INTERNATIONAL LINEAR COLLIDER - AN INTERVIEW WITH DR. LYN EVANS  p. 18

ENHANCED SURFACE POTENTIAL DETECTION STUDY USING FM-SKPM p. 15

ROOM TEMPERATURE MAGNETISM IN A FLAT LAND - TRANSITION METAL DICHALCOGENIDE  p. 9

POLYMER BASED SEMICONDUCTORS  p. 6

TOOTH WHITENING STUDY USING PINPOINT NANOMECHANICAL MODE OF PARK AFM  p. 12
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The 3D overlay of the surface potential image on topography displaying the surface charge and charge position of a polymer patterned array material deposited on silicon substrate analyzed using a Park NX10 AFM’s FM-SKPM is shown. The areas on the sample surface composing of relatively more negative charges appear darker. By taking advantage of phase input based two lock-in technique, compared to conventional SKPM techniques, the FM-SKPM (Frequency Modulation Scanning Kelvin Probe Microscope) can achieve higher signal to noise ratio and map out surface potential distribution of different materials with much improved lateral image resolution and surface potential data accuracy.
Welcome to another issue of NanoScientific.

International collaboration has played an important role in the development of nanotechnology. Scientific research knows no boundaries as we are on the brink of discoveries that change our lives.

Nanoscience is the study of the interaction, composition, properties and manufacturing methods of materials at the nanometer scale. Nanoscience facilitates the integration of many disciplinary areas of scientific research and directly impacts every sector of our economy.

Through international cooperation, nanoscience is a growing research priority in many countries, forming a massive global think tank of scientists and researchers blazing trails into our future.

In this issue, we present an article on the work of Dr. Alberto Salleo at Stanford University. His inspiring work with polymer based semiconductors has already laid a foundation for future innovative products in biomedical and neuro computing.

We also feature an article by RPI Applied Physics and Astronomy professor, Dr. Gwo-Ching Wang on Room Temperature Magnetism in a flat land—Transition metal dichalcogenide.

As the tools to “see” at the nanoscale continue to advance, scientific discoveries are setting an unprecedented pace for human progress.

We hope you enjoy this issue of NanoScientific, please share your feedback and story ideas.

Keibock Lee
Editor-in-Chief

Developing new instruments to be able to “see” at the nanoscale is a research field in itself. Shown here is the tip of an atomic force microscope (AFM), one of the foremost tools for imaging, measuring and manipulating matter at the nanoscale. Here, a platinum electrode measuring one hundredth of a nanometer has been deposited on the tip of this pyramid-shaped AFM tip via focused ion beam (FIB) deposition. (Image: C. Menozzi, G.C. Gazzadi, S3 (INFN-CNR), Modena. Artwork: Lucia Covi)
Dr. Alberto Salleo
Associate Professor Materials Science & Engineering, Stanford University

Professor Salleo received his Laurea degree in Chemistry from the University of Rome and his M.S. and Ph.D. in Materials Science from UC Berkeley investigating optical breakdown in fused silica. He spent 5 years at the Palo Alto Research Center as a postdoc and then a member of the research staff in the Electronic Materials Laboratory before joining the Department of Materials Science and Engineering at Stanford University in 2005. Dr. Salleo has been a Principal Editor of MRS Communications since 2011.

While at Stanford, Salleo won the NSF Career Award, the 3M Untenured Faculty Award, the SPIE Early Career Award and the Tau Beta Pi Excellence in Undergraduate Teaching Award and the Gores Award for Excellence in Teaching, Stanford’s highest teaching honor. He has been a Thomson Reuters Highly Cited Researcher in Materials Science (top 1% cited scientists) since 2015.

The Salleo Research Group is interested in novel materials and processing techniques for large-area and flexible electronic/photonic devices. They also study defects and structure/property relations of polymeric semiconductors, as well as nano-structured and amorphous materials in thin films.

**Polymer-based Semiconductors and Neuromorphic Devices**

Organic electronic materials offer an attractive option for polymer based semiconductor systems and could provide biocompatible and relatively inexpensive neuromorphic devices with low-energy switching and excellent tenability paving the way for neuromorphic computing to address the inherent limitations of conventional silicon technology in dedicated machine learning applications.

As Moore’s scaling law reaches an end, new brain-like (neuromorphic) computing architectures that embed memory and computation into a single device are highly sought after. Traditional semiconductor memory technology has yet to satisfy the needs of the “artificial synapse” that is the core of the neuromorphic computing architecture. This group uses organic semiconductors to mimic synaptic behavior in an electrochemical organic neuromorphic device (ENODe), which couples ionic and electronic currents to emulate the strength of neuron-to-neuron connections. The high linearity and low switching energy of ENODEs make them highly suitable for massively parallel neural algorithm accelerators, i.e. brain-like computer chips. Salleo’s research group focuses on leveraging the ionic/electronic transport properties of polymeric semiconductors to design novel devices for neuromorphic computing.

“In the electrical field there are ions and electrons moving in a field. The motion of the ions is transduced as sensors, thereby being used as electrochemical sensors. In the case of wearable sensors such as a “sweat sensor”, organic material which is able to carry both ions and electrons is used and a blend is used which carries ions. New polymers are always being tested as well as material that can carry ions, electrons or both. The advantage of organic polymers is the low cost and flexibility,” explains Dr. Salleo.
**Q & A WITH DR. ALBERTO SALLEO,**  
Associate Professor Stanford  
Department of Materials Science and Engineering, Geballe Laboratory for Advanced Materials; Principal Editor MRS Communications

**What imaging tools such as AFM do you use to study defects and properties/structures and is accurate imaging at nanoscale crucial in your research?**  
We typically use standard tapping mode AFM and look at both topography and phase. Accurate imaging at the nanoscale is crucial as we often work with materials that have very small microstructural features (e.g. polymer crystallites, phase separation), which control the functional properties of the materials.

**Can you give a few examples of how you use AFM in your research?**  
We have used conductive tip AFM to study the distribution of dopants in doped conjugated polymers. We have also used tapping mode AFM to study the terracing of crystalline organic semiconductors and the topography of grain-boundaries.

**What capabilities in AFM are most significant to assist you in research?**  
For general use, measuring roughness is important for us. Lately we have been interested in other capabilities such as the ability to measure current, electrochemical AFM and the possibility of using AFM in water.

**In the future, what advances in AFM and nanometrology can you envision that would significantly improve the functionality?**  
Multimodal capabilities (i.e. measuring several properties simultaneously) would improve the study of functional materials as we often look for correlations between different materials features.

**What are the next significant advances you see in material science research and how will they impact society?**  
I think the integration of materials with living matter is poised to have an enormous impact in healthcare and possibly even computation.

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**STANFORD RESEARCHERS, LED BY PROFESSOR SALLEO CREATE A HIGH-PERFORMANCE, LOW-ENERGY ARTIFICIAL SYNAPSE FOR NEURAL NETWORK COMPUTING**

Researchers at Stanford University and Sandia National Laboratories have made a progress that could help computers mimic one piece of the brain’s efficient design – an artificial version of the space over which neurons communicate, called a synapse.

“It works like a real synapse but it’s an organic electronic device that can be engineered,” said Alberto Salleo, associate professor of materials science and engineering at Stanford. “It’s an entirely new family of devices because this type of architecture has not been shown before. For many key metrics, it also performs better than anything that’s been done before with inorganics.”

