

MATERIALS SCIENCE AND ENGINEERING

BREAKING THE PROTEIN-DNA BOND

Study finds that free-floating proteins break up protein-DNA bonds at the single-binding site

The verdict is in: too many single, flirty proteins can break up a strong relationship.

Published in the *Proceedings of the National Academy of Sciences*, a new interdisciplinary Northwestern University study reports that the important protein-DNA bond can be broken by unbound proteins floating around in the cell. This discovery sheds light on how molecules self-organize and how gene expression is dynamically controlled.

"The way proteins interact with DNA determines the biological activity of all living organisms," said John F. Marko, professor of molecular biosciences, physics, and astronomy.

To understand this vital relationship, Marko led a study examining the sites where a single protein binds to DNA. Strands of DNA have specific sites on which other molecules can bind and become a part of the DNA's genetic code. One type of DNA-binding proteins, called transcription factors (TF), are key players in the transcription of genetic information from DNA to messenger RNA (mRNA) to produce new proteins or other types of RNA. TF proteins control the biological

processes in living cells by binding and unbinding to DNA.

In the experiment, Marko and his team developed a concentration of TF proteins bound to DNA mixed with unbound TF proteins, which competed with the bound proteins for their binding sites. They observed that unbound proteins caused the bound proteins to dissociate from the DNA. The unbound proteins then stole the newly available single-binding sites.

Monica Olvera de la Cruz, the Lawyer Taylor Professor of Materials Science and Engineering, led the development of a theoretical model and performed molecular dynamics simulations to show the prevalence of the protein-DNA break up at the single-binding site due to the competitor proteins. This disproves former beliefs that protein-DNA bonds were unaffected by unbound proteins and instead resulted from more "cooperative" interactions among many molecules, large protein clusters, or long DNA segments.

"Our results suggest that protein-DNA dissociation could have a profound effect on the dynamics of biological processes that depend on protein binding *in vivo*," Olvera de la Cruz said. "This may be an important factor to take into account when modeling gene expression in living cells."



Olvera de la Cruz

MONICA OLVERA DE LA CRUZ RECEIVED THE 2017 POLYMER PHYSICS PRIZE FROM THE AMERICAN PHYSICAL SOCIETY FOR "OUTSTANDING CONTRIBUTIONS TO THE THEORETICAL UNDERSTANDING OF POLYMERS AND THE EFFECTS OF ELECTROSTATIC INTERACTIONS ON THEIR STRUCTURE AND PROPERTIES."

FROM THE CHAIR

Dear Friends,

As I approach my first anniversary as chair, I am reflecting on the many recent accomplishments of our faculty, students, and alumni, some of which you will find described in this newsletter. These accomplishments reflect leadership and service, as well as research at the very forefront of our field. They highlight the vibrant atmosphere that makes this department a wonderful place to be and one that I am proud to lead. Apart from a significant list of faculty awards, there are two points I would like to highlight: James Rondinelli was promoted to associate professor with tenure and Jiaxing Huang was promoted to full professor. In addition, we welcomed a new staff member: **Lauren Hamilton** succeeded **Meghan Gelecke** as program assistant.

I am also looking forward to what the next year will bring. As September approaches, we are preparing to welcome an incoming class of 36 PhD and 21 MS students. The Material Advantage Chapter will hold a speaking contest on

September 18 to highlight the research accomplishments of many of our undergraduates who have spent the summer working on research, supported by the Meister Summer research grants and others. In fact, the campus has been buzzing this summer with undergraduate materials researchers from all over the country, hosted by our affiliated centers, the Materials Research Center, the Center for Hierarchical Materials by Design (CHiMaD), and the Soft and Hybrid Nanotechnology Experimental Resource (SHyNE). CHiMaD also hosted 17 high school teachers from the US and Canada ASM Materials Genome Camp, organized by CHiMaD, QuesTek Innovations, and NU-MSE. Several students have been away from campus, including a group who spent the summer at the Rijksmuseum in Amsterdam studying materials related to cultural heritage objects and students who spent the summer doing research at the Technical University of Munich. In December, faculty and students will participate in the International Conference of the African Materials Research

Society. Such exchanges reflect the global nature of our research and educational activities and continue to foster an international community.

