NANOscientific

FALL 2015

The Magazine for Nanotechnology

PRESIDENT'S 2016 BUDGET PROVIDES $146 BILLION FOR R&D, INNOVATION AND STEM EDUCATION

AN INTERVIEW WITH LLOYD WHITMAN, ASSISTANT DIRECTOR FOR NANOTECHNOLOGY AT THE WHITE HOUSE

p. 18

AUTOMATED NON-DESTRUCTIVE IMAGING

AND CHARACTERIZATION OF GRAPHENE/HBN MOIRÉ PATTERN WITH NON-CONTACT MODE AFM

p. 14

MICRO GRAVITY

THE FUTURE OF INNOVATION

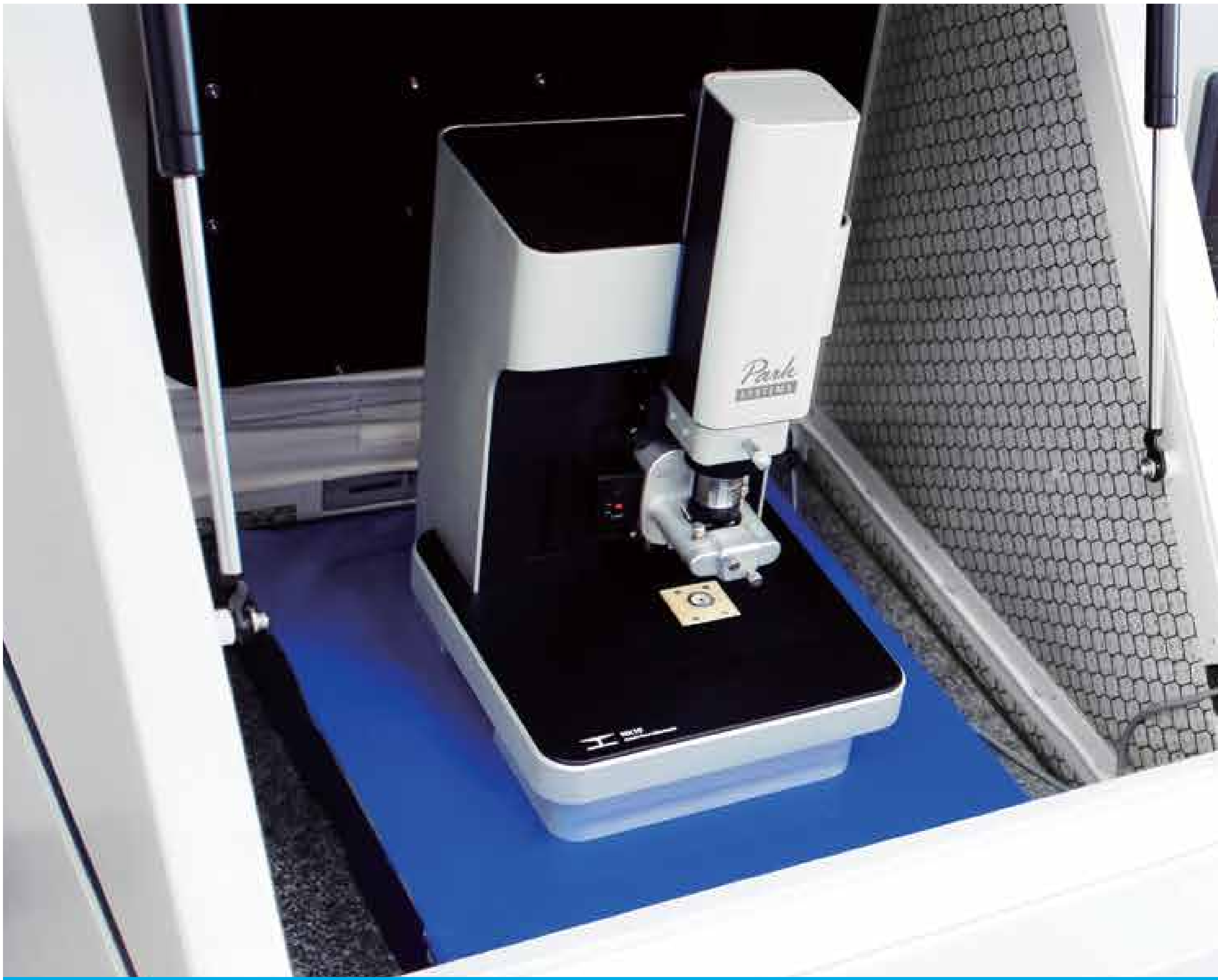
p. 6

ATOMIC FORCE MICROSCOPY (AFM)

FOR OPTIMIZATION OF SILICA CHEMICAL INHIBITION IN GEOTHERMAL BRINES

p. 12

Cover image Moire pattern for graphene on hexagonal boron nitride, courtesy University of Manchester



Park NX10 the quickest path to innovative research

Better accuracy means better data

Park NX10 produces data you can trust, replicate, and publish at the highest nano resolution. It features the world's only true non-contact AFM that prolongs tip life while preserving your sample, and flexure based independent XY and Z scanner for unparalleled accuracy and resolution.

Better accuracy means better productivity

From sample setting to full scan imaging, measurement, and analysis, Park NX10 saves you time every step of the way. The user friendly interface, easy laser alignment, automatic tip approach, and analysis software allow you to get publishable results faster.

Better accuracy means better research

With more time and better data, you can focus on doing more innovative research. And the Park NX10's wide range of measurement modes and customizable design means it can be easily tailored to the most unique projects.

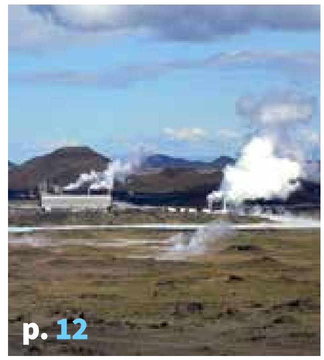
To learn more about Park NX10 or to schedule a demo, please call: +1-408-986-1110 or email inquiry@parkafm.com

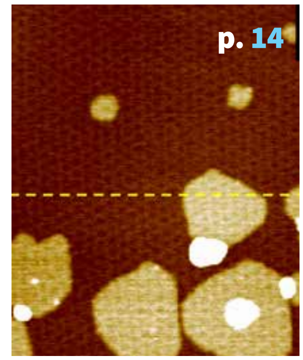
www.parkAFM.com

The Most Accurate Atomic Force Microscope

Park SYSTEMS

TABLE OF CONTENTS





NANOscientific
The Magazine for Nanotechnology

www.nano-scientific.org

Keibock Lee, Editor-in-Chief
kei@nano-scientific.org

Deborah West, Content Editor
debbie@nano-scientific.org

Art Director, Ryan Mackenzie

Gerald Pascal, Digital Media & Advertising Manager
gerald@nano-scientific.org

Published by Park Systems, Inc.
3040 Olcott St. Santa, Clara CA 95054
inquiry@parkafm.com, 408-986-1110
www.parkAFM.com

NANOscientific is published quarterly to showcase advancements in the field of Nanoscience and technology across a wide range of multidisciplinary areas of research.

The publication is offered free to anyone who works in the field of Nanotechnology, Nanoscience, Microscopy and other related fields of study and manufacturing.

For inquiries about submitting story ideas, please contact Deborah West, Content Editor at debbie@nano-scientific.org for inquiries about Advertising in NANOscientific, please contact Gerald Pascal at gerald@nano-scientific.org

Park SYSTEMS

Keibock Lee, Editor-in-Chief

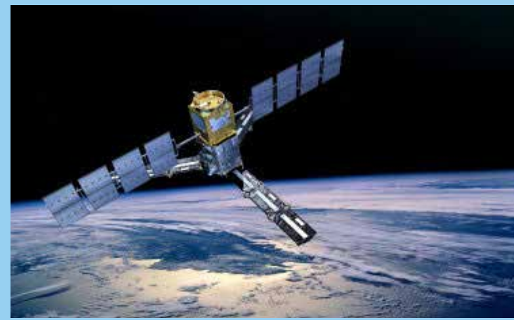
MESSAGE FROM EDITOR

Nanotechnologies have demonstrated the potential to alter the modern world significantly and live up to the National Science Foundation prediction that nanotechnologies would become a trillion dollar industry. The Nano-Revolution is global and countries world-wide are gearing up with enormous Nanotechnology budgets. Between 2001 and 2014, over sixty countries followed the United States and established nanotechnology initiatives. These countries range from advanced industrial countries in Europe to Japan to the emerging markets of Russia, China, Brazil, and India to developing countries such as Nepal and Pakistan. China has designated nanotech R&D as one of twelve "mega-projects" under its Medium and Long Term Development Plan 2006-2020. In 2007, India launched a new Mission on Nano Science and Technology under the Department for Science and Technology, with a budget of approximately $145 million over five years. Russia has also established a government-controlled nanotechnology venture capital firm, RUSNANO, to invest in and acquire nanotechnology start-ups around the world.

In this issue, we have an exciting interview with Lloyd Whitman from the White House Office of Science and Technology about the expanding U.S. budget for Nanotechnology that will launch many research projects into commercial applications. According to the Presidents Report on NMI, this next technological generation will see the evolution from nanoscale components to interdisciplinary nano-systems and the movement from a foundational research-based initiative to one that also provides the necessary focus to ensure rapid commercialization of nanotechnology. In this issue, we also discuss the expanding space exploration program where Nanotechnology is poised to be a key player. Our story focuses on research into micro gravity where as we go further out into space, our next frontier, many exciting programs are underway. Space innovations are vast and unprecedented. In July, the US Patent and Trademark Office granted a patent to a Canadian company for its invention of an inflatable space elevator tower. It is composed of a 96,000-km carbon nanotube cable, a 400-m diameter floating Earth Port and a 12,500-ton counter-weight. Other facilities include Martian/Lunar Gravity Centers, a Low Earth Orbit Gate, a Geostationary Earth Orbit Station, a Mars Gate and a Solar System Exploration Gate. Microscopes are already sending us images from Mars and could soon be on orbital platforms and the International Space Station. Scientists are already taking nanoscale images of individual dust particles on the surface of Mars and relaying these pictures back to Earth.

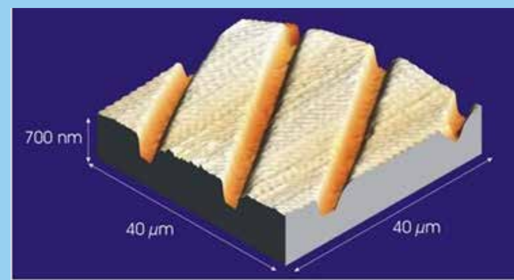
Nanotechnolgy and AFM are a great combination because real-time imaging is crucial to the advancement of new science. In this issue, we have two fabulous articles about specific AFM applications. One story is about how AFM is used for optimization of slilica chemical inhibition in geothermal brines. The other article discusses in detail the automated non-destructive imaging and characterization of graphene/HBN Moire pattern with non contact –mode AFM. Both of these application articles explain new innovative concepts relevant to Nano Science.
In each issue of Nano-Scientific, we try to provide informative articles about Nanotechnology trends balanced with leading edge scientific research applications and concepts. As always, I encourage readers to submit your story ideas and user experiences. For our next issue, we are looking for stories from all over the globe, so please submit someone who you feel we should profile, someone whose work you admire from any location in the world, as we share NanoTechnology global news.

It is exciting time to be a part of the explosion of Nanotechnology and I sincerely hope you enjoy this issue.

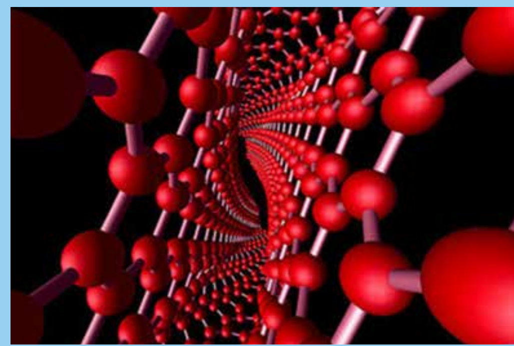


Materials scientists of the Helmholtz-Zentrum Geesthacht develop new magnesium materials for ground bound vehicles, airplanes and satellites in the EU-project EXOMET, which is coordinated by the European Space Agency (ESA).

