered physics out there. As our experiments and theory get better and better, more and more science is coming into range and these discoveries will change the way we look at materials and quantum states."

leading towards discoveries to see more at the quantum level and how will that affect our understanding of materials?

The ORNL quantum materials initiative has really been focused on jump starting some new quantum research at the laboratory and helped prepare the ground for the Quantum Science Center, one of five new national quantum centers established though the National Quantum Initiative Act. The Quantum Science Center at ORNL focuses on challenges involving topological quantum information and the materials needed for it. Being able to measure what is going on is a big part of this and we are doing a lot of new work from the use of quantum sensors to measure what is happening in a material to the application of new measurement protocols inspired by quantum information science to probes like neutron to quantify quantum entanglement. This innovation is driven by the need to find new ways to expose the underlying states so we can harness and improve them in materials.

The Shull Wollan Center has a three-fold mission: science incubator, portal for industry, and training and education. Research groups explore biophysics of membranes, glasses and disorder, quantum magnets, theory and high-performance computing, as well as neutrino and neutron physics.

6) You are Director of the Shull Wollan Center, which is a purpose-built institute co-located with the Spallation Neutron Source, Center for Nanophase Materials Science on the ORNL campus supporting over 100 researchers at any given time. How important do you think global & interdisciplinary collaboration is for the future of quantum science?

Shull Wollan Center is an interdisciplinary research institute. It provides labs and interactive spaces for researchers studying a wide range of science problems. It hosts fundamental physics experiments looking at the origins of matter in the universe; biology experiments on proteins and membranes; complex behavior in liquids and glasses; experiments in extreme conditions, to name a few. Of course quantum science is an important part of what we do. It's definitely the case that global and interdisciplinary collaborations are important. Many of the challenges need a range of researchers with special expertise to address them. I like to think this is a reason the center exists. We need places now where researchers can get together and explore and solve important problems. By having the Shull Wollan Center sited near Department of Energy's two neutron sources researchers have a chance to come and do really unique work.

Above: Ariel view of the Spallation Neutron Source complex.

Neutron Scattering Science at Oak Ridge National Laboratory

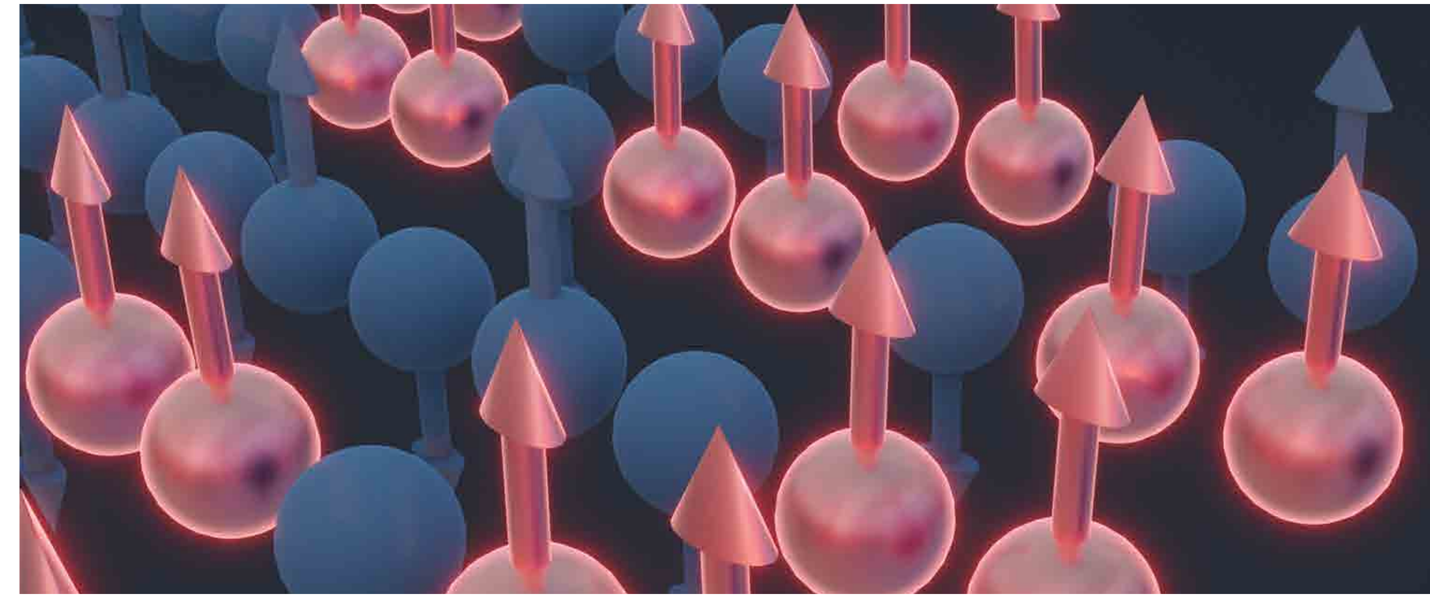
Neutrons are abundant in the universe making up more than half of the visible matter. Neutron scattering provides information about the positions, motions, and magnetic properties of materials. When a beam of neutrons is aimed at a sample, many neutrons will pass through the material. But some will interact directly with atomic nuclei and "bounce" away at an angle, like colliding balls in a game of pool. This behavior is called neutron scattering.

Neutrons are nondestructive and highly penetrating, which makes it possible to study things like polymers, proteins and other biological materials, and mechanical components in real time and in real-world environments without destroying them.

Using special detectors, scientists count scattered neutrons, measure their energies and the angles at which they scatter, and map their final position. This makes it possible for scientists to glean details about the nature of materials ranging from liquid crystals to superconducting ceramics, from proteins to plastics, and from metals to metallic glass magnets.

A partial list of materials and characteristics that neutrons can probe and measure includes: residual stress, weld quality, magnetic materials, biological processes/structures, drug-target interactions, quantum materials / phenomena, catalysis / chemical processes, internal deviations from design specs, extreme temperature / pressure performance, internal chemical / mechanical processes, microelectronics / data storage.

Neutrons provide the ability to look at quantum states of matter in unrivaled detail. Using quantum magnets in conjunction with magnetic fields exotic phases of matter can be generated that are highly quantum entangled. The wave functions in these states can be probed in space and time and in quantum critical states in particular elaborate symmetries and strange properties like fractional quantum numbers are revealed.



