VOLUME 2, ISSUE 1 - SUMMER 2017

INFORMER

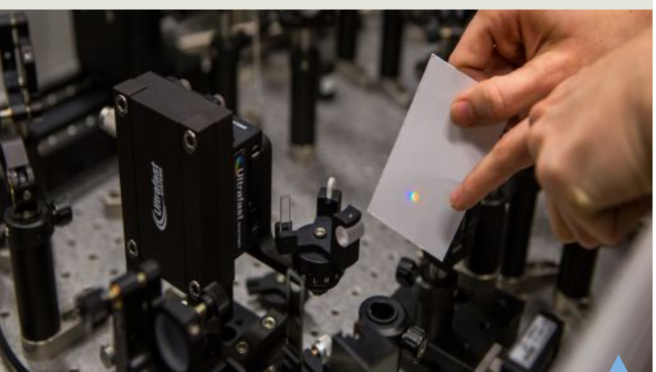
Molecular Engineering & Sciences Institute
UNIVERSITY of WASHINGTON

NEWS FROM THE UNIVERSITY OF WASHINGTON MOLECULAR ENGINEERING & SCIENCES INSTITUTE

A FUNDAMENTAL INVESTIGATION WITH LONG-LASTING IMPACT

Through a Clean Energy Institute Exploration Grant, UW professors Vincent Holmberg and Cody Schlenker, and Lab Fellow Dr. Nigel Browning of Pacific Northwest National Laboratory, are exploring chemistries that affect the lifespan of high-capacity lithium-ion battery electrodes.

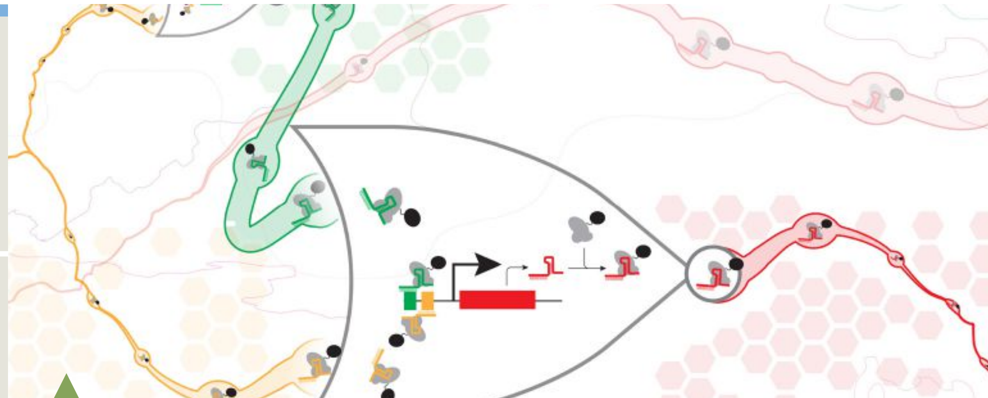
Though their investigation may seem fundamental, it could have a significant impact on how long your batteries last before they need to be replaced.



Holmberg's model systems make Schlenker's operando spectroscopy measurements much easier to interpret.

The new collaboration was sparked by a conversation between Holmberg and Schlenker at the Orcas 2016 International Conference on Energy Conversion & Storage – a biennial meeting organized by CEI at the UW Friday Harbor Laboratories. After the conference, Schlenker and Holmberg reached out to Browning to see if he would be interested in contributing to an Exploration Grant proposal. The grant was funded, and the collaborators launched the first phase of their research in September 2016.

CONTINUED: see " A Fundamental Investigation" page 4



An artist's impression of connected CRISPR-dCas9 NOR gates. Justin Vrana, University of Washington

UW ENGINEERS BORROW FROM ELECTRONICS TO BUILD LARGEST CIRCUITS TO DATE IN LIVING EUKARYOTIC CELLS

Living cells must constantly process information to keep track of the changing world around them and arrive at an appropriate response.

Through billions of years of trial and error, evolution has arrived at a mode of information processing at the cellular level. In the microchips that run our computers, information processing capabilities reduce data to unambiguous zeros and ones. In cells, it's not that simple. DNA, proteins, lipids and sugars are arranged in complex and compartmentalized structures.