The new artificial synapse mimics the way synapses in the brain learn through the signals that cross them producing a significant energy savings over traditional computing because the processing creates the memory. This synapse may one day be part of a more brain-like computer, which could be especially beneficial for computing that works with visual and auditory signals. Examples of this are seen in voice-controlled interfaces and driverless cars. “In looking at neuromorphic computing, companies design neuro electrochemical devices designed to emulate a synapse and neurotransmitters diffuse their device. The strength of the connection can be modulated like a synapse, making a network similar to the brain. As we approach the end of Moore’s Law in semiconductor like Carver Mead thought of 30 years ago, the advantage of neuromorphic computing is the very low power it requires, like a brain. Where I see this going is specialized chips instead of general purpose chips. For instance there can be a specific chip for computer vision. The silicon cmos chip is so powerful; I see neuromorphic chips as a compliment to them to augment this technology, not to replace it,” explains Dr. Alberto Salleo.
Organic electrochemical transistors (OECTs) are of high interest due to their ability to transduce ionic signals, such as those produced in biology, with relatively high gain at low operating voltages (<0.5V), making them ideal candidates for biosensing applications. Our group’s research spans from elucidating fundamental structure-property relations in mixed ionic-electronic-organic materials to developing novel wearable biosensors. We use characterization (i.e. synchrotron X-ray scattering, device modeling, spectroscopy, electrochemical measurements) to develop a fundamental understanding of organic materials for OECT devices. Extrapolating from fundamental principles, our group has developed various biomimetic membranes to selectively sense metabolites, ions and hormones from various bodily fluids including sweat and saliva.

In an article recently published in Science Advances (July 20, 2018), authors Onur Parlak, Scott Tom Keene, Andrew Marais, Vincenzo F. Curto and Alberto Salleo demonstrated the integration of an artificial receptor as a biomimetic polymeric membrane for stable and selective molecular recognition using OECTs to produce a wearable sweat diagnostics platform for real-time analysis of the human stress hormone cortisol. The group led by materials scientist Alberto Salleo at Stanford University has created a stretchy patch that applied directly to the skin, wicks up sweat and assesses how much cortisol a person is producing.

This wearable sensing device for cortisol detection was realized using a conductive polymer channel functionalized with a cortisol-selective membrane produced on a flexible and stretchable elastomeric substrate. The molecularly selective polymer-based membrane shows high chemical and physical stability at body temperature, as well as resistance to physical deformation. The presented sensor tolerates mechanical testing such as bending and stretching in conditions similar to those found in the normal range of motion of the human epidermis. Moreover, we used a simple strategy to generate a passive fluid control system consisting of a laser-patterned micro capillary channel array that provides fast and precise delivery of sweat directly to the sensor interface. The resulting wearable sensor was used for measuring cortisol concentration in a real human sweat sample collected during exercise. Considering that traditional blood analysis is often used for cortisol sensing, the wearable device provides many advantages including noninvasiveness, ease of operation, and user comfort.

“We are particularly interested in sweat sensing, because it offers noninvasive and continuous monitoring of various biomarkers for a range of physiological conditions,” said Onur Parlak, a post-doctoral scholar in the Salleo lab and lead author of the paper. “This offers a novel approach for the early detection of various diseases and evaluation of sports performance.”

“Wearable electrochemical sensor can analyze sweat which occurs under stress. The advantage of organic material is that it is soft and pliable, making it suitable for wearing. These sensors can detect heart beat, blood pressure, blood oxidation and create bio feedback mechanisms for precision medicine. Research being done now is testing wearable electrochemical sensors worn in socks and printed on textiles so they are transparent to the user by being printed on textiles with organic integration. Evaluation of common household items such as a toilet and a toothbrush to analyze bodily secretions could be the health detection devices of the future,” explains Dr. Alberto Salleo.

The Stanford team is currently working to miniaturize the device, and also hoping to develop a user interface that will assist in the evaluation of data. The team also wants to adapt the device so that it could be powered by harvested energy rather than by an internal battery. The device could be modified to detect other hormones and non-charged ions within sweat. The end goal is to have a device that is capable of monitoring several different biomarkers at the same time, which would help researchers and health professionals gain a more holistic, individualized representation of a person’s health and mental state.

(A) Molecular memory is introduced on the sensor surface by copolymerizing functional monomer and cross-linker in the presence of the analyte, which acts as a molecular template. After elution of the analyte, complementary binding sites are revealed complimentary in size and shape to template by creating molecular memory on the surface that allows specific rebinding of the target molecule. The recognition sites obtained in this manner have binding affinities approaching those demonstrated by antibody-antigen systems. Tapping-mode atomic force microscopy (AFM) analysis of cortisol-selective polymer (B) and its corresponding control (C). Scanning electron microscopy (SEM) images of cortisol-selective polymer (D and F) and its control (E and G) with two different magnifications. Pore size distribution for cortisol-imprinted (H) and nonimprinted polymers (NIPs) (I). The BJH method was applied to calculate pore size distribution from experimental isotherms using the Kelvin model of pore filling. The method applies only to the mesopore and small macropore size range.
In the past decade there has been a world-wide research interest in two-dimensional materials such as graphene (one layer of graphite), transition metal dichalcogenides (TMDCs), and 2D oxides (mica, layered Cu oxides, etc.)\(^1\). A bulk TMDC consists of a stack of MX\(_2\) monolayers. Each MX\(_2\) consists of X−M−X where M is a transition metal atom (Mo, W, V, Nb, etc.) sandwiched between two X chalcogen atoms (S, Se, or Te). See Fig. 1(a).

The out-of-plane interaction between MX\(_2\) is weak van der Waals (vdW) interaction and the in-plane interaction is strong chemical interaction.

Fig. 1 (a) Side view and (b) top view of a VS\(_2\) monolayer in octahedral 1T phase. The V and S atoms are in blue and gold, respectively. The red parallelogram is a two-dimensional unit cell. [From Ref. 8]

Among over 40 low-dimensional TMDCs, most are semiconducting dichalcogenides. Low-dimensional vanadium disulfide (VS\(_2\)) is one of the metallic dichalcogenides. On the theoretical side, first principles spin polarized density function theory (DFT) calculations predict that a large magnetic moment exists in a free standing VS\(_2\) monolayer form due to the quantum size effect\(^2\)\(^-\)\(^9\). DFT calculations also predict the existence of magnetic moments for a few monolayer thick VS\(_2\). These DFT predictions extended the potential of electrons in the controls and manipulations of electronic and magnetic properties of TMDCs that may enable electronic/spintronics applications.