Life on Mars? That's the plan for Mars One, which plans to take its first crews to Mars in 2024. This is an artist's rendition of a Mars One colony. (Source: Bryan Versteeg for Mars One)



First atomic force microscope image on Mars. This calibration image presents three-dimensional data from the atomic force microscope on NASA's Phoenix Mars Lander, showing surface details of a substrate on the microscope station's sample wheel. It will be used as an aid for interpreting later images that will show shapes of minuscule Martian soil particles. Image NASA/JPL-Caltech/University of Arizona/University of Neuchatel



Nanotechnology, which alters the fundamentals of nature by manipulating matter on an atomic or molecular scale, is becoming a larger part of everyday life through its use in more than a thousand products ranging from solar panels and scratch-resistant automobile paint to enhanced golf clubs. This image shows a view from within a flattened, twisted carbon nanotube. Nanotubes are tiny tube-like structures that have unique electronic, thermal, and structural properties that make them potentially useful for nanotechnology, electronics, optics and other fields of materials science.

FEATURE INTERVIEW

MICRO GRAVITY: THE FUTURE OF INNOVATION

"LOOK BEYOND OUR WORLD OF ORIGIN TO UNDERSTAND OUR FUTURE"

AN INTERVIEW WITH IOANA COZMUTA, PHD, INDUSTRY INNOVATION LEAD, SPACE PORTAL SCIENCE AND TECHNOLOGY CORPORATION

Why do you feel that Micro-Gravity and Space Resourcesare a leading factor in our future innovation?

There are three major reasons:
1. There is a shortage of resources on Earth
2. Current manufacturing processes are unsustainable, highly polluting and mostlyinefficient. When building a business the focus is on making things work and not necessarily on howto optimize them based on foreseeable long term consequences.
3. Key applications such as computers, telecommunications, energy devices, and automotive are nearing or have reached the performance limits of the underlying materials -metals, semiconductors, granular materials, biomaterials, glasses and ceramics, polymers and organics. Currently there is a struggle to create resource intensive operational parameters and conditions on Earth that are mostly consequences of physical phenomena masked by gravity.

Moving key manufacturing processes to space carries potentially huge benefits. In addition to long duration exposure to reduced (micro) gravity, the space environment inherently provides nearly infinite cold and limitless access to solar power.

What is the potential for Micro Gravity for understanding material and life science that can change our lives?

Research in the microgravity environment of space has already furthered our understanding of fundamental physical, chemical and biological processes and generated a wealth of results across multiple disciplines. The microgravity environment of space provides a unique opportunity to study materials phenomena involving the molten, fluidic and gaseous statesby reducing or eliminating buoyancy driven convection (purely diffusive driven transport) and sedimentation effects. Many materials in space can stably exist as a *free suspension, in a perfect spherical shape.* Four general categories of material science microgravity experiments arebeing explored:

1. Melt growth (i.e. processing multicomponent alloys from the liquid). These experiments frequently require high temperatures and closed containers to prevent elemental losses.
2. Aqueous or solution growth experiments (i.e. zeolites, triglycene sulfate; hydrothermal processing of inorganic compounds; sol-gel processing). These experiments require moderate to low temperatures.
3. Vapor or gaseous environments (i.e. growing mercury iodide or plasma processing; flame dynamics).
4. Containerless processing environments (i.e. formation of metallic and nonmetallic glasses during levitation melting and solidification; the float-zone growth of crystals measurement of thermophysical properties like diffusion coefficients and surface tension, etc) leading to the elimination of impurities and stresses introduced by contact with the container wall which, in turn, avoids nucleation.

As pointed out earlier, gravity is an important, yet often overlooked, variable of phase diagrams. Whether applied to crystallization or colloidal mixtures, in microgravity, the initial component distribution within the system is uniform and the progress through the phase diagrams usually occurs slower (diffusion driven). It is clear that lack of gravity impactsthe modality and length scale over which the physical and chemical interactions occur at atomic level leading, at macroscopic level, to a repositioning of the solubility and saturation curves and a resizing of the nucleation and precipitation zones. This usually leads to a more controlled nucleation process and either longer-range order (colloids) or higher resolution, larger crystals. In a gravitational field, a binary mixture prepared with a composition between the binodal and the spinodal curvesspontaneously decomposes, quickly driving the composition to thecoexistence curve. Microgravity can 'fixate' unstable regions in the phase diagram and it is in this region where microgravity experiments can unravel and create new materials with exciting new properties.

Several hypothesesin multiple areas in fundamental physics are investigated in combined low-gravity ultra-cold temperature

environment with the potential of unraveling gravitational-quantum effects. This could potentially solve existing limitations and challenges in the physics world of today and unravel new insights into understanding the Universe.

In terms of life science applications, contrary to earlier beliefs, microgravity induces changes in single cells or simple organisms as well as in large, complex organisms. The overall response to gravity (or lack thereof) is complex and can be captured in two categories:

Cells affected by gravity: The molecular mechanisms by which gravity affects biological systems are still largely unknown. A "gravity sensor" has not yet been identified.
Cells respond to gravity: Adaptation to force of Earth's gravity (up-down asymmetry, structural strength, sensory systems) is encoded in genes. An organism expects to experience the physical effects of unit gravity: sedimentation, convection, transport processes, hydrostatic pressure, boundary conditions, and friction.

Atmospheric pressure directly influences cell structure, adhesion and signaling; stirring/thermal convection are responsible for slower heat and nutrient exchange important in tissue cultures; sedimentation and buoyancy are related to root growth and cell culture strategies; surface forces are important for the "chemical communication" aspects of a cell (i.e. development, disease, function). Similarly to the case of material science, exploration of crystallization phase diagrams for soft matter (proteins, polymers of biomolecules, etc) systems is of direct value to drug design efforts on ground.

What types of new materials are currently being developed in low orbit Micro Gravity that cannot be made here on Earth?

There are many, but I can quickly highlight two examples: Exotic Optical Fibers and Compound Semiconductor Wafers.
Currently, a vast spectrum of applicationsrelies on Silica and its properties. This is because silica fibers are much less expensive to produce than exotic fibers and therefore sell for as low as $20/meter. In comparison, ZBLAN commercial prices are $150/meter to $300/meter, depending on quality and composition. Customization such as multimodal transmission or doping increases the prices even more, up to $3000/meter. Silica fibers are also stronger and more flexible than exotic ZBLAN, which is the most stable of the exotic fibers and an excellent host for doping. Multiple kilometer lengths of silica fiber can be manufactured in a single run while for ZBLAN the production is limited to 700-meter long fibers. There are however significant limitations to silica –transmission losses are very high and the operational bandwidth is very narrow, cutting off before right at the transition to the mid-IR region. The mid-IR region (where most molecular spectra lie) however is essential for applications relevant to laser oil drilling, medical, computers, telecommunications, high frequency market transactions, defense, sensors, etc. With the recent growth of the field of photonics, the demand and utilization of exotic fibers such as ZBLAN has increased exponentially. ZBLAN fibers have large reflectivity important in short distance transmission and broad optical transmission window extending into the IR with reduced loss. Making exotic fibers requires melting the various component elements together to create a preform glass Fibers are then produced by melting the preform and drawing the fibers on a take-up spool. The heavy elements entering the composition of ZBLAN have different densities and lead to different crystallization temperatures. In a gravitational field this leads to unwanted crystallization. It is further believed that gravity-induced sedimentation causes the separation of ZBLAN's constituents by density a cause for internal inhomogeneity. Manufacturing exotic fibers in microgravity

Dr. Ioana Cozmuta is the Microgravity Lead at the Space Portal, in Silicon Valley providing fair broker technical, economic, market and business intelligence. She developed the innovative concept of "Verticals of Microgravity" to translate and infuse microgravity driven discoveries in various verticals of the private sector and introduced the measure of "Economic Readiness Level" as a selection criteria for maturing technologies based on their understanding of their economic potential.

Ioana is a featured TedEx "Future Spoiler" speaker and has given numerous (invited) talks in the US and abroad. She holds a PhD in Physics from University of Groningen, The Netherlands, a Computational Chemistry Research Associate degree from Caltech and a Biochemistry Research Associate degree from Stanford. Ioana joined the NASA Ames Research Center for Nanotechnology in 2003 to design a nano pore sensor for DNA sequencing. Thereafter shepioneered the use of molecular dynamics methods in the field of EDL engineering for the development of fundamental models for surface catalysis and gas-surface interactions. Through her expertise in reentry systems, Ioana provided support to the Stardust post-flight analysis team and acted in leadership roles for the Orion CEV Margins Management Team, and Material Response team for MSL/MEDLI.
She initiated and chaired the first Gordon Research Conference on Atmospheric Reentry Physics, Fundamentals of Environment-Materials Interactions, Models and Design Approaches to Meet Emerging Space Needs.
She will be a speaker at the International Symposium for Personal and Commercial Spaceflight (ISPCS) in Oct, at the Space 2.0 and Space Technology and Investment Forum in the fall.

At the Space Technology and Investment Forum in San Francisco, successful space industry CEOs and founders of new space startups will share their experiences about how to secure funding, and identify creative financing solutions to launch new products and services. Select startups will also be asked to make presentations on how to facilitate new business ventures in space technology and bring big ideas to fruition.

“THERE ARE MANY BENEFITS OF CREATING A SYNERGY BETWEEN NANOTECHNOLOGY AND MICROGRAVITY: LACK OF GRAVITY IS EXPECTED TO IMPROVE ACCURACY OF CONTROLLED ATOM ARRANGEMENT AND MANIPULATION AT NANOSCALE. BY PERFORMING THE SAME EXPERIMENTS ON GROUND AND IN SPACE NANOTECHNOLOGISTS COULD UNRAVEL AND EXPLAIN GRAVITY-RELATED IMPEDIMENTS AND ADDRESS EXISTING LIMITATIONS; OPERATING IN MICROGRAVITY WILL CREATE A WIDE SPECTRUM FOR NANOTECHNOLOGY APPLICATIONS.”

“AS A SPECIES, WE ARE IN THE MIDST OF EMERGING OUT OF A FEAR-BASED CONSCIOUSNESS INTO AN ERA OF EMPOWERMENT THAT TREATS ALL SENTIENT LIFE WITH KINDNESS AND RESPECT. I PERSONALLY DO NOT THINK THAT CREATING AND MAINTAINING SENSELESS WARS HELPS HUMANITY TO THRIVE. OUR MOST IMPORTANT ISSUE IS NOW BEFORE US- WE MUST CHOOSE HOW WE WILL LIVE BEYOND OUR PLANET OF ORIGIN AS WE EMERGE INTO A SPACE FARING RACE! SENDING INTO SPACE OUR MOST OPEN-MINDED, PEACEFUL EXPLORERS TO UNCOVER THE UNLIMITED POTENTIAL TO IMPROVE OUR LIVES IS MY PERSONAL WISH - NOT ONLY FOR OUR GENERATION BUT FOR ALL THOSE TO COME.”

it is believed to be the only way that one could push the performance of these fibers close to the theoretical absolute predictions –100-1000 times better than current Si fibers over wavelengths ranging from 1-4.5 microns. Significant improvement is observed already by only reprocessing the preform in microgravity. Microgravity suppresses both nucleation and crystallization effects–directly underlying attenuation-broadband properties. There is theoretically no limit to the length of the fibers that can be produced in space using a relatively small-sized payload, another important manufacturing limitation on Earth. A rough estimate shows that 1lb of preform would produce 8 km of ZBLAN fiber with an approximate ROI of 90-300x.

The second example has to do with using microgravity as a means of “healing” low quality wafers manufactured by the semiconductor industry. For example, defects in Silicon Carbide wafers impact reliability of operation, limit high power performance and prevent the fabrication of large-scale devices. A2M, a company in Albuquerque, uses short term exposure to microgravity to correct electrically significant defects in existing SiC wafers, as measured by their electrical performance. Producers/wafer growers start with lower cost developmental wafers and let A2M turn them into “S-grade” for a flat fee per wafer.The exact mechanism of in-depth defect healing is currently being investigated by prof. Debbie Senesky and her group at the XtremeLab at Stanford University. Further improvement can be achieved fromreprocessing the wafers to their full manufacturing in long-term exposure to a microgravity environment.