But scientists — who want to harness the potential of cells as living computers that can respond to disease, efficiently produce biofuels, or develop plant-based chemicals — don't want to wait for evolution to craft their desired cellular system.

In a new paper published in *Nature Communications,* a team of UW synthetic biology researchers has demonstrated a new method for digital information processing in living cells, analogous to the logic gates used in electric circuits. They built a set of synthetic genes that function in cells like NOR gates, commonly used in electronics, which each take two inputs and only pass on a positive signal if both inputs are negative. NOR gates are functionally complete, meaning one can assemble them in different arrangements to make any kind of information processing circuit yeast cells instead of at an electronics workbench. The circuits the researchers built are the largest ever published to date in eurkaryotic cells, which, like human cells, contain a nucleus and other structures that enable complex behaviors.

CONTINUED: see "Engineers Borrow from Electronics" page 6

MESSAGE FROM THE DIRECTOR

Pat Stayton

This summer the MolES Institute celebrates its fifth anniversary. Standing in the courtyard between the full, active MolES Building and the beautiful new NanoES Building, it is obvious how much has changed in the past five years.

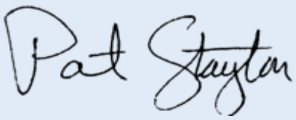
But our goal has always been that the Institute would be "more than a building," and we continue to seek new ways to foster connections and partnerships both inside and outside the university to grow our impact.

In this issue, you will learn about several new collaborations that exemplify this kind of promising, cross-disciplinary work. Assistant Professor of Chemical Engineering Vince Holmberg, Assistant Professor of Chemistry Cody Schlenker, and Pacific Northwest National Laboratory Fellow Dr. Nigel Browning initated a fundamental investigation of lithium batteries with implications for many other electrochemical systems. Meanwhile, working in the third floor collaboratory, Professors James Carothers and Eric Klavins developed a new method of digital information processing in living cells, which has received a great deal of attention.

We also continue our series of graduate student profiles, featuring an interview with Mengying Zhang, a MolE PhD student working in the lab of Assistant Professor of Chemical Engineering Elizabeth Nance.

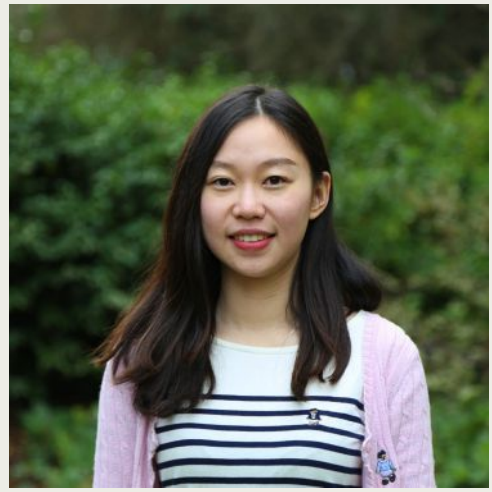
Finally, take a sneak peek at the new NanoES Building, which provides classrooms as well as additional instrumentation space, collaboration areas, and labs for engineering researchers. We are excited to work with the Nano-Engineered Systems Institute led by Electrical Engineering Professor Karl Bohringer.

We hope you enjoy reading about the work of our researchers working inside and outside the MolES Building.



Patrick Stayton
Director, Molecular Engineering & Sciences Institute

Interview wit



"We are working to apply nanotechnology platforms to characterize fundamental common neonatal brain disorder hallmarks and then use the knowledge we gain to direct the development and engineering of nanomedicine."

–Mengying Zhang

h MolE PhD Student Mengying Zhang

What led you to join the Molecular Engineering PhD program?