The vdW TMDC crystals have been shown experimentally to possess many fascinating mechanical, optical and electronic properties. However, there have been fewer studies on the magnetic property of vdW TMDC crystals, because most TMDC crystals are nonmagnetic in the bulk forms. Practical methods such as defect engineering\(^1\)\(^0\) have been designed to extrinsically induce magnetism within these vdW TMDC materials with the hope to observe magnetism. The challenges in the synthesis of low-dimensional TMDCs are the control of thickness, size and stoichiometry. Take VS\(_2\) as an example. Hydrothermal\(^1\)\(^1\)\(^-\)\(^1\(^4\), liquid exfoliation\(^1\)\(^5\), and chemical vapor deposition (CVD)\(^1\)\(^6\)\(^,\)\(^1\(^7\) methods have produced VS\(_2\) nanosheets, nanoplates, and nanoflowers. These nanostructures have been applied in battery anodes\(^1\)\(^7\)\(^,\)\(^1\(^8\), supercapacitors\(^1\)\(^9\), moisture sensor\(^1\)\(^0\), and electrocatalytic hydrogen evolution reaction (generating hydrogen by splitting water)\(^1\)\(^4\)\(^,\)\(^2\(^6\). Despite the possibility that defects or impurities or substrates from these synthesis methods may contribute or influence the intrinsic magnetic property of nanostructure VS\(_2\), there are signs of magnetic signals from these nanostructures measured by vibrating sample magnetometer (VSM) or superconducting quantum interference device SQUID\(^1\)\(^1\)\(^1\)\(^,\)\(^1\(^2\), 20. One exciting work of monolayer (ML)
and nanoflowers. These nanostructures have been applied in battery anodes\textsuperscript{17, 18}, supercapacitors\textsuperscript{13}, moisture sensor\textsuperscript{19}, and electrocatalytic hydrogen evolution reaction (generating hydrogen by splitting water)\textsuperscript{14, 16}. Despite the possibility that defects or impurities or substrates from these synthesis methods may contribute or influence the intrinsic magnetic property of nanostructure VS\textsubscript{3}, there are signs of magnetic signals from these nanostructures measured by vibrating sample magnetometer (VSM) or super conducting quantum interference device (SQUID)\textsuperscript{11, 12, 20}. One exciting work of monolayer (ML) and few ML VSe\textsubscript{2} (Se is in the same chalcogens column) grown by molecular beam epitaxy in ultra high vacuum was reported to show strong room temperature ferromagnetism measured by VSM and surface magneto optical Kerr effect (SMOKE) \textit{ex situ} using a Se capping layer\textsuperscript{21}.

We have used CVD targeting at synthesizing monolayer and ultrathin VS\textsubscript{2} films and search for room temperature ferromagnetic ordering in the films. The precursor used was VCl\textsubscript{3} and sulfur vapor came from heated S powders. The growth parameters were systematically tested by varying the S powder amount, VCl\textsubscript{3} precursor amount, carrier gas type, carrier gas flow rate, heating zone temperatures and the growth duration. Under the optimum CVD growth condition various sizes and thicknesses of flakes were observed on SiO\textsubscript{2} substrate. Flake sizes ranged from a few microns to about 100 microns. The flake thicknesses ranged from sub-tens nm to 200 nm. Fig. 2(a) is an example of many large and thick flakes on SiO\textsubscript{2}. Monolayer and bilayer were also observed but rare. The surface of the large flake is smooth as seen in the 50 μm × 50 μm AFM image in Fig. 2(b). Figure 2(c) shows a height scan along the white line on the surface of the flake in Fig. 2(b). The height variation is within one or two nm over 50 μm. On the surface there are 3 nm spikes occasionally observed.

The Energy Dispersive Spectroscopy of these flakes shows approximately 1 to 2 stoichiometry ratio of V to S with slightly V rich.

To study the magnetic property of ultrathin VS\textsubscript{2} flakes on SiO\textsubscript{2} substrate, we use AFM first to identify the flake and then measure the magnetic phase contrast using magnetic force microscopy (MFM) at room temperature. A Park Systems NX20 scanning probe microscope with a Park MFM cantilever (k ~ 2.8 Nm\textsuperscript{-1}, selected frequency ~ 75 kHz, CoCr coated with nominal coercivity ~ 400 Oe) was used for MFM measurements.

Both the sample and tip were magnetized by a ~ 500 Oe permanent magnet prior to image collection. The MFM\textsuperscript{22} data collection began with a traditional non-contact AFM scan to map the sample’s topography by measuring the attractive van der Waals forces between the sample and the probe tip\textsuperscript{23}. After acquiring the topography data, the tip was lifted to a pre-set distance (typically 20 – 50 nm) beyond the influence of the vdW forces. It then followed the collected topography line scan to maintain a constant sample-probe distance and detected the magnetic interactions via a shift in the cantilever’s vibrational phase.

Figure 3 shows an AFM topography and MFM phase maps of a VS\textsubscript{2} flake on SiO\textsubscript{2}. The optical image (not shown here) indicates an ultrathin flake with a diameter of about 20 μm that is visible due to an optical interference with the 300 nm SiO\textsubscript{2}/Si substrate. Figure 3(a) shows a AFM topography scan revealing the flake thickness to be ~ 4.7 nm thick, corresponding to eight S-V-S layers. MFM phase map of the area shown in (a), collected at a lift height (L) of (b) 25 nm and (c) 50 nm. Scale bars in (a) is 1 μm.
To demonstrate the dependence of MFM phase contrast on the sample-tip distance, data were collected at the lift heights (L) of 50 nm shown in Fig. 3(c). Qualitatively, the interferential phasecontrast decreases with an increase in L. Averaging over approximately 50 line scans in the framed box across the faucet/substrate interface ensures the data’s reliability and provides optimal signal-to-noise ratio. The decay of the MFM phase shift with an increase in lift height likewise indicates a decrease in the attractive force between the tip and sample, consistent with what one would expect for a magnetic interaction. The observation of the MFM phase signal reveals the existence of ferromagnetism in the ultrathin VS$_2$, film consistent with density functional theory calculations. This negative MFM phase shift was reproducibly measured for several flakes ranging in thickness from 5 nm to 20 nm with consistent results. In fact, slightly stronger phase signal (indicating stronger magnetization) was measured as thickness decreased, consistent with the theoretical predictions.

Through the use of magnetic force microscope, room temperature ferromagnetism has been detected in ultrathin VS$_2$ crystalline flakes grown by CVD. This property does not exist in the bulk VS$_2$ material, but arises due to quantum confinement effects resulting from a reduced dimensionality. This is in significant to both fundamental physics, of which the study of ultrathin layered materials (and specifically transition metal dichalcogenides such as VS$_2$) is a field attracting much attention. We learned that CVD growth of low-dimensional VS$_2$ materials, including monolayer (ML) thickness, remains challenging. A better controllable method to grow monolayer VS$_2$ is molecular beam epitaxy in ultra high vacuum. Different monolayer of magnetic TMDC can be stacked to form artificial heterostructures that have the potential application to emerging research areas including future high density storage and spintronics.

**Acknowledgement**

The growth of ultrathin VS$_2$ flakes was performed by Z. Li and A.J. Littlejohn. The AFM and MFM images were collected by A.J. Littlejohn with the assistance from Dr. Wengying Shi at Park Systems. Graduate student Yu Xiang (see photo) uses AFM extensively for morphological study of graphene and TMDC materials. He gave a talk entitled “2D Materials in Real and Reciprocal Spaces: Complimentary AFM and RHEED Studies” at the NanoScientific Symposium on SPM in Sept. 2018. This work is supported by the New York State’s Empire State Development’s Division of Science, Technology and Innovation (NYSTAR) through Focus Center Contract C150117.