The team simulated a single spin chain's KPZ behavior, then observed the phenomenon experimentally in multiple spin chains. Credit: Michelle Lehman/ORNL, U.S. Dept. of Energy

Quantum Materials to Revolutionize Every Aspect of Society

Quantum materials have unusual magnetic and electrical properties that, if understood and controlled, could revolutionize virtually every aspect of society and enable highly energy-efficient electrical systems and faster, more accurate electronic devices.

Quantum materials include systems based on metals, oxides, and organics which have a range of potential applications including magnetic field sensors, low-power memory modules, high-density storage devices, and quantum computers. Quantum materials are also important components of the infrastructure for energy-related technologies.

Quantum materials research focuses on designing and synthesizing energy-efficient, revolutionary new forms of matter that have specific, tailored properties; understanding and controlling complex, atomic- and subatomic-level interactions of magnetic and electrical properties in materials and understanding how complex phenomena emerge from simple ingredients.

Engineering New Quantum Defects

The quantum materials research at ORNL includes an active effort on how to model quantum defects in solids to help guide the development of next-generation scalable quantum systems. Through ab initio calculations and new theoretical methods, they are working towards "artificial atoms" with desired quantum properties that advance artificial quantum coherent systems.

An enhanced understanding of the laws of quantum mechanics is enabling a quantum revolution that promises to transform a vast range of technologies. Oak Ridge National Laboratory is leading the way by hosting a multidisciplinary team of world-renowned researchers, including partners from major corporations, universities, and other national laboratories. Using diverse capabilities and a theory-driven understanding of the quantum world, ORNL scientists are conducting a wide variety of quantum research efforts, from developing and benchmarking scalable, fault-tolerant algorithms to designing quantum sensors. Other projects focus on synthesizing and characterizing superconducting and topological materials, as well as engineering the most promising candidates as quantum-classical systems for next-generation computing, sensing, and networking.

USING DIVERSE CAPABILITIES AND A THEORY-DRIVEN UNDERSTANDING OF THE QUANTUM WORLD, ORNL SCIENTISTS ARE CONDUCTING A WIDE VARIETY OF QUANTUM RESEARCH EFFORTS, FROM DEVELOPING AND BENCHMARKING SCALABLE, FAULT-TOLERANT ALGORITHMS TO DESIGNING QUANTUM SENSORS.

Breaking News: Quantum material's subtle spin behavior proves theoretical predictions

Using complementary computing calculations and neutron scattering techniques, researchers from the Department of Energy's Oak Ridge and Lawrence Berkeley national laboratories and the University of California, Berkeley, discovered the existence of an elusive type of spin dynamics in a quantum mechanical system.

The team successfully simulated and measured how magnetic particles called spins can exhibit a type of motion known as Kardar-Parisi-Zhang, or KPZ, in solid materials at various temperatures. Until now, scientists had not found evidence of this particular phenomenon outside of soft matter and other classical materials.

These findings, published in Nature Physics, show that the KPZ scenario accurately describes the changes in time of spin chains — linear channels of spins that interact with one another but largely ignore the surrounding environment — in certain quantum materials, confirming a previously unproven hypothesis.

"Seeing this kind of behavior was surprising, because this is one of the oldest problems in the quantum physics community, and spin chains are one of the key foundations of quantum mechanics," said Alan Tennant, who leads a project on quantum magnets at the Quantum Science Center, or QSC, headquartered at ORNL.

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APPLICATION NOTE

DEFECT RECOGNITION ON COATING LAYER USING PINPOINT NANOMECHANICAL MODE, ATOMIC FORCE MICROSCOPY

Moses Lee, Jake Kim and Cathy Lee
Park Systems Corporation, Suwon, Korea

Introduction

Surface treatment is a critical component in a variety of fields and industries such as automobile1, aerospace2, construction materials3, and mobile and precision4. Surface coating treatment techniques normally involve a coating process, which is widely used industrially to prevent surface abrasion and corrosion. More recently, the ability to convey special properties to coating materials such as anti-static5, antibacterial6 and electromagnetic wave shielding7 have been developed. The popularity of digital devices increased significantly during the 1990's; this popularity led to rapid developments in industrial coating technologies. These technologies advanced device protection in a number of ways, including scratch resistance, anti-fingerprint, chemical resistance and UV protection.8

Atomic Force Microscopy (AFM), largely used in the field of material surface research, is also utilized extensively on coated surfaces9. From analysis of AFM images, the thickness of the coating can be derived from the morphology of the sample surface while surface roughness yields information about the uniformity of a coating once applied. AFM images allow for a review and inspection of quality control for possible defects. AFM measures both surface morphology and mechanical properties. Using force-distance curves on the coated surface, mechanical properties such as stiffness, adhesion and modulus can be measured10.

This application note introduces the latest method developed by Park Systems called "PinPoint™ nanomechanical mode" that probes the mechanical properties of a surface. Furthermore, this note describes how the method can be used to analyze the stages at which defects are generated during the material surface processing, specifically during the coating process. In general, defects on the sample surface can be observed through AFM images. However, it is difficult to determine when the defect was generated (during production) solely from surface morphology observation. PinPoint nanomechanical mode resolves this issue: it gathers mechanical information about the coated surface and determines whether defects were created before or after the coating during production.

Materials and Methods

PinPoint Nanomechanical Mode

PinPoint nanomechanical mode collects high resolution topographical data while simultaneously obtaining force-distance data for each pixel of the scan area11. This allows measurement of the sample surface morphology while simultaneously obtaining quantitative nanomechanical properties including modulus, adhesion, deformation, stiffness and energy dissipation.