I know some of you will return to campus for Homecoming. The department conference room will be available for an informal “open house” where you can gather and chat with faculty and students on that Friday, October 6. We look forward to seeing you.

Other fall events include the Jerome B. Cohen Lectures which are scheduled for October 16 and 17. Professor Daan Frenkel from the University of Cambridge, winner of the 2016 Boltzmann Medal, will present two lectures.

In addition to these events, I would like to announce that we are planning a special **MSE REUNION** for the third weekend in May. It is noteworthy that the Northwestern Board of Trustees approved the name change from Department of Metallurgy to “Graduate Department of Materials Science” in December 1958. As we celebrate this first Materials Science department, we are also looking forward to the role that materials

play in creating new technologies and solving societal problems. The events that week will begin with the annual Hilliard Symposium and Celebration Banquet on Thursday May 17, followed by opportunities to connect with friends and classmates. We’ll be sending more information soon. We hope you will join us.



Erik Luijten
Department Chair

UPCOMING EVENTS

OCTOBER 6

Homecoming

Department Open House
Cook Hall, Room 2058 1-3 p.m.

OCTOBER 16 & 17

Jerome B. Cohen Lectures

Daan Frenkel
University of Cambridge

TMS Renames Educator Award for Weertmans

Julia and Johannes Weertman have educated generations of students

The Minerals, Metals, and Materials Society (TMS) has established the TMS Julia and Johannes Weertman Educator Award.

The award honors **Julia** and **Johannes Weertman**, who are both Walter P. Murphy Emeriti Professors in Materials Science and Engineering in Northwestern’s McCormick School of Engineering. Members of the National Academy of Engineering, the Weertmans are pioneers in materials research and have educated generations of students.

Previously called the TMS Educator Award, the annual honor was instituted in 1985 to recognize outstanding contributions to education in metallurgical engineering and/or materials science and engineering. The award is not limited to the classroom as it can include the acknowledgement of innovative ways to educate the general public.

“TMS is honored to be able to bestow this award in the names of Julia and Johannes, valued members who have contributed to TMS and science in many



Julia and Johannes Weertman

exemplary ways,” said James J. Robinson, executive director of TMS. “This award seems most fitting as it will honor them as educators to the many students they have touched and mentored. Their legacy will live on in many ways including in this Society award.”

LAURENCE MARKS RECEIVES SURFACE STRUCTURE PRIZE

Award honors Marks' outstanding achievement in the field of surface and interface structure

Northwestern Engineering's **Laurence Marks** received the 2017 Surface Structure Prize from the International Conference on the Structure of Surfaces (ICSOS).

The international award each year recognizes a researcher for outstanding achievement in the field of surface and interface structure.

Marks, a professor of materials science and engineering, accepted the award at the ICSOS-12 meeting, held July 23-28 at the Georgia Institute of Technology.

"It is a great honor to receive this prize from my peers all over the world," Marks said. "I really owe everything to my very talented graduate students — both past and present — and to the patience of my wife."

A theoretical and experimental engineer, Marks is renowned for his contributions to the study of nanoparticles and his work in the fields of electron microscopy, diffraction, and crystallography. He discovered a type of nanoparticle, the Marks Decahedron, which has become his most highly cited work. His current research interests include transmission electron microscopy, density functional theory methods, direct methods for inversion of diffraction data, surface science particularly of oxides, tribology, hip replacements, and nanoparticle structure, growth, and plasmonic properties.

In 2001, Marks was elected fellow of the American Physical Society for his "contributions to quantitative imaging and diffraction methods for determining



Marks

"IT IS A GREAT HONOR TO RECEIVE THIS PRIZE FROM MY PEERS ALL OVER THE WORLD."

LAURENCE MARKS

the atomic structure of surfaces and bulk materials." He has received several awards, including the 2015 Warren Award from the American Crystallographic Association for his contributions to electron diffraction, a Sloan Foundation Fellowship from the Alfred P. Sloan Foundation, and the Burton Medal from the Electron Microscopy Society of America. He also served as the 2015 Astor Visiting Lecturer at the University of Oxford.