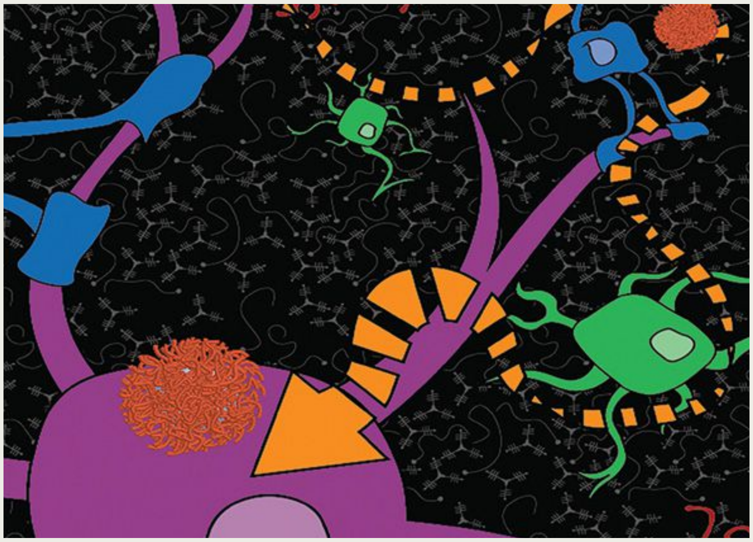
I did my undergraduate degree in Biological Science in China. During my undergraduate studies, I completed a one year exchange program at the University of Washington. During that program, I was able to take classes from multiple disciplines including neuroscience, materials science, public health and bioengineering. I was interested to combine the basic biology knowledge to an applied engineering side and was lucky to join a research lab in Materials Science and Engineering Department and studied biomaterials for drug delivery and cancer treatment. This unique experience led me to apply for the MolE PhD program. Since I had already taken courses in biology, I wanted my graduate studies to combine both biology and engineering.

What drew you to the Nance Lab?

During the first year of the MolES program, I attended one of our Tuesday seminars and the speaker happened to be one of Elizabeth Nance's post-doc advisors. Talking with the speaker, I realized the research that Elizabeth did was exactly aligned with my interest -- the combination of neuroscience and nanotechnology. I happened to take a biomaterials class and a neuroscience class during my undergraduate exchange at the UW, where I enjoyed these two areas a lot. In addition to finding her research engaging, I think Elizabeth is one of the most passionate women I've ever met. She's helped launch other women in their careers in science, and I value the support that she provides for women in engineering and science. I also knew that since Elizabeth was new to the university at the time that her group would be small at first and continue to grow.

How are molecular engineering principles applied in your lab?

We are working to apply nanotechnology platforms to characterize fundamental common neonatal brain disorder hallmarks and then use the knowledge we gain to direct the development and engineering of nanomedicine. With the long term goal of utilizing nanotechnology in patients to give real-time, quantitative information about the brain, we are combining research on platform characterization, bioimaging and therapeutic delivery. My research works specifically on the imaging side, where I study nano size fluorescent quantum dots behaviors in the developing brain, including quantum dots' stability, toxicity and cellular uptake. By systematically understanding the nanoparticle platform behaviors, it is possible for me to develop a quantum dot based biomarkers to characterize the severity of neuroinflammation in the developing brain and apply to neonatal brain disorders such as autism and HIE (hypoxic ischemic encephalophathy). Generally speaking, it is most important to understand the interaction, not only of the molecules or nanoparticles themselves, but also of the molecules of the surrounding environment, to be able to better engineer and design the targeting product.



Nance group research image

How has MolE coursework helped prepare for this research?

The advanced molecular engineering class was very relevant to the work I do in the lab. Since it's a cross between my undergraduate discipline, biology, and the graduate coursework I've done in engineering, I was more able to understand that from a biological prospective but applied in a more engineering application. It addressed themodynamics and molecular interaction considerations when designing biomolecules for medical applications, which was interesting and also critical for working in the field of molecular engineering and sciences and biology.

Learn more about Mengying Zhang and the research being done in the Nance Lab (pictured left) by visiting depts.washington.edu/nancelab.

For more information on the Molecular Engineering PhD program and its students, visit www.moles.washington.edu/phd.