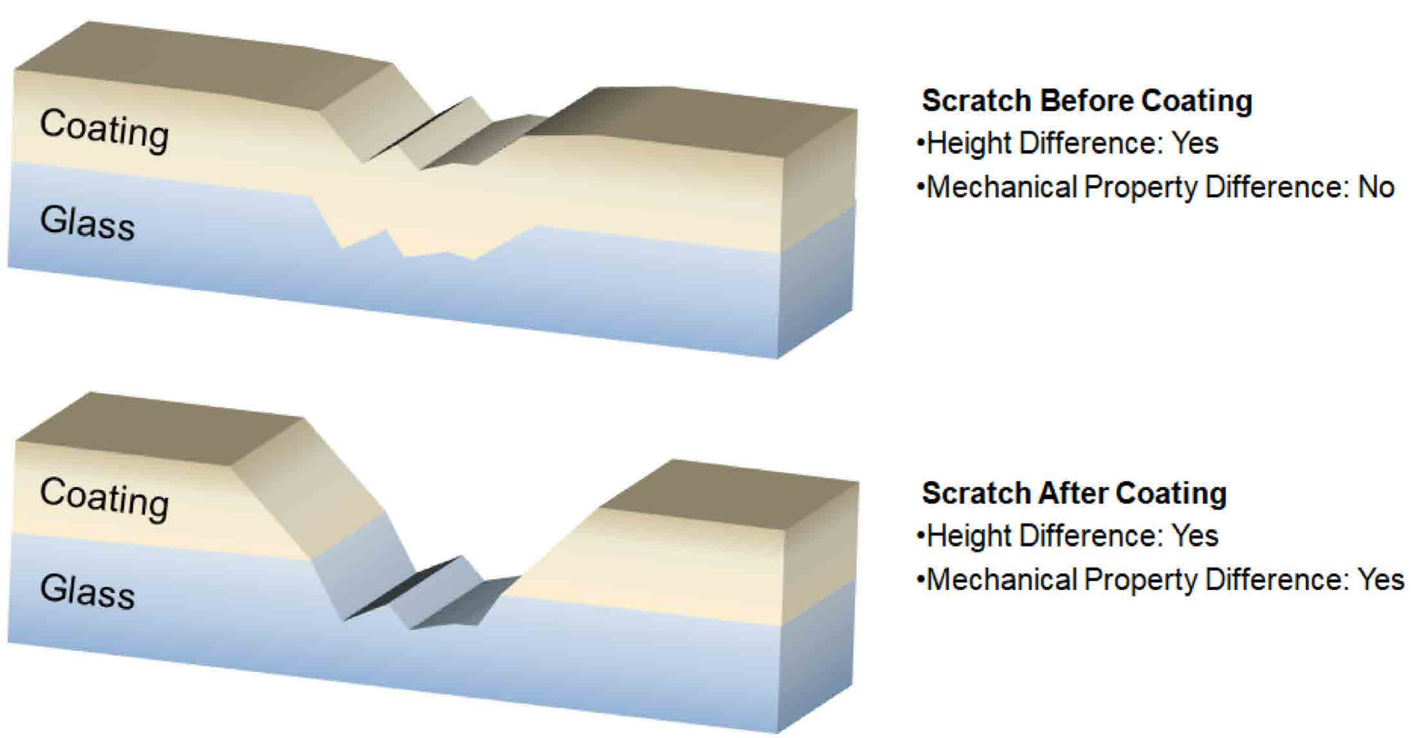

Figure 1. Illustration of a defect created before and after coating. The difference between the materials cannot be seen through the depth of the scratch alone but through the mechanical properties of the material.

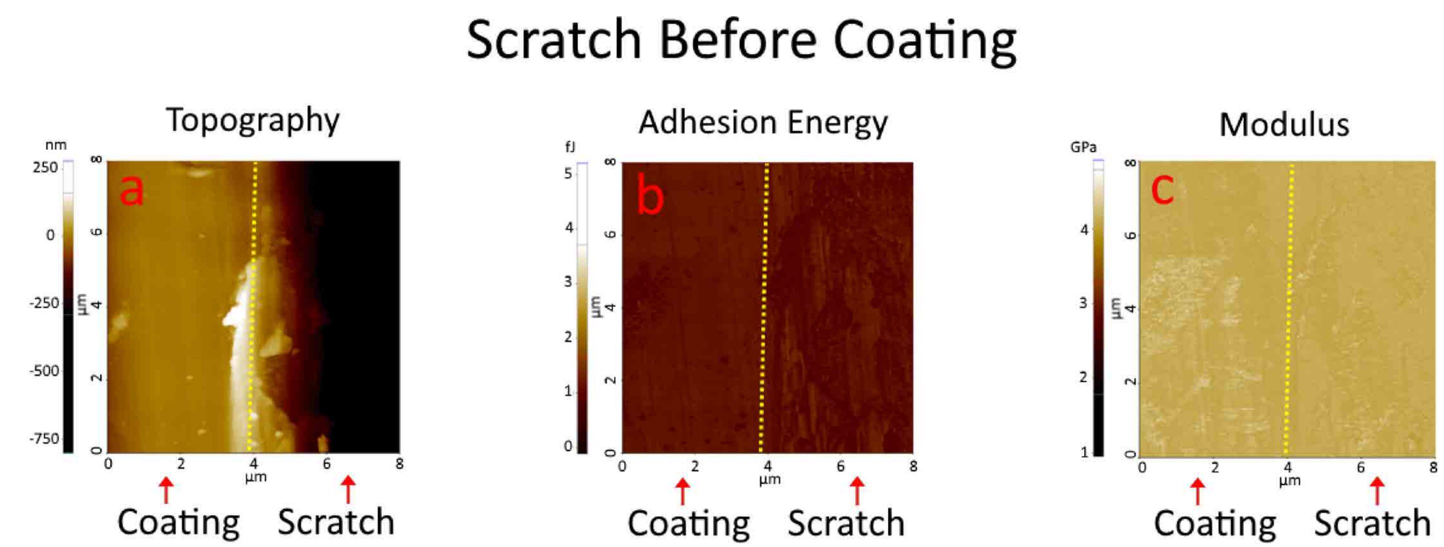

Figure 2. PinPoint nanomechanical mode images of a glass substrate when the scratch was created before coating was applied. No contrast was observed between the coated area and the scratched area, in both adhesion energy and modulus images.

