2015 Annual Report

Engineering without Boundaries

IME's Vision Takes Form

THE UNIVERSITY OF CHICAGO

Institute for Molecular Engineering

VISION: The Institute for Molecular Engineering will lead engineering research and education in new directions, solve major technological problems of global significance, and continually inspire applications of molecular-level science.

On the cover and this panel: the William Eckhardt Research Center. (See story p. 12)

Engineering without Boundaries
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Engineering Without Boundaries

IME achieved several milestones during the year 2015. Two new faculty members joined us, and three more agreed to join us, bringing our faculty cohort to fourteen, and putting us across the halfway point to our initial objective of twenty-five. The Pritzker Nanofabrication Facility (PNF) is now fully equipped and open for business, thanks to the generosity of The Pritzker Foundation, and the hard work of the PNF staff. Fundamental to our goal of 'Engineering without Boundaries' is the launch of our undergraduate major, approved in May of 2015, and to be delivered beginning April 2016.

Matthew Tirrell speaks with a guest at IME's inaugural Industrial Affiliates Day reception in August 2015. (See p. 48)

In several ways, the construction of a successful undergraduate program is a very important test of our vision for the Institute for Molecular Engineering. Our graduate student education and research programs are exciting and innovative amalgams of traditional lines of engineering and applied science. In those endeavors, we are working in groups that intimately mix students with undergraduate degrees in physics, chemistry, biology, as well as biological, chemical, mechanical, electrical, and materials engineering. Unanticipated insights and techniques are emerging, such as biological sensing based on quantum phenomena in the solid state, or novel glassy materials with a tunable degree of molecular order.

Though we respect disciplines, we also believe that traditional, one-discipline training in engineering often does not prepare students optimally for solving complex technological problems. On a recent review of a program at a renowned international institution, I heard a colleague say in a rather offhand manner, "There is no physics, chemistry or biology, there is only nature." A similar statement can be made about engineering. Narrow slices of engineering are artificial university constructs; the true discipline is engineering: How do you translate science into technological solutions for society? At UChicago, we are doing this from the molecular level up.

Undergraduate students entering The University of Chicago have not yet acquired disciplinary education. This is the challenge that the IME is addressing. Our approach is to provide many elements of a classical engineering and applied science education. However, we do not try to imprint students with a traditional disciplinary label. Instead, we seek to develop our students' intellectual range. We will give them a set of fundamental engineering tools, to be sure, comparable to that which all good engineering curricula do. But we will also go above and beyond that to insist on breadth as well as depth, an appreciation that solutions of complex problems require creativity, lateral thinking, articulate expression and, ultimately, an ability to function in the space of different disciplinary mindsets.

I am often asked two variants of roughly the same question: (1) who else is doing this? (e.g., what IME is doing), and; (2) who are your competitors? To answer the second question first, every engineering school that is not asleep at the wheel, is our competitor. The questions that IME is tackling are important and widely appreciated. We are developing engineering approaches, and new pedagogy aimed at building functional, technologically relevant systems from the molecular level up. Many engineering schools have activities encompassing what we call molecular engineering. However, they have neither the clean slate nor the innovative approach that The University of Chicago has in creating a new way of pursuing engineering research and education. The answer to the first question is that only a few have tried to break the new ground that we are developing organizationally, at least with the imagination and inventiveness we are bringing. We are pioneers in engineering research and education, with the history and credentials of The University of Chicago supporting us. Our distinctive approach is attracting favorable attention from partners and competitors alike.

Matthew Tirrell
Pritzker Director and Dean
Institute for Molecular Engineering

Letter from Barry MacLean

As Chair of the inaugural Visiting Committee for the Institute for Molecular Engineering, it gives me great pleasure to introduce the 2015 Annual Report of the Institute. Entering its fifth year under the leadership of Pritzker Director and Dean Matthew Tirrell, the Institute has experienced rapid growth in breadth and depth, including expansion into a new building, top-tier faculty recruitment, world-changing research in water, energy, bio-immunoengineering, soft materials and quantum information.