Currently $1.5 billion is being invested into Nanotechnology research and investment in microgravity is minimal in comparison. How can joint research in Nanotechnology and micro gravity support rapid scientific advancement?

Indeed, nanotechnology and microgravity are synergistic in many aspects. Both are important to a wide variety of applications, not just a narrow segment, and have an in-depth transformative potential.

Gravity leads to alterations of the “perfect” order at nanoscale. Lack of gravity is expected to be able to reverse this effect and improve accuracy of controlled atom arrangement and manipulation at nanoscale. The approximate annual investment in Microgravity R&D in the US is about $250M/year –significantly smaller than the national Nanotechnology budget. By making Microgravity an available research tool for nanotechnologists and encouraging cross pollination between the fields, the benefits could be multiple: by performing the same experiments on ground and in space nanotechnologistscould unravel and explain gravity-related impediments and address existing limitations with which they currently struggle; generation of new ideas and technologies on both sides; operating in space requires miniaturization, which leads to serendipitous applications on Earth and thus create an even wider spectrum of applications. In this context, Microgravity research can be thought of as enabling entire branches of Nanotechnology that are simply not possible on the ground. Who knows what amazing advances may arise?

How could an Atomic Force Microscope help with the research done on Micro Gravity?

AFM is a technology that any respectable laboratory should have, yet I am unaware of the existence of an AFM on the ISS. For a spectrum of microgravity experiments, having “on-site” accurate atomic scale characterization technologies would align the capabilities on ISS with those of laboratories on the ground. Moreover by comparing AFM analysis of samples on ground vs AFM analysis of counterparts in space this is important in terms of establishing direct evidence comparative evidence of the consequences of reduced gravity and increase credibility.

Due to the large costs associated with reaching Low Earth Orbit , most technologies used in space need to be miniaturized, something that may not have happened otherwise on Earth. This is beneficial on both ends.

Can you explain orbital gravity, gravitational waves and ranges of g's as it is currently understood and how this helps us define our place in the universe ?

Putting my physicist hat on, I would look at gravity as another physical parameter that, together with pressure and temperature, defines the phase diagram and states of a given system. Humanity has acquired an impressive collection of information so far in terms of existence, stability and behavior of inert and living systems. However this database corresponds almost entirely to one single value on the gravity axis, that of 1g. We have barely scratched the surface in terms of creating a similar database in Low Earth Orbit. But there are so many more values to explore- the surface of every planet is in fact an open laboratory corresponding to that gravity value. The truly valuable information is carried in the long-term exposure to that environment and has to be studied in-situ, not through simulated gravity experiments on Earth. (That does not mean that experiments in simulated gravity don't have their place and value).
The moment one startswondering about gravity, the awareness on how much our thinking and intuition is calibrated and attuned to the 1g field in which we live is also highlighted. There are questions I carry with me throughout the day and ponder upon– how would we, products of the 1g-Earth environment, act or think if living and working in a stable habitat on Mars or the Moon or another remote planet at the other end of the Universe? Or have that experience and then come back and live back here? I believe that would be a humbling experience. I would hope that we would be more grateful for the amazingly hospitable conditions we have on Earth. We would hopefully be more respectful to this planet. More considerate of resources, more moderate and sustainable in terms of how we live. Society structures would be different too. This Earth-centric, ego-centric view would definitely be broken. Each one of us is an infinitesimal fraction of a pixel on the canvas of the Universe. Or to make a "nanotechnology" comparison – and use the standard model in physics- a vibration of a string, possibly creating a particle, somewhere in the depths of a material.

Harvesting fundamentally new information, such as the study of a system in a changed gravitational environment, is a powerful source for creativity. Historically major breakthroughs and innovations were achieved by studying systems under extreme conditions, i.e. at low temperatures or high energies. To unravel a new system variable, its precise way of modifying the phase diagram of inert and live systems, to translate that information to applied value and infuse it into what should matter to us as a species (sustainable living, public benefit, economic growth etc) requires a thorough, well validated, solid, stable, long-term plan to setup this huge machinery. Will humanity be able to align interests and work in harmony and agreement towards its own benefit and survival?

Why is it important to our future as a species to thrive beyond our planet of origin and importantly to do so in a kind way?

The new frontier in long-term innovation belongs to those who will have the vision and the determination to learn how to make smart, good use in their business (and why not their daily lives) of space resources. We all need to undergo a paradigm shift in the philosophy around doing business and the way we treat each other, the environment, the future of humanity. This requires individuals to act and think maturely and responsibly for themselves and for humanity. Big corporations could set the stage in terms of redefining the notion of return on investment to encompass sustainability and increased efficiency in addition to revenue making. Some forward thinking CEO's have already done just that. Wealth generation is not anymore thought of in terms of individual or local scale revenue but rather the ability to generate it globally and for the long term; for generations to come.

What are the current economic challenges and limitations on advancing Micro Gravity research and commercialization and how critical is recognizing the intangible value of such research?

The list of economic challenges and limitations is fairly long, unfortunately. First and foremost,

one needs to set in place a self-sustainable machinery for microgravity commercialization. How business can make money in LEO should be easily understood and transparent. How microgravity can help to unravel cutting edge, fundamental science or serve, as a unique tool for new IP should be presented in a more compelling manner.
It is still on the government's shoulders to prime the pumpand incentivize the establishment of a flourishing LEO economy. This will not happen overnight. It relies upon creating a long term, stable program, dedicated and focused on the outcome. In a way, I think people look up at NASA as being the steward of our future as species. A job at NASA is not just a job- it is a serious responsibility.

In terms of policies, one way to do this is by remembering the situation in the 1860'swhere a need to promote the construction of a "transcontinental railroad" was established. The "Pacific Railroad Acts" authorized the issuance of government bonds and the grants of land to railroad companies. Since it is not possible to give free land in LEO, the translation to microgravity would be to allow companies to Incorporate in LEO and offer them a tax break.Since a LEO economy does not yet exist, a ten-year tax holiday revenue from the sales of microgravity productswould be a $-neutral cost. Another incentivewould be to allow companies to take back to the US tax free one dollar from the money parked overseas for every dollar spent commercializing space. For companies, this would be an immediate way to make money in the US.
From a technical perspective, the value of research in microgravityis generally well understood and accepted once familiar with the details. That does not mean that some experiments still don't have enough data collected to be conclusive or that all the potential that microgravity offers has been harvested. Here is where scientific, fundamental, thorough research is critical. For companies in the private sector to be more engaged in the process of using space as a source of IP or revenue the following should be considered:(1) existence of a public, commercial microgravity database to provide relevant technical and economic context (2) ability to identify, understand and promptly address the dependencies and risks of operating in space so that they do not become hampering factors in developing the space aspects of their business (3) access to affordable, off the shelf hardware.

History and Value of Micro Gravity Research

The understanding and utilization of processing material in a microgravity environment has in fact been used on Earth since 1753 when William Watts of Bristol, England built a 168 foot drop-tower in Chester, England to process molten lead into uniformly spherical shot for firearms. Similarly, the tallest tower in the US is the 234' Phoenix Shot Tower in Baltimore, MD, built in 1828. Long duration exposure to microgravity however is required for creating high-performance materials. This condition is accessible in Low Earth Orbit and beyond. In the Space Shuttle Era, a Wake Shield Facility was deployed and operated. The ultra high vacuum created in the wake enabled "clean room" conditions for film epitaxial growth of semiconductor crystals.

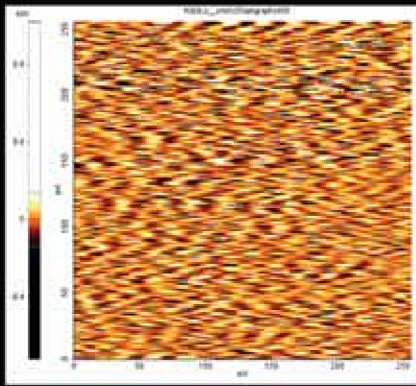
There are four major categories in which the value of long-term exposure to the microgravity environment:

1. New insights into systems behavior and response to variations in their environment and identifying new final states of systems. This knowledge is captured in LEO through a series of targeted experiments. A technology is then developed on ground that is able to mimic the newly observed state of the system. This technology is then commercialized.
2. Processing/reprocessing in space of products manufactured on Earth. This approach seeks improvements in the ultimate properties and performance of the product by having it undergo a (re)processing cycle in space.
3. Manufacturing and Assembly in space. This is the process in which a product is built in the reduced gravity environment, usually from its compound elements.
4. Technology Demonstrations and miniaturization. In this instance a technology is developed for some specific purpose in space that turns out to be of serendipitous value on Earth. Due to severe mass limitations technologies are miniaturized for use in space which in turns increases their utilization and application on Earth.

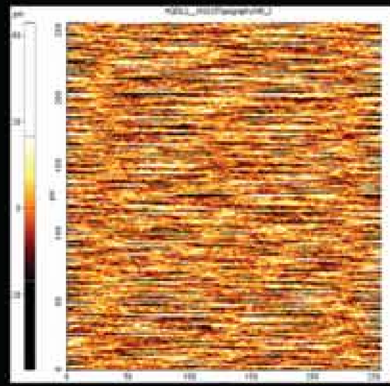
Current Opportunities for Funding for micro gravity technology research

Microgravity R&D and most flight opportunities are primarily funded and supported by the government. On the NASA side, the existing solicitations are listed on NSPIRES: (http://nspires.nasaprs.com/external/solicitations/solicitations.do?method=init&stack=push
Another option is through the ISS National Laboratory managed by the Center for Advancement of Science in Space, CASIS (http://www.iss-casis.org), either responding to one of their RFP's or by submitting an unsolicited proposal.There are also several commercial space companies like NanoRacks that have the ability to enable access to space and the ISS and execution of microgravity experiments.

When you need vibration isolation you need *Negative-Stiffness* technolgy from Minus K®



No isolation → RMS roughness value of 0.7A



With Minus K isolation → RMS roughness value of 0.1A

Atomic Force Microscopes (AFMs) really *DO need vibration isolation*. Some people don't realize that a vibration isolator can really improve their images.

* No electricity or air required
* 0.5 Hz Vertical & 1.5 Hz Horiz
* Low Cost
* 6 DOF
* Light and easy to use.
* Costs a fraction of typical active systems
* Completely passive vibration isolation

Minus K's bench top vibration isolator is a perfect accessory for your compact low cost AFM.

Improve your images with our patented Negative-Stiffness technology.

Minus K® vibration isolation systems deliver 10x to 100x better performance than high-performance air systems and are even better than active systems.

The best performance *and* the lowest price. Now that's hard to beat!

minus k® TECHNOLOGY

Give us your *Vibration Isolation* Challenge

460 Hindry Ave., Unit C, Inglewood, CA 90301
Tel: 310-348-9656 Fax: 310-348-9638
sales@minusk.com • www.minusk.com

As featured in Laser Focus World, Motion System Design, Machine Design, Design News, Photonics Spectra, Laboratory Equipment, The Scientist, R&D Magazine and Microscopy Today.

FEATURE STORY

ATOMIC FORCE MICROSCOPY (AFM) FOR OPTIMIZATION OF SILICA CHEMICAL INHIBITION IN GEOTHERMAL BRINES

Al de Leon, Richard de Guzman, Rigoberto C. Advincula

Richard C. de Guzman is an R&D Specialist from the Innovations and Development for Energy Advancement Centre of the Energy Development Corporation, a global diversified renewable power company. His current focus projects are innovations and solutions in renewable energy such as the applications of nanotechnology techniques in geothermal operations including scaling and corrosion, exploration and resource management. He presented his recent studies at the 2015 World Geothermal Congress in Melbourne, Australia. Richard obtained his B.S. in Chemical Engineering at the University of the Philippines- Diliman (magna cum laude) in 2011 and his professional license (4th place rank) in the same year.