**References**

TOOTH WHITENING STUDY USING PINPOINT NANOMECHANICAL MODE OF PARK AFM

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Park Systems Inc., Santa Clara, CA USA

Introduction
In recent years, the importance of mechanical properties measurement has become evident in various applications, ranging from understanding and screening of integrated circuit failure mechanisms of microelectronics, to diagnosis of diseases in the field of medicine, and to the development of restorative materials for human teeth [1-3]. However, during the measurement, some samples when pressed with too much force can lead to surface deformation and change in its surface characteristics that may result in inaccurate measurements. Moreover, since the sizes and features of interest in functional materials are continuously shrinking down to nanoscale level, and given that material failures start from atomic lattice structures, conventional techniques used in materials characterization are no longer adequate in identifying defects and abnormalities on material surfaces as they only allow up to millimeter range measurements. For these reasons, a next generation characterization tool that is benign and allows for nanoscale measurements is greatly needed. Recently, a new operational AFM mode developed by Park Systems called PinPoint Nanomechanical mode [4] offers researchers an innovative solution to these problems. This technique operates by moving the tip horizontally and moving down vertically in approach-retract manner with only few nano-Newton force. This ensures a frictionless operation that eliminates the lateral force due to continuous tip-sample contact. Furthermore, it preserves tip and sample condition. At each point of the image, force-distance curve is acquired and used to calculate the mechanical characteristics of the sample. During the data acquisition, the XY scanner stops, and the contact time is controlled to give enough time for the scanner to acquire precise and accurate data with nanoscale resolution. Every material structure deteriorates over time when kept in natural setting. Such changes originate from a point defect at the nanoscale level. This applies to the teeth whitening process. Everyone who whitens teeth desires for the teeth to remain whitened without redoing it often. Thus, to realize this, one must know how the topological and mechanical changes take place on the surface of teeth at the nanoscale level. In this study, PinPoint Nanomechanical mode was used to acquire topographical and mechanical data of a tooth sample to understand the effect of tooth whitening strips on the tooth’s mechanical and topographical properties. The results show that tooth whitening strips lead to a decrease in tooth roughness and an increase in modulus and adhesion. This newly developed technique by Park Systems enables researchers to investigate the topographical and mechanical properties variations of different varieties of samples at nanoscale level.

Experimental
A tooth sample was analyzed using a Park NX10 AFM [5] under ambient air condition. PinPoint Nanomechanical mode with AC160TS cantilever (nominal spring constant k = 26 N/m and resonance frequency f = 300 kHz) [6] was used in the measurement to acquire topography and mechanical signals.

Before undergoing AFM scanning, the tooth was treated by placing it in deionized water and leaving it to sit for 30 minutes followed by placing it in 50% by volume isopropyl alcohol for 2 minutes, then rinsing it again in deionized water. Compressed air spray was used to dry off the tooth. This was in attempt to remove “debris” and “dirt” from the teeth that may have accumulate on to the teeth over the time. Figure 1 shows the setup of the experiment. A carbon tape and super glue were used to stabilize the sample during imaging. Tooth was placed onto a magnetic disk and stuck to double sided carbon tape. To be sure that the tooth was secured so that it would not move while taking measurements, a toothpick was placed to hold the tooth upward so that an area of the tooth would be leveled for examination. Super glue was used for extra stability.

To validate the acquired modulus values, a reference sample was used. The sample was a PS-LDPE blend film (polystyrene and polyolefin elastomer). The scan parameters were set such that the modulus measurements were measured to be ~2.0 GPa for the PS matrix, and ~0.1 GPa for the circular features that appeared in the modulus images that are blended into the matrix—which were in agreement with the manufacturers’ description of the PS-LDPE sample [7]. Figure 2 shows the 15 µm x 15 µm acquired modulus images of PS-LDPE reference sample. The images were analyzed using Park XEI software developed

Figure 1. Experimental set up of the tooth sample. Tooth underneath Park NX10 AFM system (above). Tooth with AC160TS cantilever (anded onto sample (below)
by Park Systems which mapped the acquired signals to a color table. The darker regions (color black in Fig. 2 left) with circular features represent the areas with lower modulus values while the lighter regions (color brown in Fig. 2 right) with flat surface known to be the PS matrix are the areas with higher modulus. All areas with purple color mean that these areas are excluded in calculating the mean modulus value. The calculated elastic modulus mean of the LDPE copolymer region is 0.116 GPa while for the PS polystyrene flat region is 2.039 GPa.

After the reference sample measurements were taken, the tooth was placed under the Park NX10 AFM with the same tip used for reference sample measurements. For statistical relevance, three measurements were taken at three different teeth surfaces of the same teeth sample that could be found using the optical microscope built in to the Park AFM. Measurements were taken in areas of the tooth no farther than 500 microns apart so that roughly the same area are imaged consistently. These measurements were performed using the same scan parameters as were used for the PS-LDPE reference sample. These parameters were utilized because under those conditions, the AFM recorded accurate modulus values.

To whiten the tooth sample, whitening strips were used [8]. One strip was applied onto the tooth surface and left to sit for the recommended 1-hour period. After this, the tooth was rinsed in deionized water and dried off with compressed air spray. A total of 3 whitening strips were used as the final whitening.

**Results and Discussion**

The representative topographical and mechanical images acquired in the experiment are presented on Table 1. The images are analyzed using the Park XEI software. The quantitative results of surface roughness and mechanical properties are shown in Table 2. The experimental values of the elastic modulus before and after the whitening process are compared on the previous studies [2]. The tooth is composed of three major layers, known as the enamel, dentin, and cementum. These layers are found in the respective order: enamel at the surface, dentin underneath the enamel, and cementum underneath the dentin. Based on the existing studies, the elastic modulus of the top layer of the tooth was found to be 1.3382 ± 0.3079 GPa. The measured value of the elastic modulus before the whitening process was 1.072 GPa and it increased up to 1.571 GPa after the process. Same trend is observed on the adhesion energy values wherein the measured adhesion energy prior to the process was 0.196 fJ and it increased to 1.608 fJ after the whitening process. On the other hand, the surface roughness is observed to be in decreasing trend wherein the surface roughness prior to the process was 201.0 nm while the...
value for surface roughness after the process was 38.33 nm.

Tooth whitening via whitening strips is known to work by reacting the hydroxide chemicals on the strip with the staining molecules known as chromogens on the surface of the tooth. This reaction is known as oxidation. The oxidation causes the chromogen molecules to break down when gaining electrons from the hydroxide, causing it to split into molecules that do not reflect light and can be removed from the tooth later. As for whitening treatment, expectations based on previous studies were that the hardness would fall, and the roughness would increase with more whitening applied [9-10]. This experiment however found that the roughness decreased and modulus increased. A possible explanation would be that the hydroxide oxidation smoothed out the surface as staining chromogen molecules would be removed from the tooth, while modulus increased since the chromogens had a lower modulus than the enamel itself.

### Conclusion

The topography and mechanical data of the tooth sample was successfully acquired using PinPoint Nanomechanical mode on Park NX10. Based on the data acquired through this testing, PinPoint Nanomechanical mode found that its method of characterizing mechanical properties of the tooth matched and agreed with mechanical properties found in other methods such as macro and microindentation. It was also found that the tooth roughness decreases and the elastic modulus as well as the adhesion properties increase after it had undergone whitening process. Overall, PinPoint Nanomechanical Mode AFM technique is an ideal approach to characterize and quantify mechanical properties at nanoscale, with best precision and maximized tip life due to its frictionless and to the point operation.