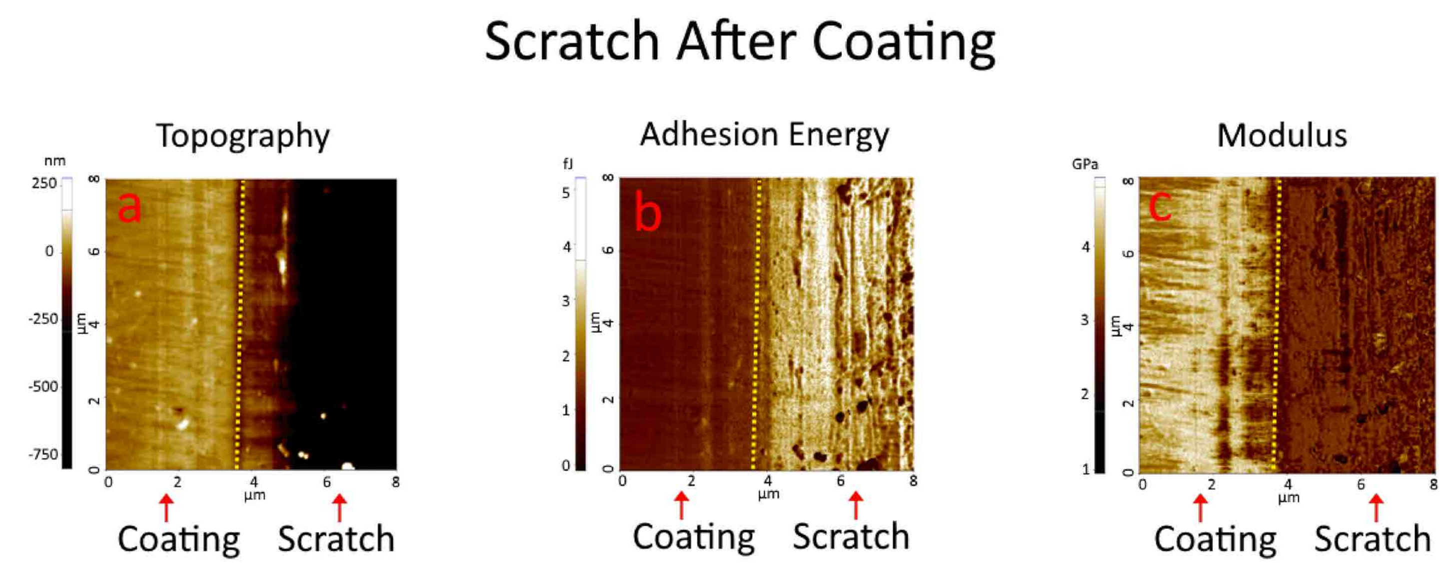

Figure 3. PinPoint nanomechanical mode images of a glass substrate when the scratch was created after a coating was applied. The contrast between the coating area and the scratched area is clearly visible in both adhesion energy and modulus images.

Experimental Setup

In order to measure mechanical properties of the sample, the PinPoint nanomechanical mode was employed on Park NX10 AFM from Park Systems coupled with an NSC36 cantilever, acquired from MikroMasch. The resonant frequency (f = 130 kHz) and spring constant (k = 2 N/m) of the cantilever allow adequate sample deformation while maintaining sufficient cantilever deflection. The results were analyzed using the Park XEI data processing software, which provides quantitative data from the images, comparisons of mechanical property values, and characterization of the surface material.

Testing Samples

Samples were prepared in two ways to test the ability of the PinPoint nanomechanical mode in distinguishing defects generated before and after the coating application. The first test involved a scratch produced over the surface of a coated glass substrate. The second test featured a scratched glass substrate whose surface was subsequently re-coated. The difference between the creation times of the defect can be determined from whether the glass material was exposed to the scratch site. If the scratch was created prior to coating, the glass will not be exposed, as the coating is applied over the scratch. If the scratched was created after coating, the coating will peel off and expose the glass material. By imaging the site using PinPoint nanomechanical mode, surface mechanical properties (such as adhesion and modulus) show a clear contrast when the AFM tip probes different materials (glass and coating). This information cannot be determined from the topography alone, and Figure 1 clearly shows this.

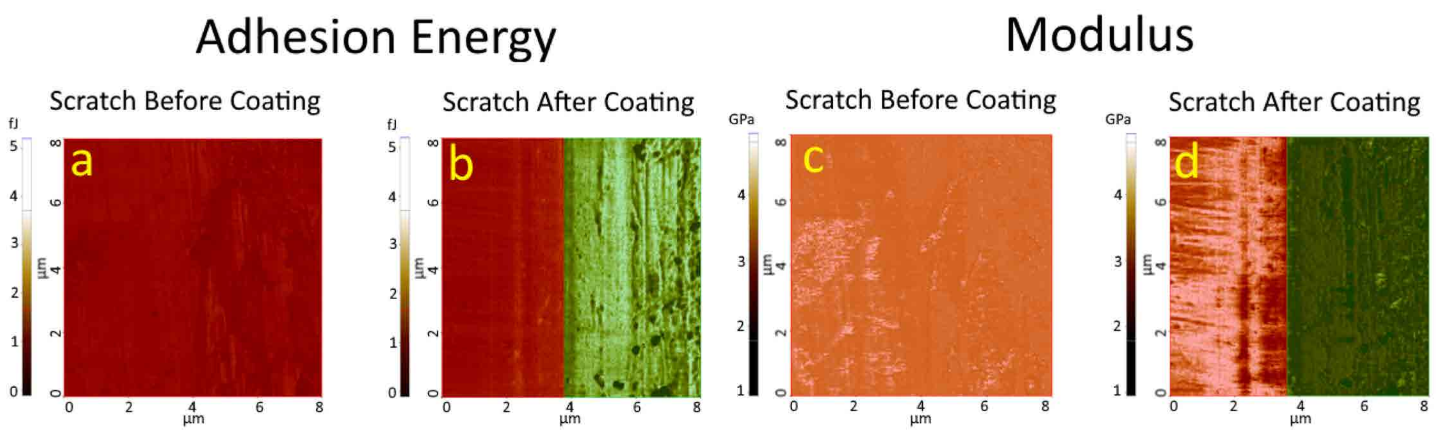

Figure 4. Region selection applied in Park XEI software, to calculate mean adhesion and modulus values of each distinct area.

	Adhesion Energy			Modulus		
Scratch	Before Coating	After Coating		Before Coating	After Coating	
Figure	4a (Full Area)	4b (Red)	4b (Green)	4c (Full Area)	4d (Red)	4d (Green)
Average	1.22 fJ	1.15 fJ	2.47 fJ	3.15 GPa	3.08 GPa	1.79 GPa

Table 1. Calculation of mean adhesion energy and modulus values based on the region selected from Figure 4.

Results

Topography, adhesion energy and modulus images from two samples with defects created before and after coating were obtained using PinPoint nanomechanical mode.

The topography images in both cases confirmed the scratch behind a trench (Figure 2a and 3a). Images from this site highlight the mechanical property differences between the scratch area and the unaffected area.

Examining the adhesion energy and modulus images of the scratch before coating (Figure 2b and 2c), they show no visible difference in the mechanical properties between the areas of the scratch and the coating. Figures 3b and c, where the glass substrate is scratched after the coating, show a very clear contrast between the scratch and the adjacent surface.

Comparing the mean adhesion energy and modulus values of the surfaces before and after scratching clearly differentiates the two different surfaces. Using Park XEI data processing software, different regions of the same image can be selected i.e. area of the scratch and area of the coating (Figure 4.). For each region, the mean value of each mechanical property was calculated; those values are listed in Table 1 for comparison.