Al de Leon is a PhD Candidate at Case Western Reserve University, Department of Macromolecular Science and Engineering. His research interest involves the fabrication and application of hierarchically structured polymer systems. This includes the design, assembly, and characterization of colloidally textured conducting polymer film with superhydrophobic property and its application as superior anticorrosion coating. He obtained his B.S. in Chemical Engineering at the University of the Philippines – Diliman in 2006.

Silica scaling has been a huge problem for geothermal plants because it significantly lowers the efficiency of heat extraction from geothermal fluids. Geothermal electricity is generated by using the geothermal energy to rotate the turbine that activates the generator. In contrast with most power plants that use fossil fuels, geothermal power plants utilize the steam produced from the water reservoir found a couple of miles below the earth's surface (Figure 1). The extracted geothermal fluid usually contains minerals that can lead to scaling. The presence and level of silication on pipes, heat exchanges, storage tanks, etc. in the extracted geothermal fluid is one of the major parameters in the design and operation of the plant. Silica is known to polymerize and precipitate from water soluble monomeric silica when it exceeds the saturation level. This could be due to the decrease in pressure or temperature of circulating fluids. The deposition of the silica on the pipe and instrument walls increases the resistance to heat flow and therefore the amount of heat extracted from the geothermal fluid. Extreme cases of silica scaling also constricts the flow, which further decreases the efficiency of heat extraction (Figure 2).

The amount of silica in the geothermal fluid is currently being monitored by performing silicomolybdate test (ASTM D859-00), which measures the amount of oligomeric silica in the geothermal fluid. The silicomolybdate test involves the formation of the yellow color due to the reaction between the molydate ion with silica and phosphate under acid condition. If the concentration of silica is low, then amino-naphthol sulfonic acid can be added to convert the faint yellow to dark blue. Although the silicomolybdate test can be used to check if the silica level is going beyond the saturation level, it fails to see any premature silica polymerization brought about by sudden change in chemistry of the geothermal fluid. Other disadvantage includes interferences from substances that are present in the geothermal fluid such as iron compounds. Large amounts of ferrous and ferric substances can be introduced to the geothermal fluid due to the corrosion of the pipes and equipment. Other interferences can come from phosphate, slow-reacting forms of silica, sulfides, and turbidity. Unfortunately, all of these are usually present in geothermal fluids. Therefore, extra care should be done in interpreting the results of the silicomolybdate test if used to geothermal fluids.

Figure 4. Atomic Force Microscopy (AFM) can be used to effectively monitor the presence of the polymeric silica nanoparticles in the geothermal fluid. The AFM is coupled with the silicomolybdate test to have a complete picture of the silica polymerization process. Basically, it measures the amount of silica still dissolved in solution, while the AFM measures the size of the polymerized silica particles. The combined technique is used to determine the optimum

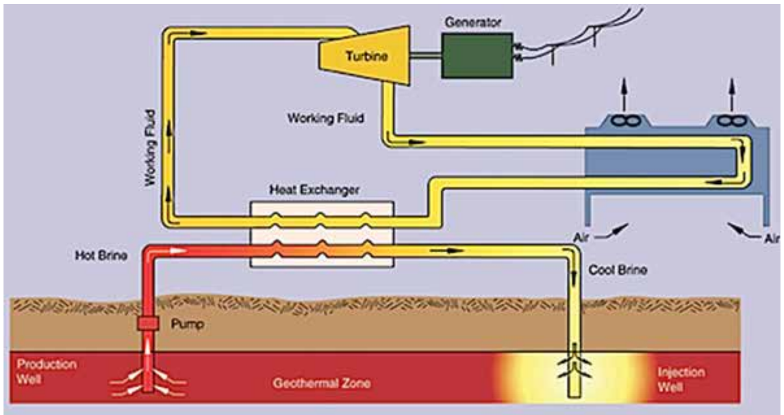


Figure 1.
Schematic diagram of a geothermal power plant (credit www.seg.gov).

Figure 2.
Scaling and Silica deposition on pipes handling geothermal brine (credit www.geokem.co.nz)

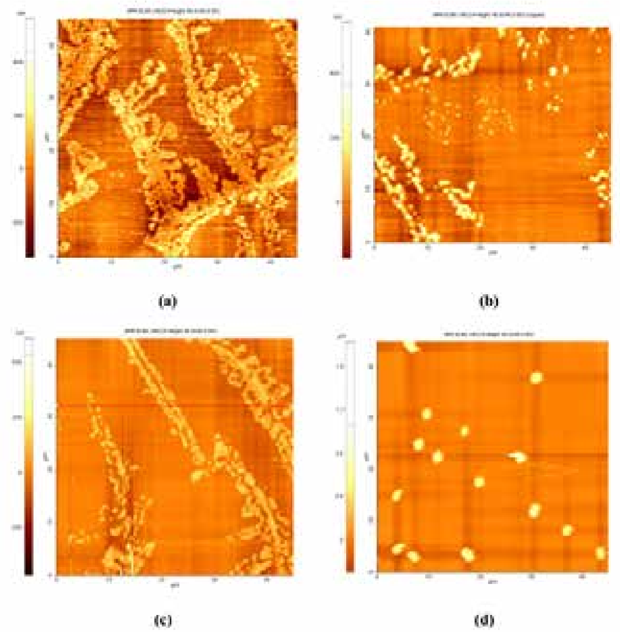


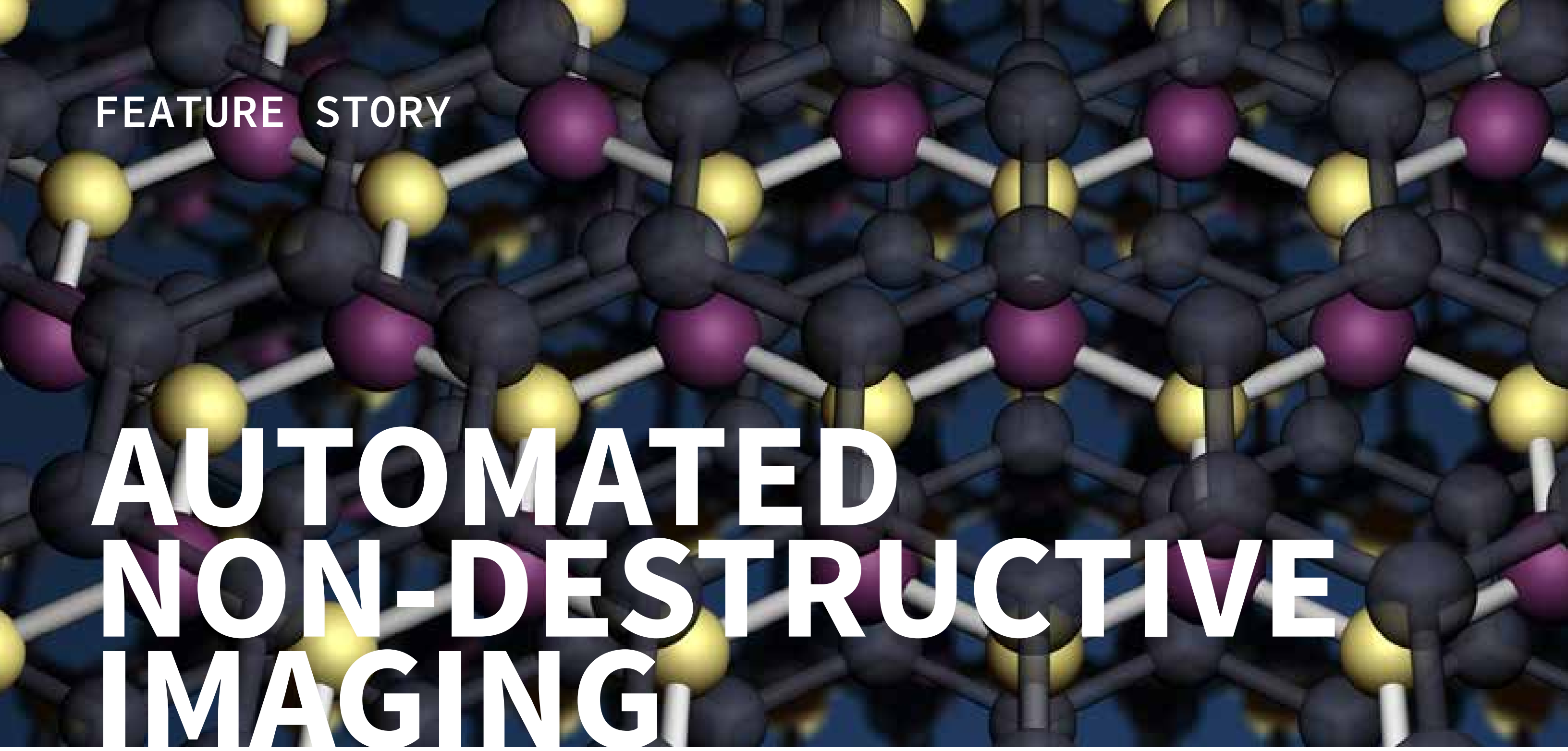
Figure 3.
AFM images of the silica polymerized from (a) untreated geothermal fluid, (b) 5.0 pm, (c) 8 ppm, (d) 10 ppm of phosphinocarboxylic acid.

dosage of the phosphinocarboxylic acid, a known silica inhibitor.The solution containing the polymerized silica particles was drop-casted on freshly prepared mica substrate. Excess solution was wicked away and the mica substrate with the silica nanoparticles was dried for at least 24 hours. Park NX10AFM from Park Systems in non-contact mode was used to image and measure the particle size of the polymerized silica nanoparticles. In non-contact mode, the cantilever is driven to oscillate at its resonance frequency. This imaging mode lessens the chance to move the silica particles during scanning.

Figure 3. shows the silica polymerized from geothermal solution containing different levels of the phosphinocarboxylic acid inhibitor. One can see from the figure that the particle size decreases as we add more silica inhibitor. However, adding too much actually worsens the problem because it actually promotes the formation of larger silica particles. It can also be seen that addition of the phosphinocarboxylic acid inhibitor decreases the degree of linking among the precipitated silica particles. At 10 ppm dosage, it can be seen that silica are present as isolated particles on mica.

In conclusion, the AFM proved to be a very valuable tool in measuring the size of the silica particles polymerized from the geothermal fluid. The AFM coupled with the conventional silicomolybdate test provide a more holistic understanding of the phenomena of scaling even before it starts significantly affecting the efficiency of heat extraction from geothermal fluid.

Figure 4.
Atomic force microscopy system (Courtesy Park Systems Inc).



AUTOMATED NON-DESTRUCTIVE IMAGING

AND CHARACTERIZATION OF GRAPHENE/HBN MOIRÉ PATTERN WITH NON-CONTACT MODE AFM

By Dr. Ardavan Zandiatashbar, Ph.D., Park Systems Inc., Santa Clara, California.

INTRODUCTION

Graphene has attracted researchers' attention due to its unique band gap structure, which allows it to be used in high-mobility semiconductor devices. However, realization of such a graphene-based high-performance device has been challenging due to lack of a suitable substrate. This challenge has been recently addressed by the development of epitaxial growth of graphene on hexagonal boron nitride (hBN)[1, 2].hBN is a suitable substrate for graphene due to its highly similar hexagonal patterns. A moiré pattern is the superlattice generated as the result of a ~2% mismatch between graphene and hBN lattices, with periodicity values larger than each of the two materials' lattice constants by two orders of magnitude[3].