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Alvin Lee is an intern, undergraduate student from Worcester Polytechnic Institute, Worcester, MA.
ENHANCED SURFACE POTENTIAL DETECTION STUDY USING FREQUENCY MODULATION SKPM

John Paul Pineda, Charles Kim, Cathy Lee, Byong Kim, and Keibock Lee
Park Systems Inc., Santa Clara, CA USA

Introduction
Scanning Kelvin probe microscopy (SKPM) is a tool used to measure work function and local electrical potential distribution of various materials with nanoscale features. The most common application of this technique is the study of electronic properties of semiconductor nanostructures and surfaces. Potential profiling of such materials composed of negatively or positively changes are some of the measurements that can be done using this technique at nanoscale lateral resolution. Implementation of such technique to unveiling the variation of charge distribution that occurs on the nanoscale helps to better understand and improve the performance of CMOS semiconductor devices. [1-2] The SKPM has also been instrumental in characterizing and determining the quantitative physical information such as the total charge and charge position of polymer materials. [3, 4] There are other surface potential or work function measuring tools that have been introduced, such as electron beam induced current (EBIC), scanning electron microscopy (SEM), and photoelectron spectroscopy (PES). However, some of these techniques are only applicable for inorganic types of semiconductor samples, some are destructive and require high vacuum, while others don’t provide high enough spatial resolution. [5] Compared to other techniques, SKPM is a nondestructive and air-ambient compatible technique, which is undoubtedly one of the easiest to use electrical failure analysis and nano metrology tool available in the market today. Conventional SKPM technique (also known as Amplitude Modulation AM-SKPM) has already made remarkable contribution in maintaining device reliability and analysis of advance materials compared to other measurement techniques. However, there is room for improvement in the signal to noise detection ability of AM-SKPM technique such that even the features having less optimal surface potential strength can be detected and mapped out with higher lateral resolution and accuracy. Toward this end, recently, Park Systems has developed a technique called Frequency Modulation FM-SKPM with Atomic Force Microscope (AFM). This technique is useful for electrical characterization allowing measurements with better sensitivity compared to AM-SKPM. In this study, a polymer material is measured to compare the performance of AM-SKPM to FM-SKPM. The results acquired in the experiment show that FM-SKPM is significantly more sensitive compared to AM-SKPM in measuring both work function and surface potential distribution of different materials.

Experimental
A polymer patterned array material deposited on Silicon substrate was analyzed using a Park NX10 AFM. Two separate scans were conducted to acquire AM-SKPM and FM-SKPM measurements. The scan parameters and the tip used in acquiring images were all the same. A conductive Mikromasch NSC36Cr-Au cantilever (nominal spring constant k = 1 N/m with resonant frequency f = 90 kHz) was used in the experiment.

Figure 1. Diagram of FM-SKPM
In SKPM mode, there are two interaction forces between the AC biased tip and the sample: the electrostatic force and the Van der Waals force. The Van der Waals force is harnessed to generate the sample’s surface topography while the electrostatic force between the tip and sample generates data for the sample’s electrical properties. The obtained cantilever deflection signal contains both sets of information; therefore, a method that can completely separate these signals is the key to successful imaging. In Park NX10, lock-in amplifiers embedded to its electronics are used to separate the signals. This allows for the acquisition of both topography and EFM data simultaneously. Two amplifiers are used by the system, named lock-in 1 and lock-in 2. Lock-in 1 obtains the topography information by analyzing the tip motion caused by the Van der Waals interaction, while lock-in 2 obtains electrical property information by analyzing the frequency of the applied AC voltage signal to the tip which, in turn, generates an electrostatic force interaction with the sample. The frequency of the applied AC voltage signal is chosen to be smaller (5 - 20 kHz) than the cantilever oscillation frequency (70 - 330 kHz), enough so that the two signals do not interfere each other. In FM-SKPM setup [6], the NCM phase signal of Lock-in 1 is transferred to Lock-in 2 to serve as a source for EFM operation by connecting BNC cable between ‘Aux2 out’ and ‘Aux1 in’ shown in Figure 1. Furthermore, a separate DC bias was applied to the cantilever and controlled to create a feedback loop that would zero out the electrical oscillation between the tip and the sample caused by the application of an AC bias to the cantilever. The value of this offset DC bias that zeroes out the AC bias-induced electrical oscillation is considered to be a measure of surface potential.

**Results and Discussion**

The topography data obtained in this experiment show that polymer patterned array with square-like features were successfully deposited on silicon substrate, but showed no significant information related to its surface potential. In contrast, the surface potential data acquired in AM-SKPM and FM-SKPM show the surface potential structure, but shows no significant information related to physical structure of the sample. The domain structure shape observed in SKPM data of the sample was similar to the physical structure observed in topography data, which was a patterned array consisting of square dots. The data acquired in this experiment were all analyzed using Park XEI software. Figure 2 shows the topography (left), FM-SKPM (center), and AM-SKPM (right) images of the polymer patterned array sample. The topography data can be acquired simultaneously with the SKPM data. In Figure 2, the topography image presented was acquired simultaneously with the AM-SKPM image. The topography shows a clear image of a well-defined lattice structure. The Park XEI software maps the acquired signals into a color table. In the topography image, the square-like features that appear to have a brighter color represent the areas with higher surface potential while the flat surface with brighter color represent the areas with higher surface potential. By comparing the surface potential results acquired from AM-SKPM and FM-SKPM, one can easily determine that FM-SKPM has better sensitivity in detecting surface potential variation compared to AM-SKPM. In this experiment, FM-SKPM technique provided a higher resolution image that shows sharper edges of the square features compared to AM-SKPM. In addition, FM-SKPM was able to detect weak potential in the irregular surface while AM-SKPM was not able to detect any potential variation.

The line profile that was generated by the XEI software in Figure 3 (bottom) provides the potential information of the polymer patterned array. The line profile for the FM-SKPM is indicated in color red while the line profile for AM-SKPM is indicated in color green. The line profile of the FM-SKPM image clearly shows that there is a slight change in potential (encircled in red) in the irregular surface compared to the areas next to it. On the other, the line profile of AM-SKPM doesn’t show any changes of potential in that surface. By comparing the line profile of the two techniques, it can be concluded that FM-SKPM is at least an order of magnitude more sensitive than the conventional SKPM technique also known as AM-SKPM. A slight decrease in potential (encircled in red) in the irregular surface compared to the areas next to it. On the other, the line profile of AM-SKPM doesn’t show any changes of potential in that surface. By comparing the line profile of the two techniques, it can be concluded that FM-SKPM is at least two orders of magnitude more sensitive than conventional AM-SKPM technique.
Conclusion

The polymer patterned array was successfully characterized using both the conventional method of SKPM (AM-SKPM) and FM-SKPM imaging on Park NX10. The topography data reveals that the sample surface is composed of patterned array with square-like features. Irregularity in the patterned array is observed on both AM-SKPM and FM-SKPM images. However, while FM-SKPM technique shows that the irregularity in the surface pattern is a surface with weak potential, the AM-SKPM was not sensitive enough to detect the weak potential in the same region. From the above results, it can be observed that FM-SKPM is an order of magnitude more sensitive compared to AM-SKPM and it is more useful in detecting surface potential variations. Furthermore, the increased sensitivity of FM-SKPM increases the chance of detecting defects with better resolution and accuracy in semiconductor devices and other advanced materials.