The IME made history with the creation of the first graduate and undergraduate engineering degree programs to be offered at the University since its founding in 1890. Attracted by IME's interdisciplinary coursework and entrepreneurial focus, a significant number of incoming undergraduates indicated an interest in the new major in molecular engineering. As a first-time offering for Autumn 2015 prospective students, the option for the new undergraduate major ranked 7th in interest among the sciences, and 15th overall out of 100 possible undergraduate majors. The establishment of a degree-granting program in molecular engineering is an important milestone for the IME, but also for the University as a whole as it enhances its global reputation for excellence with the added strength of a world-class engineering program focused on inventing state-of-the-art solutions to pressing societal problems.

(continued on p. 4)

Barry MacLean

Barry MacLean is CEO and Chairman of MacLean-Fogg Company. A privately held firm, MacLean-Fogg is a world-wide manufacturer of engineered products for automotive, truck, electric power, and telecommunications businesses.

Barry MacLean served as a Dartmouth College Trustee from 1990-2000, and he has served on the Thayer School of Engineering Dartmouth College Board of Overseers for more than thirty-five years.

MacLean is a member, director, and former chairman of numerous businesses and professional organizations.

Letter from Barry MacLean (continued)

The IME achieved another milestone this fall when it relocated to its permanent home in the new Eckhardt Research Center at 57th Street and Ellis Avenue. In addition to offices for the dean, faculty and staff, the state-of-the-art building houses IME's soft materials, quantum information, and bio-immunoengineering labs as well as research space for IME post-doctoral and graduate students.

The Pritzker Nanofabrication Facility (PNF), a new 10,000-foot facility located in the lower level of the Eckhardt building, will provide high-tech research and development users, entrepreneurs, and students with the most sophisticated tools available to create nano-scale devices for many key electronics industries in the Midwest and nationwide. The PNF is poised to open its doors to industry users early in 2016, and will attract and keep high-tech R&D and related industries in Chicago.

IME faculty, fellows, and students continue to drive new discoveries on the borders of science and engineering. Highlights include: a *New York Times* article featuring a phenomenon leading to possible breakthrough technology to create light-based circuits by graduate students in Professor David Awschalom's group; Professor Juan de Pablo's group is developing liquid crystals with the potential for the detection of neuro-degenerative disease; and Professor Giulia Galli and her group are studying the underlying fundamental theories to assist in the development of efficient methods to split water with solar energy to use the released hydrogen as fuel.