A member of the Northwestern faculty since 1985, Marks earned his BA and PhD from the University of Cambridge.

Upcoming Events

André Taylor

Yale University
September 19

Donald Siegal

University of Michigan
September 26

Jonathan Rivnay

Northwestern
October 3

Homecoming Open House

October 6, 1-3 p.m.
Cook Hall, room 2058

Cohen Lectures: Daan Frenkel

October 17

Xin Sun

Oakridge National Laboratory
October 24

Andrea Liu

University of Pennsylvania
October 31

Zhenan Bao

Stanford University
November 7

Nancy Sottos

University of Illinois
November 14

Veronica Augustyn

North Carolina State University
November 21

Hilliard Symposium 2017

The 30th annual Hilliard Symposium, organized by Professor **Yip-Wah Chung**, was held on May 18 at Northwestern's Norris University Center. Alumna Christina Freyman (PhD '06, Chung) delivered the keynote address, "How Do We Measure Success? The Evaluation of Federal Investments in Research and Development." Freyman is a director in SRI International's Center for Innovation Strategy and Policy, where she focuses on science and engineering indicators, workforce issues, and R&D programs for the federal government.

SPEAKERS

1ST PLACE

Stephanie Moffitt (Bedzyk/T. Marks)
"Developing Structure-Property Relationships in Amorphous Transparent Conducting Oxides"

2ND PLACE

Ashwin Narayanan (Stupp)
"Ferroelectricity and Second Harmonic Generation in Organic Supramolecular Charge-transfer Co-crystals"

3RD PLACE

Michael Whittaker (Joester)
"Synthesis of High-temperature Materials at Ambient Conditions"

Jeffrey Cain (Dravid)
"Predictive Synthesis of 2D Transition Metal Dichalcogenide Heterostructures and Alloys"

Gavin Campbell (Bedzyk)
"Epitaxial Graphene Encapsulated Surface Reconstruction of Ge(110)"

Linda Guiney (Hersam)
"Three-dimensional Printing of Hexagonal Boron Nitride for Biomedical and Electronic Applications"

Kyoungdoc Kim (Voorhees)
"First-principles/Phase-field Modeling of θ' Precipitation in Al-Cu Alloys"

Soo Kim (Wolverton)
"First-principles Design and Investigation of Mn-based Lithium-ion Battery Cathode Materials"

Andrew Mannix (Hersam)
"Exploring Synthetic Elemental 2D Materials"



Hilliard Symposium organizer Yip-Wah Chung with speaker Christina Freyman.

Ethan Secor (Hersam)
"Production, Patterning, and Application of Graphene Inks"

Yue Sun (Voorhees)
"Three-dimensional Study of Concurrent Dendrite Growth and Coarsening During Solidification in Al-Cu Alloys"

Zhiyuan Sun (Lauhon/Seidman)
"Novel Dopant Engineering Methods in Semiconductor Nanowires"

CONTRIBUTIONS

MATERIALS SCIENCE AND ENGINEERING

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JOHANNES AND JULIA RANDALL WEERTMAN GRADUATE FELLOWSHIP FUND

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Dr. Don M. Lipkin
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Joseph S. Santner, PhD
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Prof. Bruce W. Wessels

MORRIS E. FINE LECTURE

William O. Gentry, PE
Mel I. Mendelson, PhD
Joseph S. Santner, PhD
Semyon Vaynman, PhD
Mr. Terrence R. Wilkinson
James G. Zwissler, PhD

Donations made between August 23, 2016 and July 20, 2017. If you would like to contribute to MSE funds, please contact Patrick Hankey at patrick.hankey@northwestern.edu.

ALUMNI HONORED

Yoshio Aoki and Chantal Sudbrack received awards at annual banquet

Two outstanding alumni were honored at the 2017 Annual Alumni Celebration Banquet on Thursday, May 18. Yoshio Aoki received the Distinguished Career Achievement Award, and Chantal Sudbrack received the Early Career Achievement Award.

YOSHIO AOKI

(MS '72, PhD '76, Brittain)

Vice president for external collaboration at the National Institute for Materials Science

Aoki served as the president and CEO of Optware Corporation (a spin-out venture of Sony Corporation) for five years before joining NIMS, one of the largest scientific research centers in Japan. At Northwestern, he helped establish the NU-NIMS Center for Materials Innovation, one of the collaborative centers between NIMS and other institutions.