REFERENCES

THE INTERNATIONAL LINEAR COLLIDER: THE NEXT STEP IN UNDERSTANDING OUR UNIVERSE

Lyn Evans, CERN physicist. Lyn Evans (born 1945) is a Welsh physicist who became one of the leaders of the Large Hadron Collider (LHC) particle accelerator at CERN, the European particle physics laboratory. At left is part of the ring in which particles are accelerated to near the speed of light and then collided in detectors. Experiments carried out at the LHC intended to discover the Higgs boson led to the announcement of the discovery of a Higgs-like particle in 2012. Evans and other CERN physicists have received awards in recognition of this work, including the Fundamental Physics Prize in 2012. Photographed in 2008.

AN INTERVIEW WITH LYN EVANS, WHO LED THE PROJECT TO BUILD CERN AND IS NOW THE DIRECTOR OF THE INTERNATIONAL LINEAR COLLIDER COLLABORATION

A new era of discovery in particle physics opened in November 2009 with the start-up of the Large Hadron Collider at CERN in Geneva, Switzerland. Based on experiments and discoveries over the last decades, physicists believe that the Terascale will yield evidence for entirely new forms of matters, and possibly even extra dimensions of space. This new matter includes the Higgs particle, as well as the possibility of an extended family of elementary ‘superparticles’, the heavier cousins of the particles we already know. Lyn Evans joined CERN at 24 and after 40 years with CERN, he is now the Director of Linear Collider Collaboration and on brink of announcing the next generation Higgs Factory, the International Linear Collider Project proposed to be built in Japan as a world-wide collaboration to discover new physics.

“The idea of an International Linear Collider is not a new one,” explains Lyn Evans, who has been a champion of this project for many years. “In March, 2013, Lyn Evans paid a courtesy visit to Japan’s Prime Minister Shinzo Abe. The Prime Minister acknowledged the significance of the linear collider project for the whole of humankind. Given that it is an international project, he said he needed to monitor the development closely and would continue to investigate the role of Japan. While physicists agree that The International Linear Collider is essential for the next step in understanding our universe, Japan has been studying the idea for years. Recently, at the ILC technology development symposium held in Tokyo June 25, 2018, Lyn Evans stressed that, “Accelerator technology continued to develop thanks to accelerator research facilities brought online in the US, Europe, and China. This means we are in a good place to develop momentum to get [international] cooperation for the ILC.” Next year, the board of directors at CERN will begin deliberations on the next 5-year strategy for particle physics in Europe, so “this is a very crucial period. The Japanese government must make their intentions clear.”
The idea of an International Linear Collider is not a new one," explains Lyn Evans, who has been a champion of this project for many years. In March, 2013, Lyn Evans paid a courtesy visit to Japan’s Prime Minister Shinzo Abe. The Prime Minister acknowledged the significance of the linear collider project for the whole of humankind. Given that it is an international project, he said he needed to monitor the development closely and would continue to investigate the role of Japan. (Photo top right): Kicking things off in Tokyo, in 2013, Linear Collider Board Director Sachio Komamiya hands over the ILC Technical Design Report to Lyn Evans, Linear Collider Collaboration director.

With this deadline approaching, things are speeding up. It is very natural for this accelerator to be cited in Japan. In the 1930’s Japan took an early lead in particle physics and in recent decades they have continued to be important players in experimental physics.

Based on recent exciting news from the Governors Meeting in Japan, Evan's dream may soon become a reality. "It is a great time for Japan to take a leading role in Linear Collider technology. The whole world will benefit from the data it will produce," stressed Evans.

Japan Governors Agree to Push for the Realization of the ILC

On October 31st, 2018, the meeting for the governors of Hokkaido and the Tohoku region was held in Kaminoyama City, Yamagata Prefecture where a resolution was unanimously passed to push for the realization of the ILC, which is the first time this meeting has passed a resolution solely focused on the ILC. The resolution calls for the national government to make their stance clear on investment in the ILC and other international cost-sharing measures as soon as possible. Governor Tasso said, "It’s a crucial time right now, as we have to get the ILC into Europe’s next 5 year plan for particle physics. Those preparations begin in January 2019." Governor Tasso said, "It’s extremely significant that we passed a resolution solely about the ILC. We will call upon all of the governors and related organizations in Tohoku to encourage the national government to make a decision as quickly as possible."

What is the International Linear Collider?

The International Linear Collider will give physicists a new cosmic doorway to explore energy regimes beyond the reach of today’s accelerators. A proposed electron-positron collider, the ILC will complement the Large Hadron Collider, a proton-proton collider at the European Center for Nuclear Research (CERN) in Geneva, Switzerland, together unlocking some of the deepest mysteries in the universe. With LHC discoveries pointing the way, the ILC – a true precision machine – will provide the missing pieces of the puzzle.

Consisting of two linear accelerators that face each other, the ILC will hurl some 10 billion electrons and their anti-particles, positrons, toward each other at nearly the speed of light. Superconducting accelerator cavities operating at temperatures near absolute zero give the particles more and more energy until they smash in a blazing crossfire at the centre of the machine. Stretching approximately 31 kilometres in length, the beams collide 14,000 times every second at extremely high energies – 500 billion-electron-volts (GeV). Each spectacular collision creates an array of new particles that could answer some of the most fundamental questions of all time. The current baseline design allows for an upgrade to a 50-kilometres, 1 trillion-electron-volt (TeV) machine during the second stage of the project. There are also plans for a staged approach starting with a 250-GeV Higgs factory to study the properties of the particle discovered at the LHC in 2012 and then upgrading to 500 GeV.

This century, while physicists have discovered more than ever before, at the nanoscale, they can still not fully explain the origin of mass and can only account for a surprising five percent of the universe. The remaining 95 percent, the mysterious dark matter and dark energy is what the proposed International Linear Collider could explain. Not to exclude the potential of new forms of matter, new forces of nature, new dimensions of space and time and even extra dimensions.
China Electron Positron Collider (CEPC) – Plans Well Underway

China’s plans to build a huge underground ‘Higgs factory called the China Electron Positron Collider that will be a successor to the Beijing Electron Positron Collider at the Institute of High Energy Physics in Beijing, which is expected to shut down in 2020. Plans are well underway with a conceptual design report for the China Electron Positron Collider that calls for a 100 km underground tunnel that would smash together electrons and positrons at energies of 240 GeV. If built, this will be the largest electron-positron collider with a circumference of 100 km with a precision down to 1%, allowing scientists to probe into new physics.

Does the world need two Higgs Factories?

“The world could accommodate two Higgs factories,” states Yifang Wang, director of China’s Institute of High Energy Physics in an interview with Physics World. The ILC can only host one detector at any given time. We think that the world needs at least two detectors. So, in principle, we could have two Higgs factories and a minimum of two detectors, maybe three. It very much depends on future support from the international community and the respective governments. By the end of this year the Japanese government is expected to decide about the ILC. I think it’s not too late for us to then decide afterwards to go ahead with the CEPC.”