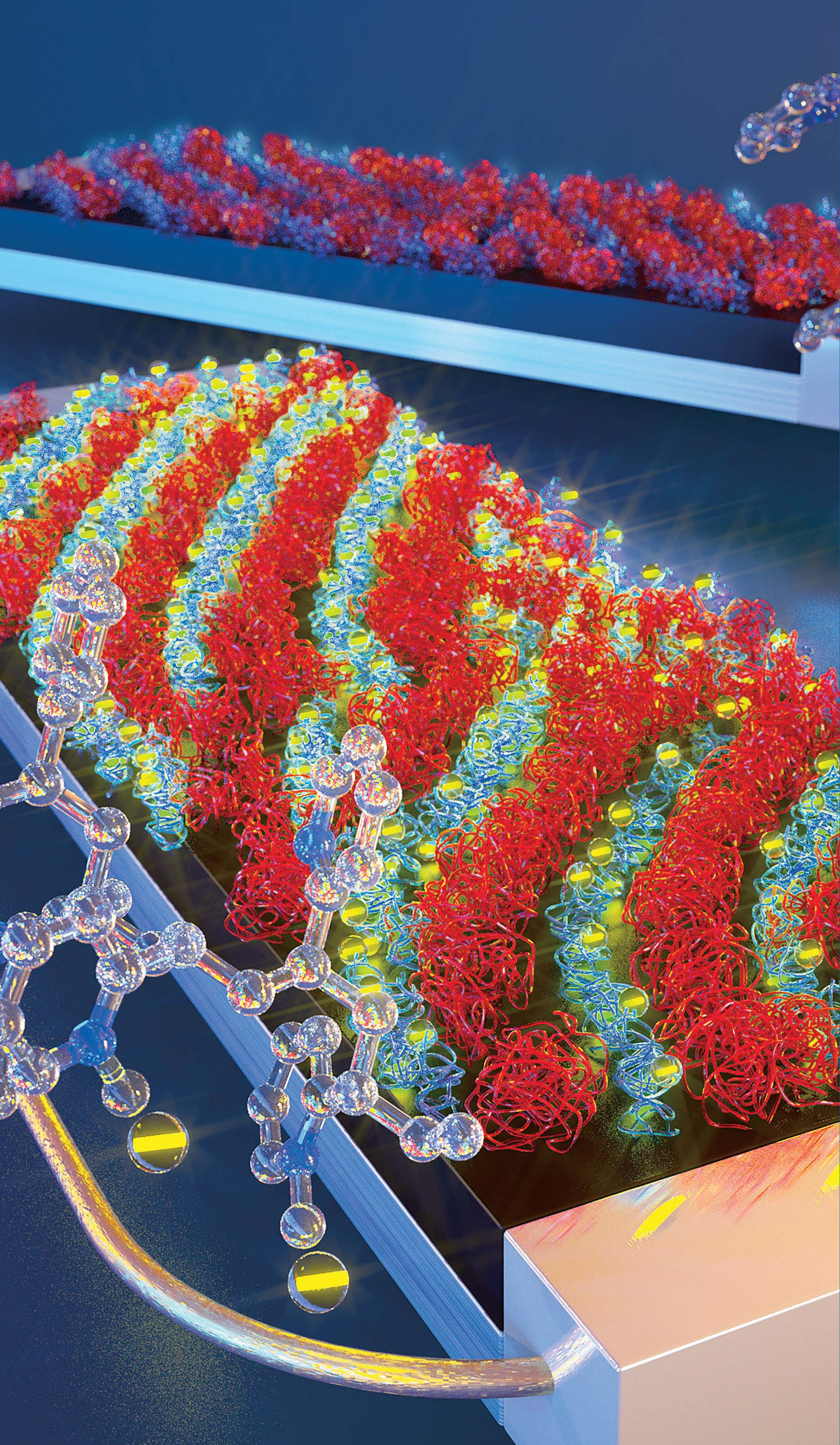
Further to their ongoing partnership, engineers and scientists from Ben-Gurion University of the Negev and the IME presented their latest collaborative research findings at a joint symposium in August that included a project to use krypton 81 dating of groundwater and its applications to water sourcing, as well as other research to create new scalable tools for freshwater production and purification that are deployable in many water-scarce regions worldwide. The IME continues to form additional international partnerships, including collaborative faculty and student exchanges with campuses including Hong Kong, China, Israel, Japan, Europe and Mexico.

The IME's progress in this past year is just a small indication of the future role of the IME at the University of Chicago and for scientific, engineering, and technological innovation on an international scale for years to come. We are grateful for your continued support as the IME fulfills its vision.

Sincerely,

Barry MacLean
Chair, IME Visiting Committee
CEO and Chairman of MacLean-Fogg Company

Scenes from the William Eckhardt Research Center dedication celebration held in October 2015. (See story p. 13) Top: University of Chicago President Robert J. Zimmer introduces William Eckhardt to the assembled guests. Middle: Attendees view a multimedia presentation. Bottom, left to right: Matthew Tirrell, Pritzker Director and Dean of the IME, Rocky Kolb, Dean of the Physical Sciences Division, and Eric D. Isaacs, University Provost.



Institute for Molecular Engineering

By the Numbers

Statistics for 2015 demonstrate the accelerating pace of growth at the IME. The Institute is positioned to continue attracting researchers and visitors from across the globe for conferences, seminars, and collaborative work—in keeping with its mission: to translate discoveries in physics, chemistry, biology, and medicine into solutions to important societal problems, and to create a research and teaching environment to enhance and transmit these capabilities to future generations.