FUNDAMENTAL INVESTIGATION (CONTINUED FROM PAGE 1)

The researchers knew that a collaboration would help them more efficiently develop new ways to improve battery technology. The Holmberg lab studies nanowire-based battery electrode materials in an effort to develop new ways to increase energy density and power density, and improve overall battery performance. The team measures how batteries change as they are repeatedly charged and discharged, to learn how changes to the electrode architecture or chemistry at the electrode interface affect the performance and longevity of the battery. They are able to build model systems with carefully controlled chemistry, which make the Schlenker lab's interface-sensitive operando spectroscopy measurements much easier to interpret. Browning's expertise in advanced operando electron microscopy enabled real time observation of structural changes at the electrode interface under working conditions.

What excites Schlenker and Holmberg is that this research has implications beyond germanium, lithium, and batteries. Their clean model system will allow them to look at new ways to control all sorts of electrochemical systems.

The first phase of the project uses germanium nanowires as a model system to gain a better understanding of how lithium-ion batteries perform as the team systematically tunes the interface chemistry of the negative electrode. Germanium forms a high-capacity alloy with lithium, with a very high intrinsic electronic conductivity and lithium diffusivity, making it an attractive model system for their studies.

Because the team can rigorously tailor the chemistry of the nanowire surface, they are able to take cleaner and more precise measurements. According to Holmberg, "one of the reasons this collaboration works out well is because we have very good control of the molecules that are on the surface of the nanowires." This precision allows the team to study how what's on the surface of the germanium electrode affects the longevity of the lithium ion battery.

AWARDS, RECOGNITION & PUBLICATIONS

Dave Castner

David Castner has won the European Conference on Applications of Surface and Interface Analysis Award, which honors the outstanding scientific achievemens of a personality within the field of Surface and Interface Analysis. The award recognizes Castner's life-time engagement and extraordinary impact on the community. He recently received this award in Montpellier, France.

Allan Hoffman

UW Bioengineering Professor Emeritus Allan Hoffman received the 2017 Acta Biomaterialia Gold Medal of the Acta Materialia at the Society for Biomaterals annual meeting in Minneapolis. The Acta Biomaterialia Gold Medal annually recognizes demonstrated leadership in the field of biomaterials science and engineering. It rewards research that has made a significant and lasting impact on the field, or recent work of great originality.

Suzie Pun

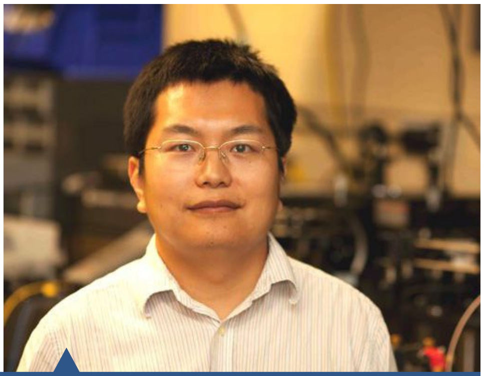
Suzie Pun, the Robert F. Rushmer Professor of Bioengineering, has received the 2017 College of Engineering Faculty Award for Research. The Faculty Award for Research recognizes extraordinary contributions and dedication to research, support of diverse students in research, and innovative approaches in research, scholarship or creative activities.

Because Holmberg's group has been able to develop this clean model system, they are able to apply their findings to all sorts of electrochemical systems. Right now, they're looking at how they can tune the electrostatic environment. "Because electrostatic charge is readily dissipated in Li-ion salt solutions, researchers commonly ignore it," Schlenker explains. "However, if one looks at very small length scales, there's a strong electrostatic interaction there, and because of this scale, we're able to use this electrostatic charge to manipulate the electrode." He offers this analogy: to better understand an electrostatic interaction, one might think of a playground slide. When a child moves down that plastic slide, they generate static electricity. As they reach to tag another child immediately upon exiting the slide, they cause a shock. This is an electrostatic interaction. Schlenker says that in their research they're "changing the charge between the person who slid down the slide and the person they're zapping."

Graduate students Jarred Olson and Elena Pandres in a CEI laboratory.