Scanning probe microscopy (SPM) is a key technique for characterization of moiré pattern. This is due to the fact that SPM can provide the highest Z resolution compared to any other microscopy technique[4].Therefore it is essential to verify successful fabrication of graphene/hBN devices by epitaxial growth methods; however, SPM has been challenging for two major reasons: perplexing parameter optimization with a steep learning curve for new researchers (and even experts), as well as the high cost of specialized tips for high-resolution imaging. In addition, frictional mode SPM involves mechanical tip-sample engagement, making it a destructive method for characterizing the graphene/hBN devices. Almost all research performed on characterization of the moiré pattern uses destructive SPM modes [1, 2, 3]

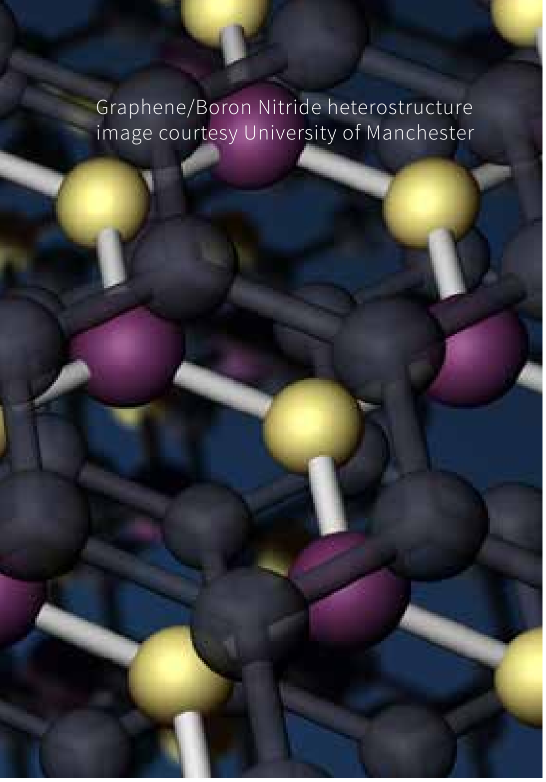
Non-contact mode atomic force microscopy (AFM) is a non-destructive SPM technique availablesince the late 80s [5].In order to perform non-contact mode imaging, tip-sample separation must be controlled accurately. This was challenging, and it was one of the limitations of this technique at the beginning. However, thanks to research and development, the technique has reached maturity over the past decade and is now provided as the standard AFM imaging mode by Park Systems.

In this article, the need for easy, non-destructive SPM characterization of moiré pattern has been addressed by the automated non-contact mode AFM imaging technique developed by Park Systems. The commercial name of the product is SmartScan™ Auto Mode. Until today, SPM characterization of moiré pattern has been challenging, expensive, destructive, and time consuming. Now, with this new solution researchers can easily and reliably perform quality control of the fabricated graphene-based devices.

MATERIALS AND METHODS

Non-contact mode AFM imaging

Non-contact mode imaging is performed by modulating the cantilever's oscillation amplitude at a frequency slightly higher than the resonance frequency of the cantilever in air (far from the sample surface). As the tip approaches the sample surface, tip-sample interaction enters into the attractive state. Non-contact mode imaging is performed when tip-sample interaction is in the attractive state. The cantilever oscillation phase is negative in the attractive state and positive in the repulsive state. By further decreasing tip-sample separation, the interaction switches to the repulsive state (dynamic or tapping mode). Variation of amplitude as a function of tip-sample separation is shown in Figure 1and is hereafter referred to as the "A-d curve". As the oscillating cantilever approaches the sample, oscillation amplitude decreases due to tip-sample interaction forces. However, as the tip descends, cantilever amplitude has a small sudden increase in value. The slight jump in amplitude is associated with changing sign of phase from negative to positive. This indicates that tip-sample interaction switches from the attractive to the repulsive state. In other words, the cantilever switches from non-contact mode to tapping mode. As the tip continues approaching the surface, the amplitude value approaches zero. Now, if the cantilever is lifted and tip-sample separation increases, the jump from the repulsive to the attractive state



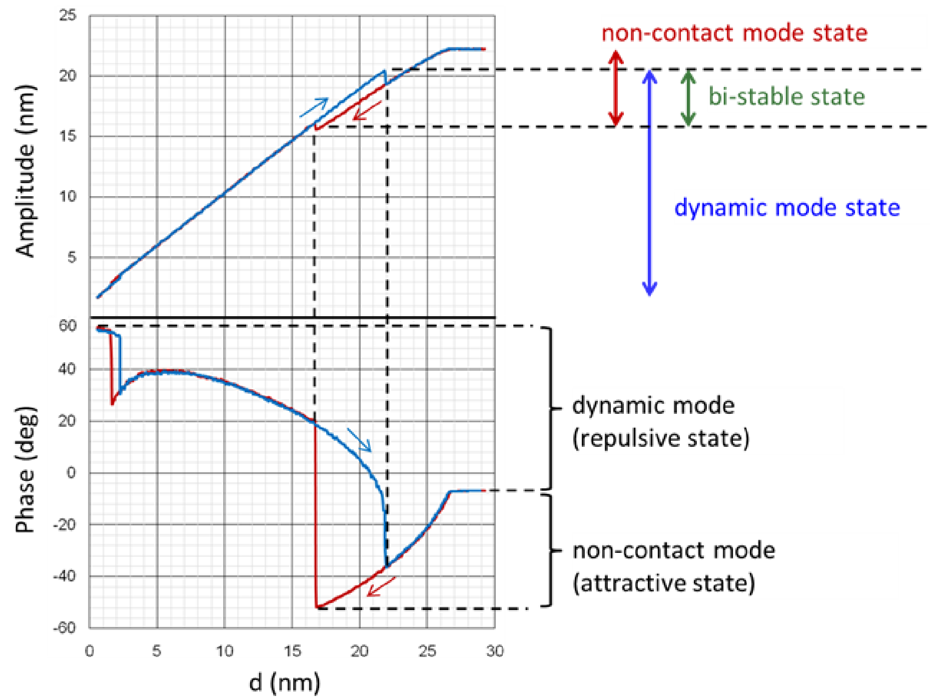


Figure 1.
AFM cantilever oscillation amplitude (upper) and phase (lower) vs. tip-sample separation (d) known as the A-d curve for constant Z actuator driving power. The red curves denote the tip approaching the sample and the blue curvs show the response when the tip is retracted from the sample surface. (Image used with permission from Nanoscientific)[7]

occurs again, but at a greater distance from the sample surface. If imaging is performed with cantilever oscillation amplitudes larger (smaller) than the second (first) jump point, imaging is performed in non-contact (tapping) mode, and tip-sample interaction is maintained in the attractive(repulsive) state. If imaging is performed with amplitude values between the first and second jump, the tip-sample interaction will be unstable and switch between the attractive and repulsive states, which is undesirable for imaging purposes[6]. In these conditions, the feedback system becomes bistable.

SmartScan™ Auto Mode

SmartScan™ is the new operating software developed by Park Systems for operating research AFM systems. Auto Mode is one of the major innovations provided by SmartScan™ and is used for performing measurements. Itessentially has two automationsteps after placing the tip and sample: positioningand imaging. In the positioning step, the location of sample surface is found by detecting tip-sample van der Waals (VdW) interactions. In this step, the tip approaches the sample at a rate of 0.5mm/sec to find the sample surface. Although this is a fairly rapid approach speed, the tip does not come into physical contact with the sample surface. Instead, thetip-sample attractive state and its effect on cantilever oscillation amplitudeare used to detect the sample surface. As a result, tip sharpness and the original state of the sample surfaceare preserved. After detecting the surface, the tip is lifted to a safe distance (about 200 μm)to allow navigating the sample surface and locating the area of interest via optical microscope. Since the location of the sample surface is known, the optical microscope is brought into focus automatically.

After locating the area of interest, theimaging stepbegins. During the imaging, oscillation frequency, free air and setpoint amplitudes, feedback control parameters, and scan rate are optimized automaticallyaccording to desired image quality.The user only needs to specify scan size, number of scan lines, and desired image quality. As described above, it is important to maintain accurate tip-sample separation to maintain tip-sample interaction in the attractive state. Accurate tip-sample separation is determined by SmartScan™ Auto Mode based on the A-d curves shown in Figure 1.

Graphene epitaxy on hBN

For this study, hBN samples were prepared by mechanical cleavage of BN crystals on a silicon substrate with a 300 nm SiO_2 epilayer. Graphene was grown by CVD epitaxial growth. Additional information can be found in the work by Yang et al.[1]

RESULTS

The graphene/hBN samples were imaged usinga standardnon-contact mode silicon AFM probe with a nominal tip radius of 7

Dr. Ardavan Zandiatashbar

nm and force constant of 42 N/m. The tip resonance frequency was selected at 316 KHz by the software. The sample surface was detected by automated software and followed by navigating the sample via optical microscopy and automated imaging. The images were collected in 500nm, 250nm, and 125nm square sizes. First, lower magnification images were collected, and thenimage size was decreased for higher magnifications. Non-contact mode AFM images of the graphene/hBN samples are shown in Figure 2.a. The moiré superlattice of epitaxial

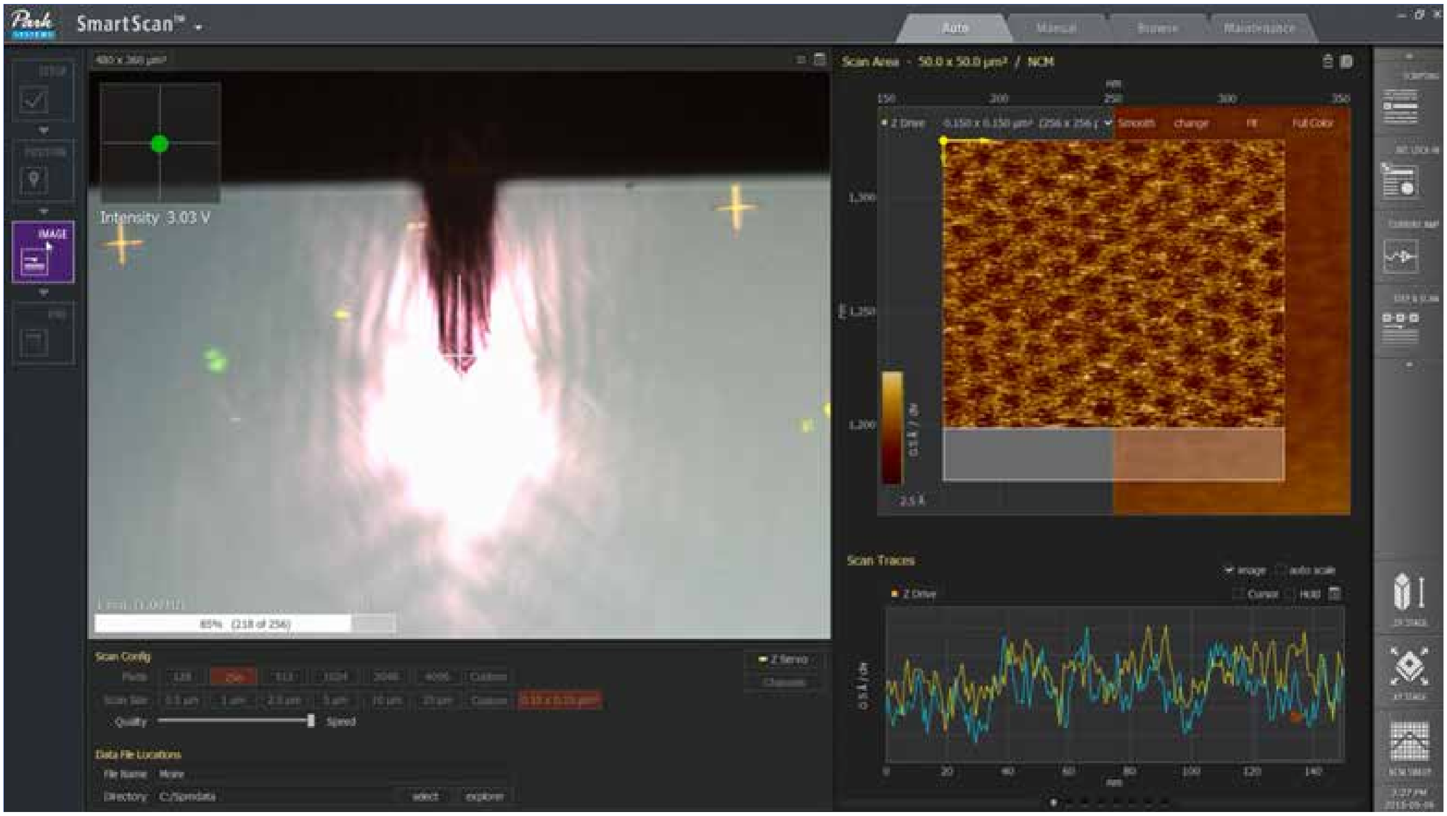


Figure 2.
The newly developed SmartScan™ Auto Mode which allows automated sample surface detection and imaging with minimal user interaction. On the left the major buttons including "positioning" and "image" are shown. Screenshot was taken while the software was collecting a 150 nm image of graphene/hBN sample in Non-Contact mode. User only needs to select scan size, image resolution, and quality/speed.

graphene is easily distinguishable in all images in the form of a hexagonal pattern. The hexagonal pattern was evaluated and confirmed by fast Fourier transform (FFT) of AFM images,illustrated in the insets of Figure 2.a. Additional grains of the secondary layer can be observed in the 500nm image. To characterize the height of the secondary grains, a line profile of the 500 nm image was selected as illustrated in Figure 2.b. The height of the secondary grain is ~3.8Å. The moiré pattern is observable on the secondary grains, as well.