Figure 4a shows the selected coating area which produced a calculated mean value of 1.22fJ. In figure 4b., the area of the coating and exposed material underneath was selected separately. The adhesion energy value of the coating (1.15 fJ) coincided with the previous value while the adhesion energy of underlying glass substrate exhibited a higher value (2.47 fJ).

Also, when comparing the modulus values, the coating from figure 4c gave a calculated value of 3.15 GPa, similar to the modulus value of the coating from figure 4d. (3.08 GPa). Conversely to the adhesion energy values, the modulus of the scratched glass substrate underneath showed a lower value of 1.79 GPa.

Conclusion

This application note highlights the utility of PinPoint nanomechanical mode from Park Systems to study the mechanical properties of defects to determine whether a surface defect was created before or after the coating process was applied. By measuring the adhesion energy and modulus differences between glass and coating materials, the initial time of the defect formation was successfully identified.

AFM can be used for diverse range of applications in the coating industry because of its ability to closely examine the surface properties of samples, properties otherwise not observable by studying morphology alone.

By using the PinPoint nanomechanical mode, one can investigate mechanical properties at nanoscale, and study the differences between different coating materials and coating methods. Such benefits will elevate the utility of AFM as a valuable instrument in the coating industry.

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ABSTRACT

SFE-WORKSHOP-2021
FREIBURG, D

Applying Sample Strain in-situ – A Multimodal Nanoscale Analysis including scanning probe microscopy

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Probing intriguing sample properties by applying external stimuli in-situ is of uttermost benefit to both fundamental research and applied sciences. Magnetic and electrical fields certainly count to the two most-spread vector fields that have been widely used into this, for probing material's phase transitions or hysteretic behavior. What is less know is the application of mechanical stress fields, i.e. in-situ straining the sample both tensile and compressively.

Here, we report on the combination of an uniaxial stress cell within the NX-10 scanning-force-microscope from ParkSystems, with the goal to inspect the nanoscale properties of 2-dimensional materials (2DMs) or ferroelectric domains and domain walls (DWs) under uniaxial mechanical stimulus. We will show how to integrate that system into a COVID-19-friendly, hence full remotely-controlled user platform. Moreover, examples of the strain impact on a variety of samples will be presented, such as DW conductivity in bulk $LiNbO_3$ as measured by cAFM, for $BiFeO_3$ ferroelectric thin-films investigated by PFM, and properties of MoS_2 as the prototype 2DM. All these experiments are backed up with complementary techniques such as µ-Raman spectroscopy or macroscopic transport measurements.

ABSTRACT

PROF. DR. GEORG PAPASTAVROU
CHAIR OF PHYSICAL CHEMISTRY II, UNIVERSITY OF BAYREUTH, GERMANY

New degrees of freedom in AFM: Combining AFM with Nanofluidics

Atomic force microscopy (AFM) has developed in the last decades to a 'classical' surface analytical technique. Based on the simple idea of 'scratching' with a sharp tip over a surface, AFM became the origin of a plethora of imaging modes and combinations with other techniques. These AFM-based techniques impressively demonstrate the potential of and the need for further analytical techniques with high lateral resolution.

Here, some applications of the combination of AFM with nanofluidic techniques, also known as Fluid Force Microscopy (FluidFM), is presented. The basic idea is to fabricate AFM-cantilevers with an internal channel and an aperture in the micro- to nanometer range at the end.[1] Originally this technique was intended to be used in the biomedical field, for example to manipulate single cells and bacteria. However, the possibility to eject and aspirate fluids, respectively, is much more universal and can be applied also in material or colloid science.

The colloidal probe technique, which is based on AFM, revolutionized direct force measurements. Unfortunately, for many applications, the surface chemistry and the minimum dimensions for the probe particles restricted the general use of this technique. The FluidFM-approach allowed for the first time to overcome these limitations.[2] We demonstrated the use of 300 nm sized carboxylate-modified latex particles as well as sub-micron core-shell particles with a soft exterior layer as probes. Moreover, by utilizing electrokinetic effects in the interior channel, it became possible to detect the aspiration of small colloidal particles to the cantilever's aperture in order to automatize the process.[3]

Furthermore, the FluidFM-technique allows for structing or deposition of materials on the micrometer-level. We demonstrate a proof-of-principle for the etching of patterns in very soft hydrogel films.[4] The resulting 'chemical writing' process has been studied in detail and the influence of various parameters, such as applied pressure and time, has been validated.

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ABSTRACT

THORSTEN HUGEL
INSTITUTE OF PHYSICAL CHEMISTRY AND CLUSTER OF EXCELLENCE LIVMATS

Comprehensive biomaterial characterization by AFM and fluorescence

The AFM is a versatile tool to investigate a large and still growing number of systems, in particular in combination with fluorescence microscopy.

First, we will present an investigation of human cartilage. In a combination of AFM and fluorescence microscopy we can show that local changes in the organization of fluorescent stained cells, a marker for early osteoarthritis, lead to a significant local reduction of the elastic modulus, local thinning of the collagen fibers, and a roughening of the articular surface [1]. This approach is currently extended towards locally measuring the frequency dependent storage and loss modulus by AFM indentation and its correlation to fluorescence images.

Second, we will present fundamental insights into the formation and breaking of multivalent bonds. Since the first mechanical characterization of the silicon-carbon bond by AFM in 1999 [2], many other physical and chemical bonds have been characterized, usually in well defined systems. Here, we disentangle physical and chemical bonds that form in mussel-inspired coatings. Both, the timescale of bond formation and their strength is determined. This helps to understand the interplay between adsorption (physisorption) and chemical reactions (chemisorption) in polymer coatings.

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APPLICATION NOTE

NANOSCALE ELECTROCHEMISTRY STUDY USING SECCM OPTION OF PARK SYSTEMS ENVIRONMENT

Park SYSTEMS

Jiali Zhang and Byong Kim
Research Technical Services, Park Systems, Inc., USA

Introduction

The Holy Grail in electrocatalysis and energy storage is to correlate electrochemical activity with nanostructured electrochemical interfaces (electrodes) [1]. However, it is challenging to quantify the heterogeneity of electrode structures or study the local structure-activity relationship for these interfaces using conventional macroscopic electrochemical techniques. This is because macroscopic electrochemical studies can only measure the total electron transfer on an entire sample. To solve this issue, a new strategy to characterize nanoscale electrochemical activity is needed.