What excites Schlenker and Holmberg is that this research has implications beyond germanium, lithium, and batteries. Their clean model system will allow them to look at new ways to control all sorts of electrochemical systems. One such "grand challenge" application is taking sunlight and using it to form chemical bonds that store energy in the form of hydrogen or liquid fuel. The immediate consequences of their findings, however, could have a huge impact on the way battery storage technologies develop.

In the second phase of their research, they plan to partner with computational researchers to bolster their findings from a theoretical perspective. They will continue to develop their interfacial characterization tools and work with other synthetic groups to modify the performance of their nanowire electrodes.

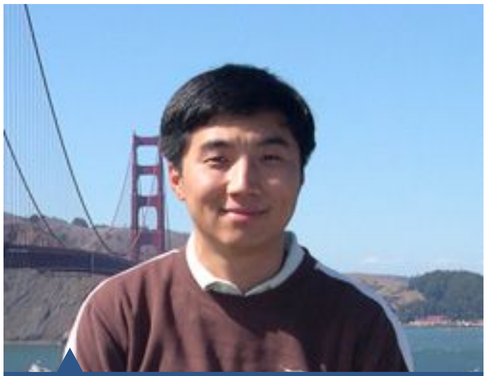


Xiaodong Xu

Xiaodong Xu has a new article in *Nature International Weekly Journal of Science* entitled "Layer-dependent ferromagnetism in a van der Waals crystal down to the monolayer limit."

Barry Lutz

Barry R. Lutz and Rahil Jain have an article in *Lab on a Chip* entitled "Frequency Tuning Allows Flow Direction Control in Microfluidic Networks with Passive Features."



Xiaohu Gao

Xiaohu Gao had an article published in *Nature Biomedical Engineering* entitled "Dramatic enhancement of the detection limits of bioassays via ultrafast deposition of polydopamine."

ENGINEERS BORROW FROM ELECTRONICS (CONTINUED FROM PAGE 1)

"While implementing simple programs in cells will never rival the speed or accuracy of computation in silicon, genetic programs can interact with the cell's environment directly," said senior author and UW electrical engineering professor Eric Klavins. "For example, reprogrammed cells in a patient could make targeted, therapeutic decisions in the most relevant tissues, obviating the need for complex diagnostics and broad spectrum approaches to treatment."

Scientists don't want to wait for evolution to craft their desired cellular system.

Each cellular NOR gate consists of a gene with three programmable stretches of DNA —two to act as inputs, and one to be the output. The authors then took advantage of a relatively new technology known as CRISPR-Cas9 to target those specific DNA sequences inside a cell. The Cas9 protein acts like a molecular gatekeeper in the circuit, sitting on the DNA and determining if a particular gate will be active or not. If a gate is active, it expresses a signal that directs the Cas9 to deactivate another gate within the circuit. In this way, the researchers can wire together the gates to create logical programs in the cell. What sets the study apart from previous work, researchers said, is the scale and complexity of the circuits successfully assembled — which included up to seven NOR gates assembled in series or parallel. At this size, circuits can begin to execute really useful behaviors by taking in information from different environmental sensors and performing calculations to decide on the correct response.

Imagined applications include engineered immune cells that can sense and respond to cancer markers or cellular biosensors that can easily diagnose infectious disease in patient tissue. These large DNA circuits inside cells are a major step toward an ability to program living cells, the researchers said. They provide a framework where logical programs can be easily implemented to control cellular function and state.

The research was funded by the Semiconductor Research Corporation and the National Science Foundation. Co-authors include UW electrical engineering graduate student Miles Gander, bioengineering graduate student Justin Vrana, chemical engineering graduate student Willy Voje and chemical engineering professor James Carothers.

Jennifer Langston, UW News

NANOENGINEERING & SCIENCES BUILDING OPENS THIS FALL

The newest addition to campus complements MolES by providing active learning laboratory classrooms, additional research and collaboration space, and instrumentation labs.

ZGF Architects programmed and designed the 70,000 square foot NanoES Building, which is slated to open this fall. Together the MolES and NanoES Buildings provide 160,000 square feet of critical research space for interdisciplinary research. Sited within the campus core, the building was designed to fit within the historic context while also reflecting the cutting-edge nature of the research housed within.