DISCUSSION

The moiré superlattice is characterized in Figure 3 by using one of the 250 nm images.A FFT filter is applied to eliminate additional signal and enable easier characterization of the pattern. The lattice constant of the moiré pattern is measured to be ~15 nm. This is consistent with the simulation results of ~14nm, which is two orders of magnitude larger than lattice constants of graphene and hBN[3].The red and green lines indicate the axes of the superlattice and are used for measuring periodicity in either direction. The peak-to-valley value for each line is below 0.7Å. The continuity of moiré pattern over all the spaces indicates successful growth of epitaxial graphene over hBN. It also indicates growth of graphene on hBNirrespective of the number of layers, as seen in the 500 nm image in Figure 2. The formation of the moiré pattern is the result of a ~2% mismatch between the lattice constants of graphene and hBN.

To the knowledge of the authors, imaging the moiré pattern of epitaxial graphene in non-contact mode has not until now been performed. This is of great importance, since the samples are fragile (low friction between graphene and hBN). Therefore, minimized interaction between the tip and sample is desired to maintain the conditions of the sample during the characterization. There is no mechanical interaction, and the imaging is performed in the ambient atmosphere without the need for a vacuum. Therefore,non-contact mode imaging, as a benign characterization technique, plays a key role for characterization of devices fabricated by epitaxial growth of graphene on hBN or other two-dimensional materials. Preserving tip sharpness is also another advantage of using non-contact mode imaging. In addition to reducing the tip cost, a reliably sharp tip preserves the image quality and improves measurement repeatability. Although finding correct tip-sample distance for true non-contact mode imaging is challenging and could depend heavily on user experience, using automated software enables performing the measurements with minimal user interaction. It also improves repeatability, productivity, and measurement throughput. A standard non-contact mode probe (PPP-NCHR) was used for this measurement, not the special or super-sharp tip usually required for this sort of high resolution imaging. In non-contact mode, VdW interaction between tip and sample is utilized to image the moiré superlattice with high resolution and repeatability. Note the moiré pattern lattice constant (15nm) is almost twice the nominal tip radius (7 nm). This enables decreasing the characterization cost for potential devices fabricated based on epitaxial graphene.

CONCLUSION

The moiré superlattice of epitaxial graphene grown on hBN has been imaged in non-contact mode using a recently developed automated AFM. Images were collected using a standard silicon probe with nominal tip radius of 7nm.

The moiré superlattice was characterized, and the lattice constant of ~15 nm was verified against simulation values. The newly developed automated AFM enables minimal user experience needed for performing this type of high-resolution measurement. It also improves repeatability, productivity, and throughput. Automated non-contact mode imaging is therefore an efficient characterization technique for quality control of devices fabricated by epitaxial growth, such as graphene/hBN-based devices.

ACKNOWLEDGEMENT

The authors are immensely grateful to David Goldhaber-Gordon and Patrick Gallagher from Stanford University and Guangyu Zhang from Chinese Academy of Sciencesfor providing the graphene/hBN sample and fruitful discussions.

REFERENCES

[1] W. Yang, G. Chen, Z. Shi, C.-C. Liu, L. Zhang, G. Xie, M. Cheng, D. Wang, R. Yang, D. Shi, K. Watanabe, T. Taniguchi, Y. Yao, Y. Zhang and G. Zhang, "Epitaxial growth of single-domain graphene on hexagonal boron nitride," Nature Materials, vol. 12, pp. 792-797, 2013.

[2] S. Tang, H. Wang, Y. Zhang, A. Li, H. Xie, X. Liu, L. Liu, T. Li, F. Huang, X. Xie and M. Jiang, "Precisely aligned graphene grown on hexagonal boron nitride by catalyst free chemical vapor deposition," Scientific Reports, vol. 3, no. 2666, 2013.

[3] C. R. Woods, L. Britnell, A. Eckmann, R. S. Ma, J. C. Lu, H. M. Guo, X. Lin, G. L. Yu, Y. Cao, R. V. Gorbachev, A. V. Kretinin, J. Park, L. A. Ponomarenko, M. I. Katsnelson, Y. N. Gornostyrev, K. Watanabe, T. Taniguchi, C. Casiraghi, H.-J. Gao, A. K. Geim and K. S. Novoselov, "Commensurate–incommensurate transition in graphene on hexagonal boron nitride," Nature Physics, vol. 10, pp. 451-456, 2014.

[4] G. T. Smith, Industrial Metrology: Surfaces and Roundess, Springer, 2002.

[5] G. Binnig, C. F. Quate and C. Gerber, "Atomic Force Microscope," Physical Review Letters, pp. 930-933, 1986.

[6] R. Garcia and R. Perez, "Dynamic atomic force microscopy methods," Surface Science Reports, pp. 197-301, 2002.

[7] A. Zandiatashbar, "Sub-angstrom roughness repeatability with tip-to-tip correlation," NanoScientific, no. Winter, pp. 14-16, 2014.

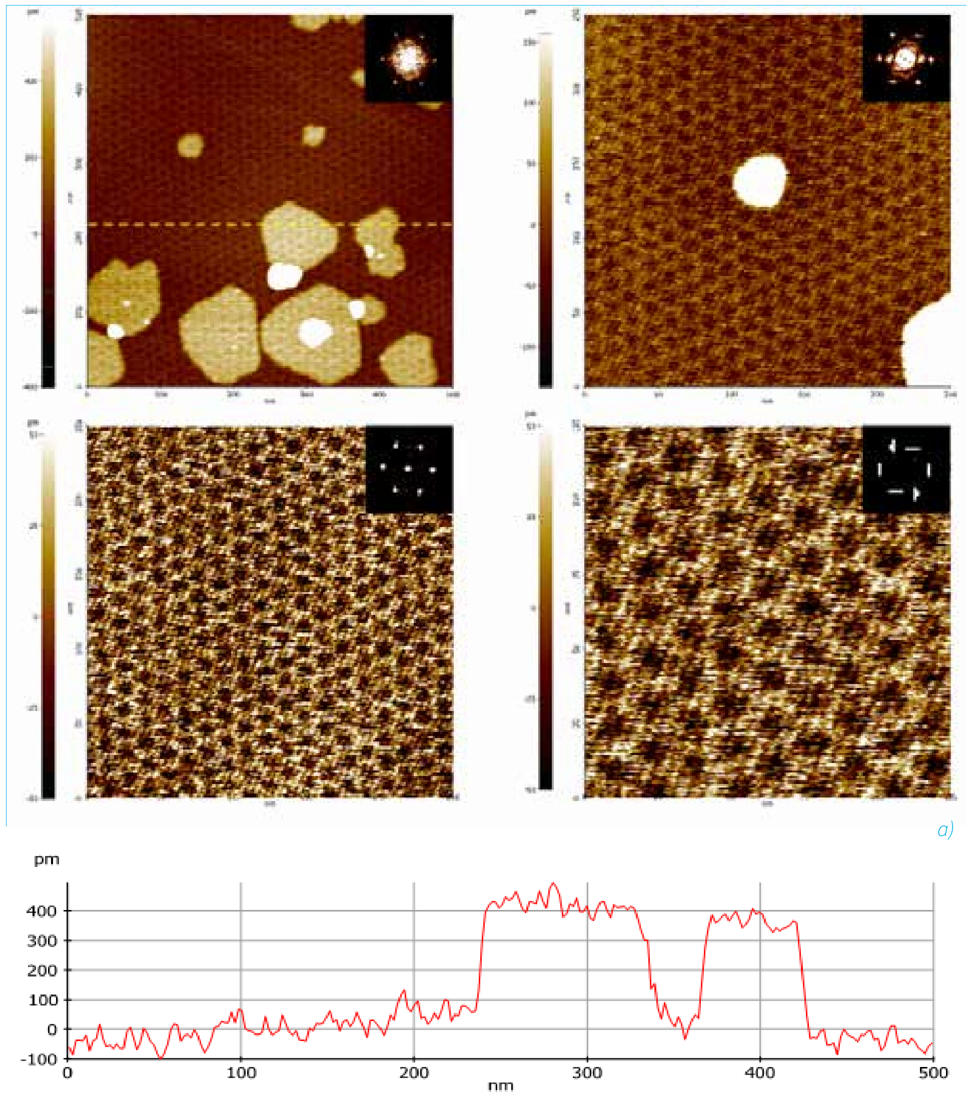


Figure 3.
a) Non-contact mode images of graphene-hBN samples with 500 nm, 250 nm, and 125 nm scan sizes. No filter has been applied to the images. The insets indicate Fourier transformation of the image. b) The profile of the dashed line in the 500nm image.

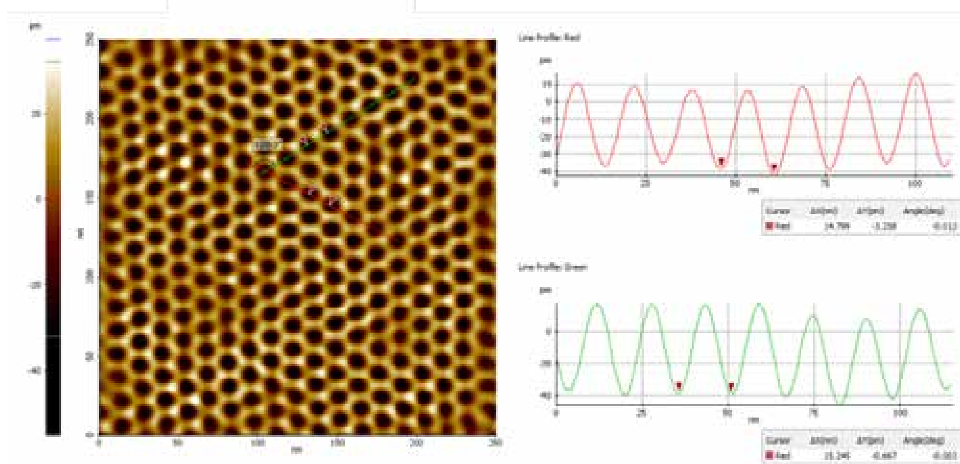


Figure 4.
A FFT filter is applied to one of the 250nm images in Fig. 2.a. to characterize the moiré superlattice. Line profiles for the red and green lines are shown on the right side.

PRESIDENT'S 2016 BUDGET PROVIDES $146 BILLION FOR R&D, INNOVATION AND STEM EDUCATION

FOCUSING ON ENGAGING INDUSTRY TO MOVE RESEARCH TOWARDS COMMERCIALIZATION

AN INTERVIEW WITH LLOYD WHITMAN, ASSISTANT DIRECTOR FOR NANOTECHNOLOGY AT THE WHITE HOUSE. OFFICE OF SCIENCE AND TECHNOLOGY POLICY

THE NNI VISION AND STRATEGIC PLAN
The National Nanotechnology Initiative (NNI) expedites the discovery, development and deployment of nanoscale science and technology to serve the public good through a program of coordinated research and development aligned with the missions of the participating agencies. These agencies work to fulfill the NNI vision by working together to accomplish four primary goals:

1. To advance world-class nanotechnology research and development;
2. To foster the transfer of new technologies into products for commercial and public benefit;
3. To develop and sustain educational resources, a skilled workforce and the supporting infrastructure and tools to advance nanotechnology; and
4. To support the responsible development of nanotechnology.

The aim of the NNI is to move nanotechnology discoveries from the laboratory into new products for commercial and public benefit, encourage more students and teachers to become involved in nanotechnology education, create a skilled workforce and the supporting infrastructure and tools to advance nanotechnology and to support the responsible development of nanotechnology.