Scanning electrochemical cell microscopy (SECCM) is a new pipette-based nanoelectrochemical scanning probe technique designed to investigate the local electrochemical properties of electrode surfaces [1-4]. A quasi-reference counter electrode (QRCE) is inserted into the nanopipette, which is filled with an electroactive species. Lowering the nanopipette using the AFM (atomic force microscope) Z scanner and creating a meniscus at the contact surface allows a tiny droplet, or nanoelectrochemical cell, to form. The electroactive species in the confined droplet undergo an electrochemical reaction when a bias is applied between the QRCE and the working electrode placed on the XY scanner. An electrochemical current mapping is extracted by collecting multiple cyclic voltammograms at various positions.

In SECCM, researchers can perform thousands of confined nanoelectrochemical measurements (droplet area ranges from nm2 to µm2) on a single surface [5]. High-throughput experimentation is achievable. Researchers can easily alter the chemical systems by merely swapping a new pipette with another electroactive species, and there is little need for special preparation of samples. Pipette preparation is straightforward and cost-effective. The data is easy to interpret; a higher current represents a higher rate or electrochemical reaction in the probed region. All of the above advantages make SECCM the suitable solution for electrochemical interrogation of individual platinum nanoparticles [3] or for correlation of local electrocatalytic activities with the local structures on polycrystalline electrode surfaces [5-6].

In this study, the electrochemically reversible [Ru(NH3)6]3+/2+ redox process at a highly-ordered pyrolytic graphite (HOPG) surface is recorded using Park NX12 AFM system. All Park NX systems can be the platform for SECCM. A glass nanopipette with a Ag/AgCl QRCE is utilized. Using previous successful experience in commercialized pipette-based electrochemical microscopy [7], Park Systems's hardware and software enable localized nanoscopic cyclic voltammetry measurements each time the meniscus contacts the surface. Thus, Park NX12 produces a spatially-resolved surface electroactivity mapping of HOPG with high-throughput at the micro- and nanoscale.

This work demonstrates the effectiveness of Park Systems's commercial SECCM option for quantitative electroanalysis at the nanoscale. This capability could also facilitate the rational design of functional electromaterials with potential applications in energy storage (battery) studies and corrosion research.

Experimental

Potassium chloride (KCl, Sigma-Aldrich) and hexaammineruthenium (III) chloride ([Ru(NH3)6]Cl3, Sigma-Aldrich) are used without modification. 0.0155 g [Ru(NH3)6]Cl3 and 0.037 g KCl are dissolved together in 10 mL deionized (DI) water to prepare the mixed electrolyte solution with a concentration of 5 mM [Ru(NH3)6]Cl3 and 50 mM KCl. The highly-ordered pyrolytic graphite (HOPG) sample is the working electrode that was cleaved using the "scotch tape method" before usage [8].

For all SECCM experiments in the Park NX12 system, decoupled XY and Z piezoelectric scanners control the pipette and sample movement. The SECCM experiments are conducted using Park Systems SmartScanTM software. Figure 1 depicts the schematic diagram of the SECCM. A glass nanopipette with a 100 nm-diameter tip opening, fabricated by pulling a borosilicate capillary, is first filled with an aqueous electrolyte solution (5 mM [Ru(NH3)6]Cl3 +50 mM KCl). Then an Ag/AgCl electrode is inserted in the pipette to serve as the QRCE. Next, the electrolyte-filled pipette is fixed on the Park SICM head and positioned above the HOPG electrode surface. The SICM head contains a current amplifier, which is assembled onto the Park NX12 system for current measurement.

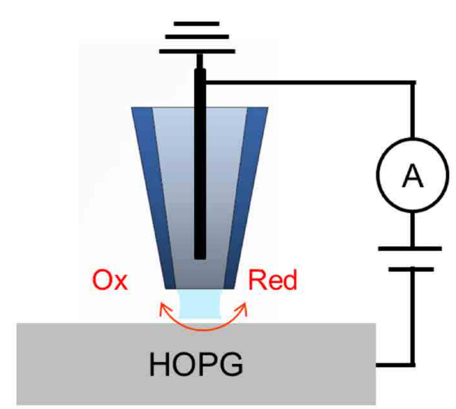

Figure 1. Schematic illustration of SECCM configuration with a single channel pipette.

The SECCM mode consists of five windows and panels that allow the operator to control the nanoelectrochemical process (Figure 2). In the first step, a liquid meniscus forms as the pipette approaches the sample, which behaves as a nanoscale electrochemical cell. Using the vision view, the operator can check the distance from the tip end to the sample surface (Figure 2A). During the approach, a potential bias of (-0.5V) is applied to the sample surface. The current log channel records the current across the meniscus (Figure 2B). Changes in this current serve as signals to control the Z scanner movement until a meniscus forms without contacting the substrate. When the probe meniscus contacts the surface, the Z scanner stops, and a reduction reaction happens within the confined droplet at the predesignated potential [9]. Thus, the current at pA range is detected by comparing it to the background fA current in the air. The current log channel in Figure 2B indicated that this sudden current change generated a current spike. This refers to the change in current versus time in the current log file when the meniscus forms and a reduction reaction happens.

After the pipette contacts the droplet, the operator can measure the electrochemical activity at the designated position using I/V spectroscopy mode to obtain a single linear, cyclic voltammogram. In the control panel (Figure 2C), the operator can input the desired experiment conditions, including sample bias voltage, sweep rate/speed, cycle repetitions, and output channels. The cyclic voltammograms (CVs) for the Ru (NH3)6]3+/2+ redox reaction are run on the HOPG surface at various scan rates by applying a sample bias voltage ranging from -0.5 V to 0 V. In the Position area (Figure 2D), the operator can use the "Point List" function to assign the location for the single CV curve to be obtained. The "Point Grid" function allows the operator to obtain the I/V spectroscopy repeatedly across a predetermined surface and create an image of the electrochemical activity. This function is referred to as the Approach-Retract-Scanning (ARS) mode [10]. As the pipette lands at various predefined grid positions using AFM, linear CVs are recorded upon each meniscus forming. Finally, the obtained CV will appear in the "Data View" panel (Figure 2E).