What are some of your most memorable classes or experiences?

Professor J. Weertman's "Dislocation Theory" class was so useful for my first R&D subject at Sony Central Research Lab — an image sensor called defect-free CCD.

What have been your most memorable or proudest career moments?

I successfully managed Sony's first R&D operation in the United States and the first US business unit. Then I was recruited to become president of its office in Japan, where I tripled sales revenue in two years. At NIMS, I doubled research funds from industrial partners, increased license income by more than eight times, increased the joint collaboration centers with industrial partners from one to 10, and grew joint collaboration centers with academic partners from zero to four.

What advice would you give to current students?

You should always keep challenging yourself.



Professor Robert P.H. Chang presents the award to Yoshio Aoki

CHANTAL K. SUDBRACK

(PhD '04, Seidman)

Superalloy metallurgist at NASA Glenn Research Center

Sudbrack is a superalloy metallurgist in the Materials and Structures Division in the High Temperature and Smart Alloys Branch of the NASA Glenn Research Center, where she works on projects related to additive manufacturing, reliability, and durability of turbo-machinery used in aerospace engine components.

Describe how your experience in the Department of Materials Science and Engineering shaped your career.

I have been fortunate to enjoy both a friendship and mentorship from my adviser Professor David Seidman that has extended well beyond my time as a graduate student. His connections helped me find a job at NASA. That experience showed me the importance of building collaborations and good will within my organization and with outside contacts.

What are some of your most memorable classes or experiences?

I learned early about the setbacks that go hand-in-hand with doing research. For my first set of samples, the NASA technician responsible for casting our alloy buttons accidentally switched the chromium and aluminum bottles to



Chantal Sudbrack with Professor David Seidman

produce an intermetallic alloy, which was next to impossible to atom probe. It took two months of unsuccessful atom probes and then SEM to sort out the issue. Back then, the Seidman's group custom 3-D atom probe was not operational during my entire first year. Though I didn't have much data for my qualifier, I fondly look back to brainstorming how to fix the broken instrument and learning the "pitfalls" of instrumentation.

What have been your most memorable or proudest career moments?

I enjoy building on the legacy of my mentors and colleagues by supporting young researchers in their pursuit of scientific research. It is extraordinarily rewarding to watch my mentees progress in their careers. I'm proud of publishing my PhD thesis work in *Nature Materials*, winning a NASA grant for new innovation, organizing my first technical symposium for the TMS, and managing and leading a large group on an additive project work.

What advice would you give to current students?

The most successful people I admire keep a long-term dream in mind. In the shorter term, they focus on obtaining skills, education, experience, and connections that will build toward their dream. As you begin your careers, keep in mind that positions offered today may open the doors for the ones you want tomorrow.

FACULTY NEWS

Zdeněk Bažant, who has a courtesy appointment in the department, was selected to receive the ASME Medal.

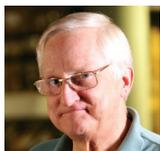
Sossina Haile became an associate fellow of the Ethiopian Academy of Sciences in 2016.

Mark Hersam is a finalist for the 2017 Blavatnik National Awards for Young Scientists.

Jiaxing Huang received a Humboldt Research Award for collaboration at the Max Planck Institute of Colloids and Interfaces and was promoted to full professor.

Yonggang Huang, who has a courtesy appointment in the department, was elected to the National Academy of Engineering.

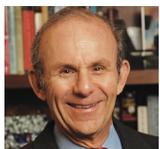
Teri Odom, who has a courtesy appointment in the department, was selected as one of three winners of the 2017 ACS Nano Lectureship.



Greg Olson received a 2016 Tibbetts Award from the US Small Business Administration for his materials design company QuesTek Innovations. He was also honored with a Materials by Design Symposium at the 2017 TMS meeting on the occasion of his 70th birthday.

John Rogers was elected into the American Institute for Medical and Biological Engineering (AIMBE) College of Fellows.

James Rondinelli received the 2017 MRS Outstanding Young Investigator Award and was promoted to associate professor with tenure.