How important is nanoscale research in the grand scheme of things in the science and technology innovation from the federal perspective?

The NanoTechnology initiative was first started 15 years ago during President Clinton's administration and now allocates 1 ½ billion per year to further the advancements, with continuing efforts towards commercialization of nanotechnology into various industries including manufacturing, precision medicine, space, defense, electronics and energy. President Obama is a strong supporter of funding science. The President's 2016 Budget provides $146 billion for R&D overall, an $8 billion or 6 percent increase from 2015 enacted levels. The Budget targets resources to areas most likely to directly contribute to the creation of transformational knowledge and technologies that can benefit society and create the businesses and jobs of the future. America's economic competitiveness and growth—including in domestic manufacturing—depend on robust investments in: research and development (R&D); innovation; and science, technology, engineering, and mathematics (STEM) education.

NanoTechnology covers so many disciplines and institutions, the government is actively engaging across all sectors to create a vast eco system of research and commercialization that explores by innovations in part by capturing the imagination of the public. For example, the Grant Challenges define ambitious grant challenges to bring communities together to create interdisciplinary nanotechnology solutions.
The Grand Challenges should stimulate additional public and private investment, and foster the commercialization of Federally-funded nanotechnology research.

Here are some examples developed by the NNI agencies, working with the National Nanotechnology Coordination Office and OSTP

> **"THE NANOTECH FUTURE IS SO BRIGHT I HAVE TO PUT SHADES ON."**
>
> **LLOYD WHITMAN, ASSISTANT DIRECTOR FOR NANOTECHNOLOGY AT THE WHITE HOUSE OFFICE OF SCIENCE AND TECHNOLOGY**

By 2025, the nanotechnology R&D community is challenged to achieve the following:

1. Increase the five-year survival rates by 50% for the most difficult to treat cancers.
2. Create devices no bigger than a grain of rice that can sense, compute, and communicate without wires or maintenance for 10 years, enabling an "internet of things" revolution.
3. Create computer chips that are 100 times faster yet consume less power.
4. Manufacture atomically-precise materials with fifty times the strength of aluminum at half the weight and the same cost.
5. Reduce the cost of turning sea water into drinkable water by a factor of four.
6. Determine the environmental, health, and safety characteristics of a nanomaterial in a month.

Is there global collaboration in NanoTechnology research?

Nanotechology is a very multi disciplinary field where every leading group in nanotechnology has multiple international collaborations. The US and EU are very keen on environmental policy at the research level - setting ANSI standards and definitions that raise the bar for environmental and safety initiatives as nanotechnology research becomes more commercialized.

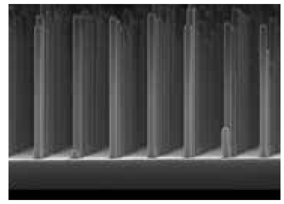
Which areas of scientific research that encompasses nanotechnology are the hottest or top priorities for the US?

The nanotechnology initiative is not a top down program; there are 11 agencies with mission critical research in many areas of science including Future of Electronics, Photonics, Energy, Nano Manufacturing,

"LAST YEAR, I LAUNCHED THE BRAIN INITIATIVE TO HELP UNLOCK THE MYSTERIES OF THE BRAIN, TO IMPROVE OUR TREATMENT OF CONDITIONS LIKE ALZHEIMER'S AND AUTISM AND TO DEEPEN OUR UNDERSTANDING OF HOW WE THINK, LEARN AND REMEMBER. I'M PLEASED TO ANNOUNCE NEW STEPS THAT MY ADMINISTRATION IS TAKING TO SUPPORT THIS CRITICAL RESEARCH, AND I'M HEARTENED TO SEE SO MANY PRIVATE, PHILANTHROPIC, AND ACADEMIC INSTITUTIONS JOINING THIS EFFORT."

PRESIDENT BARACK OBAMA
SEPT. 2014

Students learn about nanoscience and nanotechnology at the NanoDays event hosted by the University of Nebraska-Lincoln. Visit nisenet.org for this year's dates and locations. Image: UNL



Array of nanowires gallium phosphide made with an electron microscope. Photo: Eindhoven University of Technology.

Most attempts to build solar powered cars, like the one above, rely upon direct sunlight in order to provide the power needed to keep going, but new technology that has allowed scientists to use solar energy to split water into hydrogen and oxygen could provide compact solar fuel cells for powering vehicles even after dark

Bio Technology & Medicine, and Environmental Health and Safety. The extensive public and private partnerships are designed to amplify the federal government budgets for Nanotechnology with the priority of engaging industry to move research towards commercialization.

Can you describe how microscopy plays an absolutely critical role in the advancement of NanoScale Research?

Vision is central to how most people understand the world, so "seeing" at the nanoscale is an essential element both for our scientific understanding and for inspiring scientist and the public to appreciate the nanoscale. We depend on microscopy – electron, scanning probe, and innovative optical methods – to do this. It is not surprising that the inventors of methods to acquire images at the nanoscale have received Nobel Prizes for electron microscopy, scanning tunneling microscopy (both in 1986), and super-resolved fluorescence microscopy (2014).

Do you feel AFM plays a vital role in nanotechnology research and why?

AFM has evolved into perhaps the most versatile of nanoscale microscopy methods given the wide range of samples and environments with which it can operate, and the ability to measure chemical and nanomechanical interactions.

The 3 pillars of NanoTechnology are: Make, Measure, Model
Measuring thru SCIM and AFM have been the biggest enablers for the measurement pillar because it captures molecular changes at a sub atomic level. Microscopy has played an absolutely critical role in the evolution of NanoScale Research. Future advancements will provide more real-time imaging data on nanoscale behaviors that will lead us towards further commercialization of nanotechnology innovations.

Does Nanotechnology research give any promise for clean energy in the future?

The DOE is the 3rd largest investment in the budget for Nanotechology initiatives focused on every area of energy research from nano structures to photo optics to thermal electronics to conversions nano catalyst for solar fuel. Contributing to Energy Solutions for the Future spans efforts in fundamental and applied research to improve photovoltaic and thermophotovoltaic devices and advance the development of solar fuels applying nanotechnology for solar energy collection and conversion. Industry engagement is critical to ultimately realizing the potential of solar energy.

Solar energy is a promising alternative energy source that can mitigate global climate change, reduce dependence on foreign oil, improve the economy, and protect the environment.
Example: In less than two hours, the amount of sunlight falling on Earth can meet our total global energy needs for an entire year. Advanced Materials for Energy (AME) researchers are developing novel materials for solar energy conversion and electrical energy storage devices. Concurrently, researchers at Eindhoven University are using gallium phosphide to produce solar cells that make clean fuel hydrogen gas from liquid water.

At the White House Office of Science and Technology Policy (OSTP), how does nanotechnology support Outer Space Exploration?

NASA continues to support both foundational and applied research in nanotechnology through its field centers and in university and industry laboratories.

One particular example is the NASA Space Technology Research Fellowship Program. Since its inception in 2011, it has funded 41 graduate fellowships, 11 of which were awarded in 2014, to perform nanotechnology-related research in 4. Progress Towards Achieving NNI Goals, Objectives, and Priorities The National Nanotechnology Initiative—Supplement to the President's 2016 Budget 39 collaboration with NASA scientists and engineers. Current NASA research efforts have been supported through the Space Technology Mission Directorate and the Aeronautics Research Mission Directorate. Center Innovation Funds and Seedling Funds from these directorates have funded topics such as the development of nanoscale coatings to improve the aerodynamic efficiency of aircraft, nanotechnologybased sensors for high temperatures and harsh environments, carbon nanotube and boron nitride nanotube-based materials and devices, and nanoscale vacuum electronics.

Lloyd Whitman, Assistant Director for Nanotechnology at
the White House Office of Science and Technology Policy

As part of the White House Office of Science and Technology Policy, Dr. Whitman oversees national nanotechnology policy, helps the Administration maintain strong support for the National Nanotechnology Initiative within the Federal agencies and among key external stakeholders, and serves as a liaison to international nanotechnology programs and initiatives. He also serves as co-chair of the Nanoscale Science, Engineering, and Technology Subcommittee of the National Science and Technology Council's Committee on Technology, and provides guidance to the National Nanotechnology Coordination Office on its policies and operations.

As Assistant Director for Nanotechnology in the Technology and Innovation Division, Whitman supports the National Nanotechnology Initiative (NNI) and the Materials Genome Initiative (MGI), helping the Administration maintain strong support for these initiatives within the Federal agencies and among key external stakeholders, and serve as a liaison to international nanotechnology and advanced materials programs and initiatives.

He also serves as the OSTP co-chair of the Nanoscale Science, Engineering, and Technology Subcommittee of the National Science and Technology Council's Committee on Technology. Lloyd Whitman has a PhD in Physics from Cornell University, M.S. Physics Cornell University and Sc.B. Physics Brown University. He won the Naval Research Laboratory (NRL) Edison Award for U.S. Patent 7,541,062, "Thermal Control of Deposition in Dip Pen Nanolithography." The invention is for an apparatus for nanolithography and a process for thermally controlling the deposition of a solid "ink" from the tip of an atomic force microscope to a substrate. The invention may be used to turn deposition of the ink on or off by either raising or lowering its temperature above or below its melting temperature.

“AFM HAS EVOLVED INTO PERHAPS THE MOST VERSATILE OF NANOSCALE MICROSCOPY METHODS GIVEN THE WIDE RANGE OF SAMPLES AND ENVIRONMENTS WITH WHICH IT CAN OPERATE AND THE ABILITY TO MEASURE CHEMICAL AND NANOMECHANICAL INTERACTIONS.”

LLOYD WHITMAN, ASSISTANT DIRECTOR FOR NANOTECHNOLOGY AT THE WHITE HOUSE OFFICE OF SCIENCE AND TECHNOLOGY

Four years of collaboration between two organizations with seemingly unrelated missions has yielded a new medical device that could change the way doctors use deep brain stimulation. Currently, the treatment is mainly effective for Parkinson’s, but carbon nanofiber pads could open opportunities for treating many other brain disorders with this method.

PRODUCT
REVIEWS

PARK NX-HIVAC

HIGH VACUUM SSRM AFM SYSTEM IS THE NEXT STAGE ADVANCEMENT IN FAILURE ANALYSIS TOOLS DESIGNED TO PROVIDE SUPERIOR PERFORMANCE IN SEMICONDUCTOR MANUFACTURING

PARK SYSTEMS, WORLD-LEADER IN ATOMIC FORCE MICROSCOPY (AFM), TODAY ANNOUNCED NX-HIVAC, THE ONLY HIGH VACUUM AFM SYSTEM IN THE MARKET THAT MEETS THE CURRENT AND FUTURE NEEDS FOR FAILURE ANALYSIS SEMICONDUCTOR MANUFACTURING. PARK NX-HIVAC IS IDEAL FOR ACADEMIC AND INDUSTRIAL CUSTOMERS WHO ARE INTERESTED IN FAILURE ANALYSIS SOLUTIONS IN HIGHLY DOPED SEMICONDUCTOR PROCESSING WHERE MORE HIGHLY SOPHISTICATED FAILURE ANALYSIS TOOLS ARE NOW REQUIRED.

Park NX-Hivac's high vacuum AFM system is for academic and industrial customers who require failure analysis solutions in highly doped semiconductor processing. Performing SSRM measurements under high-vacuum conditions can reduce the required tip-sample interaction force, which can significantly reduce damage to both the sample and the tip. This will extend the life of each tip, making scanning cheaper and more convenient, and can provide more accurate results by improving spatial resolution and signal to noise ratio.

Park NX-Hivac allows failure analysis engineers to improve the sensitivity and resolution of their measurements through high vacuum SSRM. Because high vacuum scanning offers greater accuracy, better repeatability, and less tip and sample damage than ambient or dry N2 conditions, users can measure a wide range of dope concentration and signal response in failure analysis applications.

The high vacuum scanning spreading resistance microscopy (SSRM) of Park NX-Hivac enables 2D carrier profiling of next generation devices and measures the high resolution SSRM image under high vacuum conditions to minimize sample-tip damage and improve production yield. Park NX-Hivac is very sensitive and responsive to the current signal for its accurate measurement and repeatability.