The NanoES Building complements the MolES phase by providing additional research and collaboration space and includes a significant classroom component. Interactive programming efforts with various stakeholder groups led to supplementary ground contact space, additional general purpose classrooms, conference rooms, and collaboration spaces, adjustments to building orientation, and consideration of increased density in the complex. Design was driven by connectivity, transparency and the connection and collocation of the molecular and nanotechnology instrumentation programs. The first floor balances the research-intensive space on the first floor of MolES by providing two highly adaptable active learning classrooms, as well as informal learning spaces designed to facilitate interaction and collaboration between disciplines. Designers incorporated "plug and play" capabilities into these spaces to maximize the technological adaptability of each room. Each of the other levels feature highly flexible technology-equipped laboratory, office and meeting spaces, including the lower level which is sited entirely below-grade. The facility is designed with an open layout to encourage active participation, close collaboration, and cross-pollination of ideas.

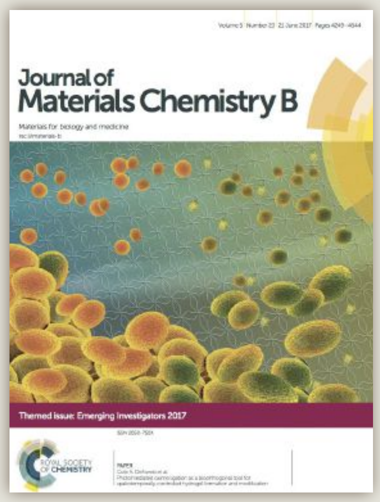
Acknowledgements

Special thanks to Erin Armstrong, Christopher Adams (MolES), Corin Shelley-Reuss (MolES), and Maeve Zolkowski (ZGF Architects) for their help in the preparation of this issue of the Informer.

SUMMER 2017

RECENT PUBLICATIONS OF NOTE

For a more complete listing of publications by faculty associated with the Molecular Engineering & Sciences Institute, please visit **www.moles.washington.edu/publications**



A new paper from Prof. **Cole De Forest is** on the cover of *Journal of Materials Chemistry B*. His article is on photomediated oxime ligation as a bioorthogonal tool for spatiotemporally-controlled hydrogel formation and modification.

Prof. **Lilo Pozzo** has a new paper out in *Soft Matter* entitled "Electric field directed formation of aligned conjugated polymer fibers." The co-authors used the Molecular Analysis Facility for SEM, AFM, and XRD, as well as device fabrication.

Profs. **David Baker** and **Paul Yager** have a new article out in *Nature Biotechnology*. Their article relates to novel molecular binders against a protein in the influenza virus.

Molecular Analysis Facility

The Molecular Analysis Facility (MAF) is a fully staffed instrumentation facility for users from the University of Washington, other universities, and industry. Capabilities include microscopy, spectroscopy, and surface science. Users can be trained to perform experiments independently, or an experienced staff member can perform experiments for you.

STAFF SCIENTISTS

The MAF employs a group of full-time staff scientists to help you design, perform, and troubleshoot your experiments. Contact the MAF with questions about instrumentation or to see if we have the right tool for your job.

Liam Bradshaw
XRD, Ellipsometer, GDOES, UPS
Expertise: Spectroscopy, nanoparticles, optics, inorganic chemistry, metalloenzymes

Scott Braswell
SEM, FIB, EDS
Expertise: Electron microscopy, FIB imaging/milling/lift-out, image processing, education, x-ray microanalysis

Micah Glaz
AFM, Raman, Confocal Microscope, Profilometer
Expertise: AFM, physical chemistry, organic/inorganic semiconductors, solar materials, microscopy, spectroscopy

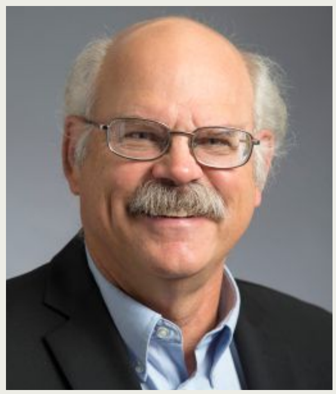
Dan Graham
ToF-SIMS, XPS
Expertise: Surface analysis of polymer and biological materials, 2D and 3D imaging, multivariate data analysis methods