David Seidman will receive the 2019 ASM Gold Medal from ASM International.

Bruce Wessels was selected as a lifetime member of TMS.

STUDENT NEWS

Kyle Bushick and **Yvonne Chart** received Outstanding MSE Junior and Sophomore Awards, respectively.

Graduate students **Pengcheng Chen** (Mirkin) and **Won-Kyu Lee** (Odom) received Materials Research Society Gold Graduate Student Awards at the spring 2017 MRS meeting.

Senior **Kyujin Jang** was among 17 students to receive a Korean-American Scientists and Engineers Association scholarship.

Jooheon Kang (Hersam) received the Materials Research Society Silver Graduate Student Award at the fall 2016 MRS Meeting in Boston.

Lauren Kearney (Dunand) received the Hilliard Award for Leadership, Scholarship, and Service.

Sophomore **Ben Laning** and freshman **Grace Young** received Meister Summer Research Grants. Laning will work with Sossina Haile's group to explore "Synthesis for Solid Acid Fuel Cells," and Young will work with John Rogers' group on "Integrating Thermal Flow Sensors into Microfluidic Sweat Devices for Continuous Sweat-Rate Measurement."

BS/MS student **Norman Luu** received the spring 2017 Chicago Regional ASM Scholarship.

Graduate student **Chris Mizzi** (L. Marks) received the 2017 International Centre for Diffraction Data (ICDD) Ludo Frevet Crystallography Scholarship.



Senior **Jake Song** (Keten, Shull) received the Hilliard Award for Research and Design for his work "Dynamics, Mechanics, and Multi-Scale Modelling of Polymer Nanostructures." He also received the 2017 Harold B. Gotaas Undergraduate Research Award.

Lanhe Zhang (Torkelson) received the 2016 Johannes and Julia Randall Weertman Graduate Fellowship.

ALUMNI NEWS

Michael Arnold (PhD '06, Stupp, Hersam), associate professor at the University of Wisconsin-Madison, was recently named a US runner-up for the ASPIRE international prize for innovation in research and education sponsored by the Asia-Pacific Economic Cooperation.

Karen Chen-Wiegart (PhD '11 Dunand) became an assistant professor in the Department of Materials Science and Chemical Engineering at SUNY Stony Brook.

Ram Devanathan (PhD '93, Meshii), technical group manager for the Reactor Materials and Mechanical Design group at Pacific Northwest National Lab (PNNL), was recently quoted in the international press as a membrane separation expert.

Alix Deymier (PhD '12 Dunand) accepted a tenure-track assistant professor position in the Department of Biomedical Engineering at the University of Connecticut.



Honorary alumna **Mildred Dresselhaus** (Doctor of Science '03) died February 20 in Cambridge, Massachusetts, at the age of 86. An Institute Professor Emerita of Physics and of Electrical Engineering and Computer Science at MIT, Dresselhaus received many prestigious awards, including the Presidential Medal of Freedom in 2014.

Theo Gao (BS '16), who is now a PhD student at Stanford, received a National Defense Science and Engineering Graduate Fellowship.

Jeff Gotro (PhD '83, Graessley) recently published the *Encyclopedia of Polymer Science* with collaborator R. Bruce Prime.

Peijun Guo (PhD '16, Chang; MS '11 Olvera de la Cruz) received the Enrico Fermi Fellowship at Argonne National Laboratory. He also received the Materials Research Society Gold Graduate Student Awards fall 2016 MRS Meeting in Boston.



Benjamin Leever (PhD '11, Hersam) received the Vincent J. Russo Award for Leadership Excellence from the Air Force Research Lab Materials and Manufacturing Directorate. Leever and his colleagues also received the Robert T. Schwartz Engineering Achievement Award for their work in the development of conformal antennae that can be integrated onto an unmanned vehicle.

Ashley Paz y Puente (PhD '16, Dunand), became an assistant professor in the Department of Mechanical and Materials Engineering at the University of Cincinnati.

STAFF NEWS



Jim Hahn, physics student shop instructor and instrument maker, retired (for a second time) on December 6 after 56 years with Northwestern. He joined the Department of Materials Science and Engineering's machine shop in July 18, 1960. In the past two decades, he continued part-time as the instructor and adviser in the physics student shop.