"The ever shrinking nanoscale geometries of semiconductor devices require sophisticated failure analysis tools which are the trademark of Park Systems AFM," commented Keibock Lee, Park Systems President. "Our customer-centric engineering and product development team is focused on failure analysis solutions for the manufacturing environment that ultimately facilitates the advancement of nanoscale production. Our commitment to superior products that enhance the customer's performance led to the development of NX-Hivac, which was designed in collaboration with a major semiconductor IC producer."

Designed with the capability for multiple sample loading (up to 5), Park NX-Hivac is also able to measure a wide dynamic range of dopant concentration (7 decades). Other features include a fast signal response even at the range of insulator – metal where the conductance is being changed dramatically. A significant advantage of NX-Hivac is that the high vacuum SSRM measurement shows much higher sensitivity and resolution than ambient condition. This is due to the applied force between the tip and sample under ambient or dry nitrogen condition which is 4 times higher than in a vacuum. The low force required reduces the strain of thin films of target samples, giving a higher spatial resolution, resulting in longer tip life and increased productivity.
24-bit Digital Electronics Minimize wasted time and maximize accuracy with the trademark NX-Series electronics controller featured in the NX-Hivac.

The controller is an all digital, 24-bit high speed device which gives the user the ability to perform a wide range of scans including our True Non-Contact mode. With its low noise design and high speed processing unit, the controller is ideal for precise voltage and current measurement as well as nano scale imaging. The embedded electronics also feature digital signal processing, allowing users to easily analyze measurements and imaging.

Park NX-Hivac complete system includes Park's unique design features such as closed-loop XY Scanner for accurate zoom-in imaging, low noise ratio (0.30 Å even when vacuum pump is ON), increased tip lifetime and the reliability of guaranteed repeatability. Special features such as software control for automatic pumping and venting, motorized laser alignment and high resolution axis-optics enhance the ease of use for operator.

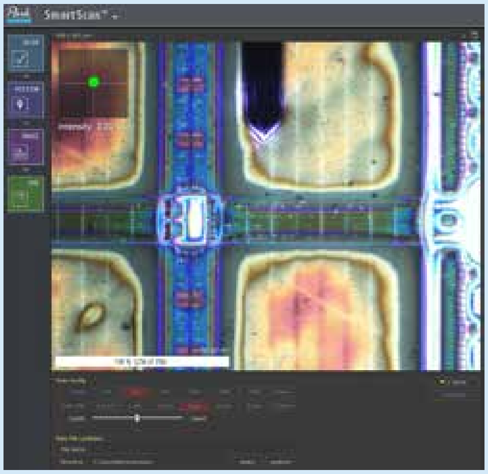
"THE EVER SHRINKING NANOSCALE GEOMETRIES OF SEMICONDUCTOR DEVICES REQUIRE SOPHISTICATED FAILURE ANALYSIS TOOLS WHICH ARE THE TRADEMARK OF PARK SYSTEMS AFM," COMMENTED KEIBOCK LEE, PARK SYSTEMS PRESIDENT.

"OUR CUSTOMER-CENTRIC ENGINEERING AND PRODUCT DEVELOPMENT TEAM IS FOCUSED ON FAILURE ANALYSIS SOLUTIONS FOR THE MANUFACTURING ENVIRONMENT THAT ULTIMATELY FACILITATES THE ADVANCEMENT OF NANOSCALE PRODUCTION."

"PARK'S COMMITMENT TO SUPERIOR PRODUCTS THAT ENHANCE THE CUSTOMER'S PERFORMANCE LED TO THE DEVELOPMENT OF NX-HIVAC, WHICH WAS DESIGNED IN COLLABORATION WITH A MAJOR SEMICONDUCTOR IC PRODUCER." KEIBOCK LEE, PARK SYSTEMS PRESIDENT

SMARTSCAN

USER REVIEWS OF PARK'S NEWLY LAUNCHED AUTOMATED IMAGING SYSTEM SMARTSCAN ARE OVERWHELMINGLY POSITIVE



Initial Feedback from users of Park Systems SmartScan, the revolutionary point and click AFM nanoscopic tool is overwhelmingly positive, citing that SmartScan lets even inexperienced, untrained users produce high quality nanoscale imaging in five times the normal speed of a traditional AFM. After the launch of the new SmartScan software earlier this year, several users gave their response to the new software upgrade, which is now offered free of charge to all Park AFM users and will be installed on all future products.

"Using SmartScan AFM by Park Systems is very easy, allowing me to take images of a sample at nanoscale resolution without the laborious manual set up. With SmartScan mode, the AFM automatically does the frequency sweep and intelligently decides on the best amplitude/frequency setting and the images are as impressive as if they were done by an expert AFM user, which makes my research even better. I am very happy that SmartScan is available." Jimmin Kim from Rutgers University.

"SmartScan offers great advantages to novice AFM users because it is so easy to produce a simple non-contact mode topography image," comments Sibel Leblebici an opto electronic researcher at the Molecular Foundry of the Lawrence Berkeley National Laboratory where they use Park AFM equipment to explore the development of next generation light harvesting materials. "We rely heavily on the PinPoint scan mode for conductive AFM. The

Sibel Leblebici, PhD student Molecular Foundry, Lawrence Berkeley National Lab

Sibel's core project is to manipulate the exiciton binding energy in small molecule organic semiconductors and develp deep understanding via Scanning Conductance and Photo Current Microscopy

ability to see a representative approach-retract curve performed in the PinPoint mode makes it much easier to select parameters to perform a high quality conductive AFM measurement. The user interface in SmartScan is much easier to use because it is more intuitive and as a result, training new AFM users is much easier."

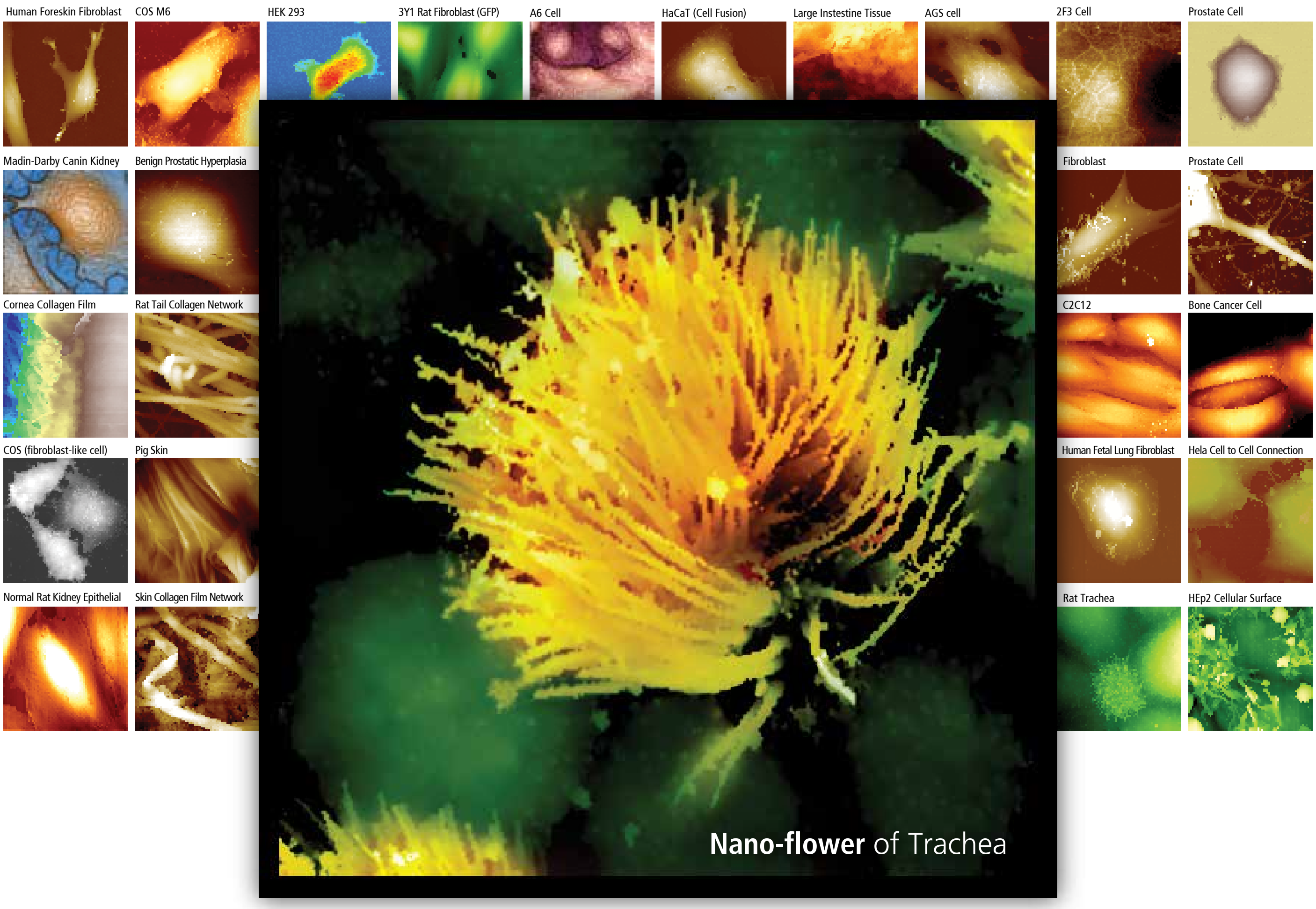
"We are so impressed with SmartScan's capabilities to enhance our research methodology because it eliminates the extensive training and time consuming operations required to obtain AFM images. Now, we are able to just think of what we need and in the next instant, the image is available, making our AFM analytical services easier and the AFM more fun to work with," comments, Dr. Byungki Kim, a Park AFM user.

SMARTSCAN™ PRODUCT HIGHLIGHTS

- **Saves You Time**
- **User-Friendly UX**
- **Easy to Find an Area of Interest**
- **Single-Click Imaging with SmartScan™ Auto Mode**
- **Speeds Up Imaging with AdaptiveScan™**
- **An AFM OS for everyone, from amateurs to experts**

Cell Discovery like Never Before

In-Liquid Biological Imaging with **Park SICM**



The main image above shows the world's first observation of tracheal tissue in aqueous condition. Scanning ion conductance microscopy (SICM) by Park Systems successfully imaged the trachael tissue's luminal surface. Both the ciliated and non-ciliated cells of tracheal tissue are pictured with a particular focus on the hair-like appearance of ciliated cells. A small piece of the tissue was obtained from Wistar rats, then mounted on a glass slide and imaged using Park NX-Bio, a three-in-one microscopy system that combines SICM, an AFM (atomic force microscope) and an inverted optical microscope.

By using the SICM of Park NX-Bio, Professor Ushiki and his team from the Microscopic Anatomy division of Niigata University Medical School captured the ciliated cells of rat trachea in liquid. "We can directly acquire cell and tissue images in liquid condition and the resolution is comparable with SEM," said Prof. Ushiki. "With SICM imaging technique, we don't need to take [the] risk of sample damage that is often caused during SEM sample preparation, causing image artifacts."

Prof. Ushiki has been active in histology and anatomy research using SEM and SICM. Park's SICM has made live cell imaging in liquid not only possible but also practical for his research and routine imaging needs.

The SICM works like this: A glass nanopipette filled with an electrolyte acts as an ion sensor. It provides feedback on its location relative to a sample completely immersed in liquid. The nanopipette tip maintains its distance from the sample by keeping the ionic current constant, applying no force on the sample surface. This way, unlike SEM or AFM, samples are not damaged at all or even disturbed by the nanopipette tip, and physiological morphology can be measured in liquid condition.

Park NX-Bio by Park Systems is a powerful 3-in-1 scientific research tool at nanoscale that uniquely combines the industry's only True Non-Contact AFM with SICM and an inverted optical microscope on the same platform. Park Systems provides its customers with a complete range of SICM solutions including the system, options and software, along with global service and support.

To learn more about Park NX-Bio or to schedule a demo, please call: +1 (408) 986-1110 or email inquiry@parkafm.com

www.parkAFM.com

Park SYSTEMS