Exciting Developments at CERN

On June 4, 2018, CERN released new results from the ATLAS and CMS experiments at the LHC revealing how strongly the Higgs boson interacts with the heaviest known elementary particle, the top quark, corroborating our understanding of the Higgs and setting constraints on new physics. The Higgs boson interacts only with massive particles, yet it was discovered in its decay to two massless photons. Quantum mechanics allows the Higgs to fluctuate for a very short time into a top quark and a top anti-quark, which promptly annihilate each other into a photon pair. These results tell scientists more about the properties of the Higgs boson and give clues for where to look for new physics.

“The superb performance of the LHC and the improved experimental tools in mastering this complex analysis led to this beautiful result. It also shows that we are on the right track with our plans for the High-Luminosity LHC and the physics results it promises.” CERN Director for Research and Computing Eckhard Elsen

“The huge mystery now is that we only understand about 5% of our universe. My greatest wish before I die is to get a hint of what dark matter is.”

Lyn Evans led the project to build CERN’s Large Hadron Collider (LHC) from its inception in 1994 until start-up on 10 September 2008. The LHC, which is the world’s highest energy particle accelerator, is the Organization’s latest flagship research facility. It is poised to provide new insights into the mysteries of our universe. Nations from around the globe have contributed to the construction of the accelerator and its experiments.
Hosted by University of Texas Arlington, the International Workshop on Future Linear Colliders held Oct. 22-26, brought together enthusiastic supporters that form an international foundation for the advancing project. Scientists attending the workshop, issued a strong conviction to give unbridled support to the ILC with a written “Texas Statement”, which says in part, “Together with colleagues around the world, we hereby issue this ‘Texas Statement’ with unshakable conviction on its scientific case and to express our strong commitment to do whatever necessary for its success. The international community represented by the participants of LCWS2018 is committed to bring the ILC to its fruition. Once the expression of intention to host the ILC is issued by the Japanese government, we will greatly expand our own efforts and work with our respective governments ever more intensively to help achieve the necessary international agreements. We eagerly await the signal to proceed and, when the ILC starts in earnest, we will be ready to carry through on its promise.”

In tandem, the support offered from Japan to be the host of the ILC promised a swift outcome. In a video address at the workshop by the Honorable Shintaro Ito, Member of the House of Representatives of Japan, he declares that the “ILA is an international project that has no boundaries, and it is open to personnel from all over the world.” And he further adds, “Japan will be proud to host such a project. It will produce the science and technology to create a better world.”

Adding that he believes it is the time for Japan to stand up and lead the ILC project, he presented the many meetings and discussions leading up to the workshop including the creation just last month by the Liberal Democratic Party of a new organization, called the Liaison Committee for Realizing the ILC which brings together various strategic groups involved in making important policies, such as science technology and innovation, regional revitalization, reconstruction from natural disasters, and national resilience. The Liaison Committee formulated their strategy to realize the ILC, by integrating the ILC project across various important policies for Japan and is working with Party members, and the Prime Minister and his Cabinet, so that the Expression of Interest can be delivered in time.

Honorable Shintaro Ito also discussed international funding and several meetings including in France and Germany and on October 10th, a very positive meeting with Under Secretary for Science of DOE in the US who said, “If the Japanese government decides to go forward with the ILC, the DOE will find it very positive, and they will participate and contribute to the project management and technology aspects. He also said, he looks forward to engaging with members of Congress, governmental figures, and others in Washington to get support for the ILC project.”

Honorable Shintaro Ito closed his statement by saying,” I sincerely believe we will be able to realize it together.”

Lyn Evans and scientists across the globe await the opportunity to pursue new physics together when the program gets underway. The global coalition said in their Texas Statement, “Global collaboration has made enormous progress in the development of the superconducting acceleration technology, improving its performance by quantum leaps. More innovations broadly benefitting science are in store as we proceed along our path.”

The 2018 International Workshop on Future Linear Colliders (LCWS18) was hosted by the University of Texas at Arlington on Oct. 22-26, 2018, where scientists from all over the world gathered together with a firm determination to make the ILC a reality. Photo Credit: UT A College of Science
Attn: students & postdocs!

2019 Park AFM Scholarship

Park Systems Park AFM Scholarship Awards
Program currently open to ALL regions around the world

Park Systems, the world’s leading manufacturer of atomic force microscopes (AFM) invites all researchers worldwide to apply to become Park AFM Scholars and receive a research scholarship. Park AFM Scholarship Awards are open to undergraduate or postdoctoral students working in nanotechnology research either already using Park AFM or who have research they would like to do with a Park AFM and need help getting access to equipment. Through this program, Park Systems has offered assistance to many researchers who qualify as Park AFM Scholars by matching them with one of thousands of nanoscience shared user facilities to perform their research using Park AFMs.

The Park AFM Scholarship Award is open to postdoctoral researchers and graduate students working in nanotechnology research using Park AFM. As progress for nanotechnology research and development advances at an unprecedented rate, universities worldwide offer degrees in fields working with nanotechnology. Park Systems, world-leading manufacturer of atomic force microscopes, is offering a $500 USD monetary scholarship to promote the education of future scientists and engineers in a number of nanoscience research areas that require advanced nanoscale microscopy for sample analysis and observation and to promote shared research findings and methodologies amongst their peers.

PARK AFM SCHOLARSHIP PROGRAM ACCEPTING SUBMISSIONS

Park Systems is continuing their successful Park AFM Scholarship Program. To be eligible:

1) The awardee must be a graduate student or postdoctoral researcher currently enrolled/affiliated with a research university, national laboratory, or governmental agency.

2) The research being presented must include meaningful data acquired using a Park AFM instrument. This data can either be the sole data being discussed in the presentation or be in conjunction with data acquired with other types of tools.

Park Systems will offer assistance to researchers who need a facility to perform their research using Park Atomic Force Microscope by matching them with one of their shared nano facilities.

For more information on the Park AFM Scholarship program, go to: https://www.parksystems.com/index.php/medias/programs/park-afm-scholarship

“We not only offer financial incentive to Park AFM scholars who are pioneering new research methodologies in nanotechnology at leading academic institutions worldwide, but most importantly are giving them access to our Park Atomic Force Microscopes,” stated KeiBock Lee, Park Systems President. “We will continue to advance nanoscale discoveries thru this Park AFM Scholarship Program worldwide.”
“Our lab focuses on the morphology of individual biomolecules by AFM technology, advanced conformation and their relationship between structure and function, especially polysaccharide. So the AFM is very useful for us to continue this scientific work, which can help us observe and analyze single molecules at the nano-scale level.”

Liang He, Ph.D., Zhejiang Academy of Forestry Key Laboratory of State Forest Food Resources Utilization and Quality Control, Zhejiang Province, China uses Park AFM

AKSHAY GOWDA, A GRADUATE STUDENT WORKING WITH DR. S.V. BABU, DISTINGUISHED UNIVERSITY PROFESSOR, CLARKSON UNIVERSITY RECEIVES THE PARK AFM SCHOLARSHIP AWARD

Title of Research Paper: Post-CMP Cleaning of Ceria Particles from Silicon Dioxide and Nitride Wafers for Advanced Technology Nodes

Abstract:
Advanced device manufacturing requires stringent process conditions to prevent defects that can lead to device failure and reliability issues. In particular, defects such as residual particles, foreign materials, scratches, etc. should be removed from the wafer surface after chemical mechanical planarization (CMP).