Gerry Hammer
XPS, UPS
Expertise: Surface and interface analysis, metals, films, polymers, fibers, composites

Ellen Lavoie
TEM
Expertise: Electron microscopy, TEM, including preparation of materials, biological, and polymer samples

A Message from the Director

As the mission of the Molecular Analysis Facility (MAF) is to provide UW researchers with the tools needed to characterize their state-of-the-art materials. New tools added in the last year such as: 1) ultra-fast laser system for measuring transient absorption and photoluminescence, 2) two atomic force microscopy



systems and 3) a new XRD instrument have been very popular with MAF users. The detailed and comprehensive material characterization that tools at MAF provide is essential information needed by UW researchers to understand what they have fabricated how to further improve their materials and devices.

MAF is continually looking for ways to advance and expand our materials characterization capabilities to better serve the UW research community. We are excited about the opening of the new Institute for Nano-engineered Systems (NanoES) and coordinating our efforts with them to provide the UW with additional shared instrumentation facilities. One topic we are currently discussing is electron microscopy (EM). The Department of Biochemistry is currently installing a new, state-of-the-art of cryoEM instrument (Titan Krios) in the NanoES ground floor than represents a significant advance in EM capabilities at the UW for characterizing soft materials. We are currently exploring ways to upgrade and expand MAF's capabilities in transmission and scanning EM (TEM and SEM) to complement the new exiting capabilities of the Titan Krios.

The advanced tools and expert staff at MAF are here to support your research and development projects. Please contact us for more information about our capabilities and how you can access our suite of tools.

Sincerely,

David Caster
Professor, Bioengineering and Chemical Engineering;
Director, Molecular Analysis Facility

Contact the Molecular Analysis Facility

Web site: **www.moles.washington.edu/MAF**
Email: **UWMAF@uw.edu**
Phone: **206-616-6627**

CASE STUDY

Characterization of CZTS Thin Film Solar Materials

Cu¬2ZnSn(SxSe1-x) thin film solar cells are of unique interest because they are non toxic and are made up of earth abundant elements. Furthermore, they can be processed from solution as molecular inks, meaning they can be printed using roll to roll printing. However, their efficiencies are much lower than their counterpart CuInxGa(1-x)Se2. Much of the lower efficiencies have been attributed to a better need of the fundamental understanding of the device chemistry and physics. Herein we show how the Molecular Analysis Facility (MAF) was used to ascertain a deeper understanding of the underlying physics of CZTS thin films. Three techniques are used: Atomic force microscopy, scanning electron microscopy and energy dispersive spectroscopy.

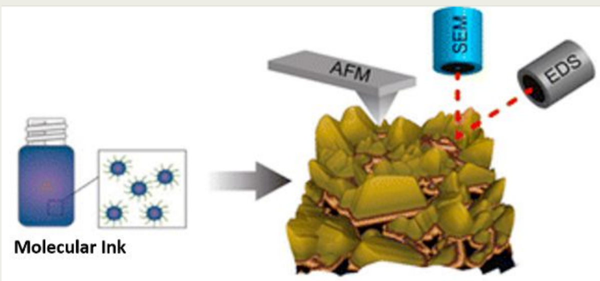
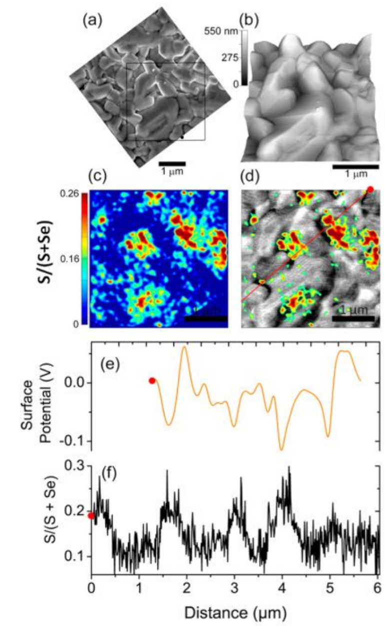


Figure 1: Illustration of CZTS molecular inks (left) producing thin film CZTS solar films (right) analyzed with atomic force microscopy (AFM) scanning electron microscopy (SEM), and energy dispersive spectroscopy (EDS) at the same area of the film.