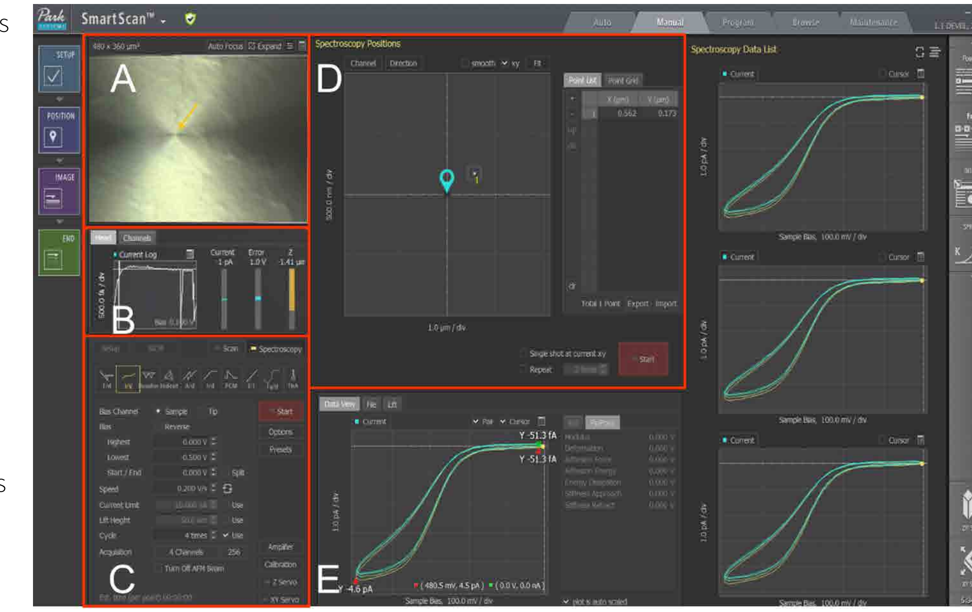

Figure 2. SECCM Mode in Park SmartScanTM software. (A) Vision & Monitoring view. (B) Current monitor panel. (C) I/V spectroscopy parameter control panel. (D) Spectroscopy positions control panel for point list or point grid function. (E) Data viewing panel.

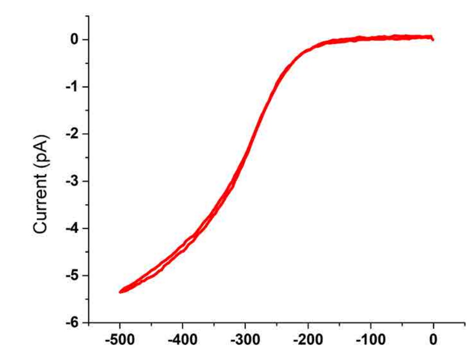

Figure 3. Single SECCM LSV acquired with a glass nanopipette filled with 5 mM [Ru(NH3)6]Cl3. The LSV is recorded at a sweep rate of 10 mV/s with an initial potential at 0 V.

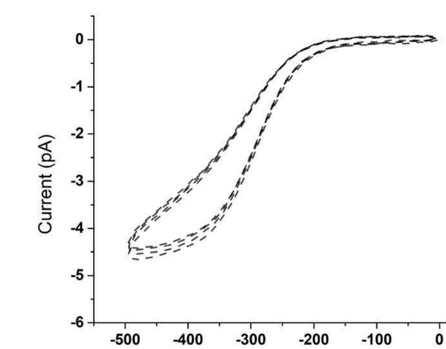

Figure 4. Four overlaid SECCM LSVs in 5mM [Ru(NH3)6]3+ and 50 mM KCl at a sweep rate of 200 mV/s

Results and Discussion

In our SECCM experiments, a glass nanopipette with a ~100 nm-diameter tip opening filled with 5 mM [Ru(NH3)6]Cl3 is mounted on the SICM head positioned above the HOPG electrode surface. Once the meniscus forms, a linear sweep voltammetry (LSV) is used to record the localized electrochemical activity across the HOPG surface. To acquire the microscopic understanding of the [Ru (NH3)6]3+/2+ electron transfer process on HOPG, an LSV is recorded in the range 0V → -0.5V → 0V. The bulk macroscopical Ru (NH3)6]3+/2+ redox reaction CV curve determined this bias range. Figure 3 shows a typical SECCM LSV curve for the reduction of (NH3)6]3+. The smooth sigmoidal wave shape observed is characteristic of the LSV acquired in SECCM format [11]. This sigmoidal plot corresponds to a quasi-steady-state voltammogram, and the steady-state limit current is about -5.3 pA with a sample voltage of -0.5 V. The small current magnitude detected demonstrates the power of Park Systems' low-noise current detector. The redox reaction is reversible. When the potential sweeps from 0V to – 0.5 V, the [Ru(NH3)6]3+ reduction occurs, and when the potential sweeps back to 0 V from -0.5 V, oxidation happens.

The SECCM LSV is highly reproducible and robust. Figure 4 shows a set of 4 typical LSV curves obtained on HOPG at an increased scan rate of 200 mV/s. There is little variation between the consecutive CVs.

Park Systems Announces Newest AFM Scholar Chao Wen

Ms. Chao Wen received her B.S. (2018) in Physics from the Wuhan University of Technology and her first M.S. in Nanoscience from the Rovira i Virgili University. She obtained the International Exchange and Overseas Training Scholarship from Soochow University during her stay in Spain to study the current generation in ZnO nanowire arrays using conductive atomic force microscope (CAFM). Ms. Chao Wen is now pursuing her second M.S. in Physics at Soochow University with an expected graduation date of June 2021. During her master in Soochow University, Ms. Chao Wen received several awards, including the Excellent Master Student Award, the Principle Scholarships, and the National Scholarship. Her research focuses on the characterization of nanoelectronic behaviors across dielectrics using CAFM and two-dimensional materials-based resistive switching devices. She has published 8 research articles in top journals (including Nature Electronics, Advanced Materials, Advanced Functional Materials, etc.) and 3 conference proceedings. Ms. Chao Wen also serves as a technical reviewer for Scientific Reports and Microelectronic Engineering

Interview with Chao Wen

Please summarize the research you do and explain why it is significant?

My current research focuses on the characterization of nanoelectronic behaviors across dielectrics which are compatible with two dimensional (2D) materials using conductive atomic force microscope (CAFM). In order to solve the problem of limited switching speed in silicon-based microelectronic devices, 2D materials, such as graphene and transition metal dichalcogenides (TMDs), have been introduced into microelectronic devices due to their high carrier mobility. However, the interface between these 2D materials and 3D traditional dielectrics (such as SiO_2 and transition metal oxides) is always problematic for the reason that there are plenty of dangling bonds on the surface of solid dielectrics. The problematic interface containing abundant defective bonds will impair the performance of microelectronic devices. Therefore, finding ultra-thin dielectric materials compatible with graphene and related materials is of utmost importance.