Special Lectures 2016-17

Morris E. Fine Lecture

October 11, 2016
Lorna Gibson, MIT

John E. Dorn Lecture

January 31, 2017
Jerry Tersoff, IBM

Dow Lecture

May 2, 2017
Paula Hammond, MIT

Jerome B. Cohen Lectures

May 30 and 31, 2017
David Muller, Cornell University

SERENDIPITY UNCOVERS BOROPHENE'S POTENTIAL

Organic material self-assembles next to borophene with nearly perfect interface

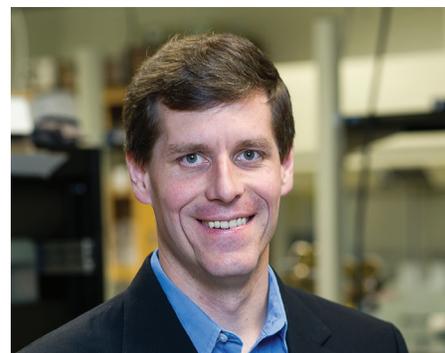
Nearly two years ago, borophene didn't even exist. Just months after a Northwestern Engineering and Argonne National Laboratory team discovered the material, another team led by Professor **Mark Hersam** is already making strides toward understanding its complicated chemistry and realizing its electronic potential.

First reported in December 2015, borophene is a two-dimensional, metallic sheet of boron, the element commonly used in fiberglass. Although borophene holds promise for possible applications ranging from electronics to photovoltaics, these applications cannot be achieved

until borophene is integrated with other materials. Now Hersam's team — and a bit of serendipity — have successfully accomplished this integration.

Because borophene does not appear in nature, scientists must grow it in the laboratory by synthesizing it on a sheet of silver. Hersam's team deposited an organic material on top of the borophene, in an attempt to integrate the two materials. What happened next was a surprise. The organic material, which is known to self-assemble on essentially any material, instead diffused off the borophene and onto the silver sheet.

The result was a self-assembled monolayer of the organic material directly next to the borophene, forming a nearly perfect interface. Well-controlled interfaces between distinct materials enable integrated devices, including diodes and photovoltaics. Hersam's surprising technique bypassed the typical



Hersam

challenge to creating a sharp interface — getting materials to touch but not mix.

The research was published in the journal *Science Advances*. Professor **Erik Luijten** co-authored the paper. Xiaolong Liu, a student in Northwestern's Applied Physics Graduate Program, was the paper's first author.

DESIGNING NEW MATERIALS FROM 'SMALL' DATA

Team develops unique workflow to design new materials

Finding new functional materials is always tricky. But searching for very specific properties among a relatively small family of known materials is even more difficult.

Now a team from Northwestern Engineering and Los Alamos National Laboratory has found a workaround. The group developed a novel workflow that combines machine learning and density functional theory calculations to create design guidelines for new materials that

exhibit useful electronic properties, such as ferroelectricity and piezoelectricity.

"When others look for new materials, typically they look in places where they have a lot of data from similar materials," said Associate Professor **James M. Rondinelli**. "When you don't have a lot of information, learning from the data becomes a difficult problem."

Along with Los Alamos's Prasanna Balachandran, Rondinelli built a database of known materials using machine learning to identify chemical compositions that are likely candidates for the potential new material. The work was published in the February 17 issue of *Nature Communications*.



Rondinelli

Sketching Sensors with Conducting Polymer Pen

Graduate students Daniel Hickox-Young and Luke Prestowitz developed a novel “smart ink” pen, which propelled them to the KAUST DIY Electronics Innovation Challenge, an international contest to encourage the development of creative and inexpensive electronics.

Called the “PolySketch Pen,” the patent-pending tool culminated from a course project in MSE 337: Introduction to Conducting Polymers, developed and taught by Professor Jiaying Huang. The pen contains a conductive polymer ink made from dispersed polyaniline nanofibers in water and can be used to sketch chemical and mechanical sensors. Hickox-Young and Prestowitz worked out the right additives to help the ink dry quickly and make writing smooth on paper.