Atomic force microscopy (AFM) is a technique that utilizes a 5-10 nm tip attached to a cantilever. When raster scanned across a surface, a topographic image is produced with sub nanometer height resolution. This technique can be coupled with a conductive tip to simultaneously probe the local potential or conductivity of a sample. An illustration of a AFM tip is shown in the right image of figure 1. Scanning electron microscopy (SEM) uses an electron beam to raster scan a sample. The electrons reflected off the surface are captured on a detector producing a high-resolution image of the sample. The MAF has an SEM that is also equipped with an energy dispersive x-ray spectroscopy (EDS) detector, which also allows for atomic detection on the surface.

Figure 2 shows how the MAF can be used to analyze a single area of a film using multiple instruments and techniques. Figure 2a is an SEM image of a CZTS device and figure 2b is the topographical image obtained by AFM of the area within the square of 2a. To increase efficiency of the CZTS materials, the sulfur is replaced with selenium by a process known as selenization. However, it has been found that the sulfur is not completely replaced. Image 2c is an EDS image showing the sulfur to selenium ratio of the exact area in 2b. The red and yellow areas in 2c are areas of higher sulfur concentrations. Finally, in 2d, the AFM topography image is simultaneous obtained with the device's local potential. Figure 2d, shows the potential coupled with the EDS image of sulfur concentration. The line scans plotted in 2e and 2f are of the surface potential and sulfur concentration, respectively. This data directly



shows that the high sulfur concentration leads to a substantial decrease in potential. These potential changes are expected to be recombination centers and leads to decreased efficiency of a device. Such information is extremely important to make more efficient devices and directly shows how multiple instruments in the MAF can be used to further understand the morphology and device physics of new materials.

This work was published in collaboration with the Hillhouse and Ginger groups. The work was published in ACS Nanoletters: 14 (12), pp 6926–6930

For more information, contact the Molecular Analysis Facility:

Website: **www.moles.washington.edu/MAF**
Email: **UWMAF@uw.edu**
Phone: **206-616-6627**

Molecular Engineering & Sciences Institute
UNIVERSITY of WASHINGTON

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Seattle, WA 98195-1653

UPCOMING EVENTS

Clean Energy Institute Interdisciplinary Seminar Series
September 28, 2017 at 4:00 p.m.
Kameshwar Poolla, UC Berkeley
Electrical Engineering Building 045
www.cei.washington.edu/seminar

MolES Seminar Series Fall 2017 Distinguished Lecturer
October 3, 2017 at 12:30 p.m.
Joanna Aizenberg, Harvard University
Anderson Hall 223
www.moles.washington.edu/seminar

CleanTech Alliance Breakfast Series
October 11, 2017 at 7:30 a.m.
Susan Petty, AltaRock Energy
Perkins Coie
www.cleantechalliance.org

ABOUT THE MOLECULAR ENGINEERING & SCIENCES INSTITUTE

The MolES Institute brings together teams from across the University of Washington campus to catalyze translational research in the cleantech and biotech areas. It is intended to serve both as an intellectual accelerator to bring fresh approaches and ideas to societal challenges and as a physical incubator where interdisciplinary teams can come together in a shared space. The Institute has more than 115 members from 14 departments.

The Institute is located in the new Molecular Engineering and Sciences Building, a facility specially designed to promote collaborative molecular-scale research. The building houses 16 faculty members, 4 institutes and research centers, and a major instrumentation center. Together these centers provide state-of-the-art instrumentation for molecular characterization and analysis for the use of the UW research community and the larger non-profit and tech communities in Seattle.

The Institute is also creating and coordinating interdisciplinary education programs for undergraduate and graduate students. Drawing on the expertise of multiple departments, these programs teach students the fundamental aspects of molecular-level engineering through core courses and top-notch research opportunities.

CONTACT US
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