How do you use AFM in your research?
Chemical mechanical planarization (CMP) is one of the most crucial steps in the manufacturing of integrated circuits (ICs). In a typical CMP process, a wafer is pressed against the polishing pad fixed to a rotating platen and the chemical slurry (consisting of abrasive particles and necessary chemical additives) is supplied on to the pad. The wafer is polished by the combination of chemical and mechanical forces. CMP inevitably introduces surface defects and contaminants due to the presence of chemical additives and abrasive particles in the slurry used to planarize wafer surfaces. Surface particles are one of the major defects induced by CMP. If not removed, they can cause short or open circuits and affect the final device performance and reliability. Therefore, cleaning such particulate defects on wafer surfaces post-CMP is critical for successful manufacturing of ICs to improve productivity. Billion or so active transistors in each IC is electrically isolated using shallow trench isolation (STI) CMP. Ceria particle-based slurries are used to polish STI structures. Due to high chemical affinity of ceria particles to silicon dioxide surfaces, STI CMP leads to particle contamination making post-CMP cleaning challenging as ceria particles adhere very strongly to STI wafers during polishing. In our research, we are developing cleaning chemistries than can remove ceria particles from silicon dioxide wafers. The particles on silicon dioxide wafer surfaces before and after cleaning are imaged using atomic force microscopy (AFM) and counted. Subsequently, cleaning efficiency is calculated to evaluate the effectiveness of the developed cleaning chemistry.
“PARTICLES ON WAFER SURFACES CAN BE IMAGED EASILY USING AFM AS COMPARED TO OTHER MICROSCOPIC TECHNIQUES. SOME OF THE BENEFITS OF USING AFM OVER OTHER MICROSCOPIC TECHNIQUES ARE AS FOLLOWS: EVEN VERY SMALL NANOPARTICLES (<20NM) CAN BE IMAGED EASILY USING AFM; IMAGING WAFERS USING AFM DOES NOT REQUIRE ANY SAMPLE PREPARATION; AFM IS A SIMPLE, FLEXIBLE, AND COST EFFECTIVE TECHNIQUE AND THE IMAGE QUALITY IS EXCELLENT WITH GOOD REPRODUCIBILITY; AFM IMAGES CAN BE FURTHER PROCESSED TO OBTAIN MORE INFORMATION LIKE SIZE, SURFACE QUALITY, ETC.” AKSHAY GOWDA
As the political, economic and cultural center of China, the establishment of branch office in Beijing means a milestone for the Chinese market. The Park Beijing Office will demonstrate advanced Atomic Force Microscopy (AFM) with cutting-edge applications to the customers from material science to chemistry, biology and semiconductor.
M iniaturization of device geometry, new materials and increasing levels of chip integration requires the semiconductor industry to face production challenges to optimize accuracy throughout the wafer manufacturing process. Conventional techniques such as SEM (Scanning Electron Microscopy) and other optical methods have become inadequate to fill the requirements of high precision and reliability. Small companies in the semiconductor field with worldwide operations have partnered with world-leading AFM manufacturer Park Systems to fulfill their nanoscale microscopy needs, with their comprehensive line of atomic force microscopes (AFM) rendering unparalleled accuracy and versatility, including Park NX-Wafer, a revolutionary AFM solution designed for bare wafer manufacturing that fully automates the process and increases production throughput by more than 1,000 percent. At the same time, the operating costs are low thanks to Park’s unique technology and innovative engineering.

“Every increasing advances in nanoscale science demand accurate and reliable 3D characterization in real-time at the highest nanoscale resolutions. Customers can choose from a diverse range of AFM products and a variety of technologies, which are ideal for you and very much a real need in scientific research today,” states Keibock Lee, President and General Manager of Park Systems.

To bring out the solutions and performances based on client requirements, Santa Clara, California-based Park Systems works diligently on the new features of the Park NX-Wafer and Park NX-3DM series, developed for high-resolution sidewall imaging and critical angle measurements of semiconductor wafers. Park’s wide range of AFM solutions includes proprietary software and cartScan, exclusively tailored for the automation of 1D/2D/3D wafer spread analysis, allowing even novice users to get accurate AFM results.

Park PinPoint AFM technique was designed to obtain higher spatial resolution and sensitivity over a variety of wafer samples, by developing a well-defined electric contact between the tip and the surface. Furthermore, Park PinPoint allows imaging of samples within extremely narrow trenches of very high aspect ratio.

Park Systems developed the Park NX-Wafer to meet the needs of customers who probe the surface, which are highly accurate and maintain their probe hardness, which is crucial for high-resolution imaging and repeatability throughout the process, and at the same time, preserve the sample from damage. Lee explains, “We have a superior technology that offers advanced capabilities in a new and fundamental architecture.”

Being a technology-driven company, Park Systems is set to develop new generations of technologies with a focus on the whole echelon of technology solutions today. Today, only a few companies offer a variety of nanoscale solutions. “We are developing the next generation software tool that will use the artificial intelligence to process this huge amount of data, employing the big data technology,” concludes Lee.

Customers can tailor our diverse range of products to their distinct needs as AFMs are highly versatile and are widely employed in the scientific research arena to develop products and efficiency.

Park Systems extensive product line in AFM product nanoscale metrology has resulted in continuous growth for over 25 years and significant rapid global expansion since 2015, when Park Systems issued a new PO, demonstrating their ambition to take a quantum leap forward as a premier nano-measurement company, based on their technological competitiveness and a unique differentiated product line. Park a also offers Park A FM S scholarships, for easy access to Park AFM for researchers globally, hosting nano scientific symposiums worldwide and has opened Park NanoScience Labs around the world, sharing knowledge centers for nanotechnology research. In addition to Korea, there are Park NanoScience Centers at SUNY Polytechnic Institute in Albany, NY, and Manheim, Germany.

Park Systems new European headquarters, Japra, China, Singapore, India, and Mexico.
**SXES (Soft X-Ray Emission Spectrometer)**

**SXES-ER (Soft X-Ray Emission Spectrometer Extended Range)**

A Synchrotron on your desk?

### SXES Specification
- **Chemical-bonding states**: Possible
- **Parallel detection**: Possible
- **Detection limit**: 20ppm (B reference value)

### SXES-ER and EDS Spectrum comparison
Specimen: SUS304

- SXES-ER
- EDS

### Parallel Detection with High Sensitivity CCD

### Detection Capability for Superior trace and light elements
Specimen: Trace of N in steel

N Conc. %
- 1.10
- 0.45
- 0.25
- Ave. 0.40

- 20 μm
Proven Performance
The Park NX12 is based on the Park NX10, one of the most trusted and widely used AFMs for research. Users can rest assured that they are taking measurements with a cutting-edge tool.

Built for Versatility
Multi-user labs need a versatile microscope to meet a wide range of needs. The Park NX12 was built from the ground up to be a flexible modular platform to allow shared facilities to invest in a single AFM to perform any task.

Competitive Pricing
Early career researchers need to do great work with cost-effective tools. Despite its outstanding pedigree, the Park NX12 is priced affordably—ideal for those on a constrained budget.

To learn more about Park NX12
Please visit parksystems.com/nx12 or email: inquiry@parksystems.com