How might your research be used?

In my work, I aim to find ultra-thin dielectrics which are compatible with 2D materials. To realize this goal, I analyze the microstructure and nanoscale electrical properties (uniformity, point-to-point variability and dielectric strength) of these dielectrics. The nanoscale electrical and morphological analysis obtained from my research can not only help to reveal the reason for the electrical performance of microelectronic devices but also provide substantial information for other researchers to choose the proper dielectric for their devices. For example, my paper published in Advanced Materials proves that ultra-thin CaF_2 films grown by molecular beam epitaxy show ultra-low variability, high dielectric strength, and low leakage current. This means that the use of ultra-thin CaF_2 films may be one possible solution to the problematic interface between 2D materials and traditional solid dielectrics. This can further solve the challenging problem for the integration of 2D materials into Si based microelectronic devices. This is what I hope to bring to the electron devices society as well.

Why is the Park AFM important for your research?

My research focuses on the electrical characterization of dielectrics at nanoscale, while CAFM is one of the few tools to realize this goal. When we use CAFM to measure the sample in air, one of the main problems is that a water meniscus forms at the tip/sample junction owing to the ambient humidity. This water layer can increase the effective contact area and the oxidation speed of the sample. Therefore, it is very significant for us to measure the sample under vacuum in order to obtain the intrinsic topographic and electrical information of our sample. With Park Nx-HiVac AFM, we can measure our samples under vacuum condition, as low as to 10-6 torr, which is very important for my research.

What features of Park AFM are the most beneficial and why?

Nx-HiVac AFM from Park Systems has two main features which are very important for my experiments. The first feature is that the topography and current maps acquired by this AFM show very small drift even over 20 scans. This is very important because one of my experiments is to analyze the influence of sample bias on the area of the conductive spots in the current map. Only when the drift is very small from one map to another, can we compare the topography and current maps at a specific position. The second important feature is the logarithmic amplifier used in Nx-HiVac AFM. With a linear amplifier, the currents arrive at the saturation level around several nanoamperes. However, this cannot prove the existence of dielectric breakdown in the dielectric layer, which always happens at a current level of microamperes. With a logarithmic amplifier, we can measure the current from picoamperes to milliamperes.

IN THE NEWS

PARK SYSTEMS, WORLD LEADING ATOMIC FORCE MICROSCOPY MANUFACTURER ANNOUNCES 1 TRILLION KRW AT KOSDAQ OPENING

(April 15, 2021 Santa Clara, CA)

Park Systems, world leading manufacturer of Atomic Force Microscopes announced the company stock valuation exceeded 1 Trillion KRW (almost $1 Billion USD) during the KOSDAQ opening on April 5, 2021.

Park Systems issued 1 million shares for its initial public offering on December 17th, 2015 at KOSDAQ, which is a Korean version of NASDAQ. Since the IPO, the company has progressed as a global leader in Atomic Force Microscopy, with a commanding lead in semiconductor advanced automated AFM systems and bringing AFM technology into the mainstream as the premier tool for nanoscale metrology.

"PARK SYSTEMS HAS RECEIVED SUCCESSIVE PURCHASE ORDERS BY ALL THE WORLD'S TOP SEMICONDUCTOR AND DATA STORAGE MANUFACTURERS," STATES DR. SANG-IL PARK, CEO AND FOUNDER OF PARK SYSTEMS, WHO WORKED AS AN INTEGRAL PART OF THE GROUP AT STANFORD UNIVERSITY THAT FIRST DEVELOPED AFM TECHNOLOGY AND CREATED THE FIRST COMMERCIAL AFM IN 1988. "WE HAVE CONTINUED TO GROW AT AN ACCELERATED RATE OF OVER 20% GDP AND A STAFF OF OVER 300, EVEN DURING THE TURBULENT PANDEMIC YEAR."

The valuation at KOSDAQ, close to $1 Billion USD brought attention from foreign investors who have made active purchases, increasing the company's holding from 11%(Jan) to 18% (March). Recently Park was recognized by Forbes Asia Best Under a Billion list for 2020, received the KOSDAQ Grand Prize, and listed on the FTSE small-cap index. In 2020, Park Systems signed a JDP with IMEC JDP to address the current metrological challenges of continuously downscaling the geometrical dimensions of devices and 3D stacking assembly and earlier this year, made an equity investment in Molecular Vista, that produces AFM tools to probe and understand matter at the molecular level through quantitative visualization using InfraRed Photo-induced Force Microscopy.

"Park Systems is a stable technology driven company that plans to play a dominant role in the future of nanoscale engineering and manufacturing," states Keibock Lee, Park Systems President. "Our forward-thinking methodology relies on market intelligence to create nanoscale tools that will perform in the increasingly dominant nanoscale environment for scientific research and applications."

Park Systems is headquartered in Seoul, South Korea and with rapid global expansion has become the premier supplier of Atomic Force Microscopy tool for industrial, research and academic nanoscale research, where AFM with the Park Systems patented true non contact mode is chosen to preserve sample integrity. Research efforts at the extensive Park Applications Technology locations worldwide have led to the development of many leading AFM technologies including SmartScan operating software, PinPoint mode which can be applied for nano-mechanical analysis and electrical modes; and most recently, the Smart Litho interface.

Dr. Sang-il Park, Founder & CEO Park Systems

Park Systems was the first company to revolutionize AFM technology with its flexure-based scanner system that brought new levels of accuracy, resolution, and sample handling to the technology. In 2024, Park Systems will move into a new expanded headquarters and will introduce a new fully automated AFM with AI and robotic intelligence.

About Park Systems

Park Systems is the fastest growing and world-leading manufacturer of atomic force microscopy (AFM) systems, with a complete range of products for researchers and engineers in the chemistry, materials, physics, life sciences, semiconductor and data storage industries. Our mission is to enable nanoscale advances for scientists and engineers solving the world's most pressing problems and pushing the boundaries of scientific discoveries and engineering innovations. Customers of Park Systems include most of the world's top 20 largest semiconductor companies and national research universities in Asia, Europe and the Americas. Park Systems is a publicly traded corporation on the Korea Stock Exchange (KOSDAQ) with corporate headquarters in Suwon, Korea, and regional headquarters in Santa Clara, California, USA, Mannheim, Germany, Beijing, China, Tokyo, Japan, Singapore, and Mexico City, Mexico. To learn more about Park Systems, please visit www.parksystems.com.


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