36
Researchers at Argonne

14
IME Faculty

5
Faculty positions open

36
New grant awards

29
Grant proposals

72
PhD students

44
Postdoctoral researchers

50+
Undergraduate researchers

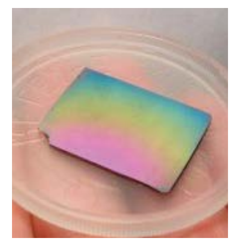
1
New degree offering (BS)

100,000
Sq. ft. of assignable laboratory and office space

87%
of IME team completed the required safety training on fire and evacuation (highest at UChicago)

125+
New publications

#1
Most read UChicago story: news.uchicago.edu (*Glass*, see p. 30)



NEW PROFESSORS

With three new appointments, the IME's faculty grows to 14 and recruiting efforts continue for five additional positions.

Supratik Guha Appointed IME Professor and Division Director at Argonne

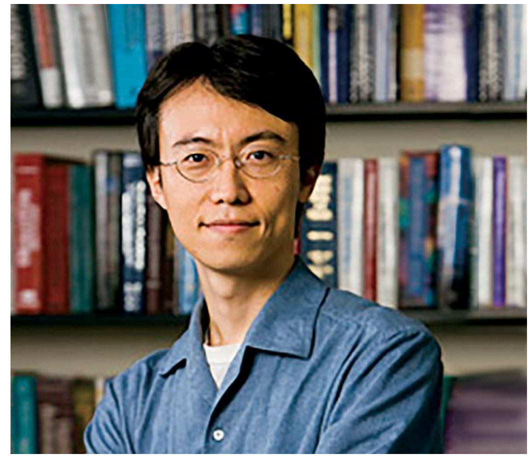
Supratik Guha is a materials scientist whose interests lie in new materials and devices for non-Boolean computing architectures, cyber-physical sensing systems, and energy conversion technologies. His background and expertise made him an excellent choice for a professorship in the IME and as the Director of the Nanoscience and Technology Division at Argonne National Laboratory.

Guha gained extensive experience in industrial research and development serving as Director of Physical Sciences at IBM Research. He pioneered the materials research that led to IBM's high-k metal gate transistor technology, one of the most significant developments in silicon CMOS technology. His work on nanoscale dielectrics and processes is used in most electronic devices.

Guha has also contributed to solar cell research, silicon microelectronics and nitride semiconductors. His more recent research has been in sensor-based studies for geo-spatial applications such as high-resolution agriculture and the tracking of pollutants in rivers.

Guha was awarded the 2015 Industrial Applications in Physics Prize from the American Physical Society and the 2013 IBM Corporate Award for his work on high-k metal gate technology. He is a Fellow of the Materials Research Society and the American Physical Society. He was elected to the National Academy of Engineering in 2014.

Jiwoong Park Jointly Appointed to the IME and Physical Sciences Division



As Associate Professor in Chemistry and in the Institute for Molecular Engineering, Jiwoong Park is the first researcher to hold a joint-appointment in the IME and the Physical Sciences Division. Not only does his work bridge molecular engineering and chemistry, it also is relevant to quantum materials and new devices.

An expert in the emerging field of two-dimensional layered materials, Park is involved in the development of electrical, optical, biological and mechanical devices, including flexible electronics and energy conversion. His research shows promise for the development of atomic-scale devices, such as 2-D semiconductors and nanotransistors.

Park has received the NSF CAREER award, the Presidential Early Career Award for Scientists and Engineers, and the Alfred P. Sloan Research Fellowship. He earned his PhD at the University of California, Berkeley, in 2003, and went on to Harvard University's Rowland Institute on an independent postdoctoral fellowship. Park was named to the faculty of Cornell University in 2006, where he is currently an associate professor in Chemistry and Chemical Biology. He will join the faculty at The University of Chicago in July 2016.

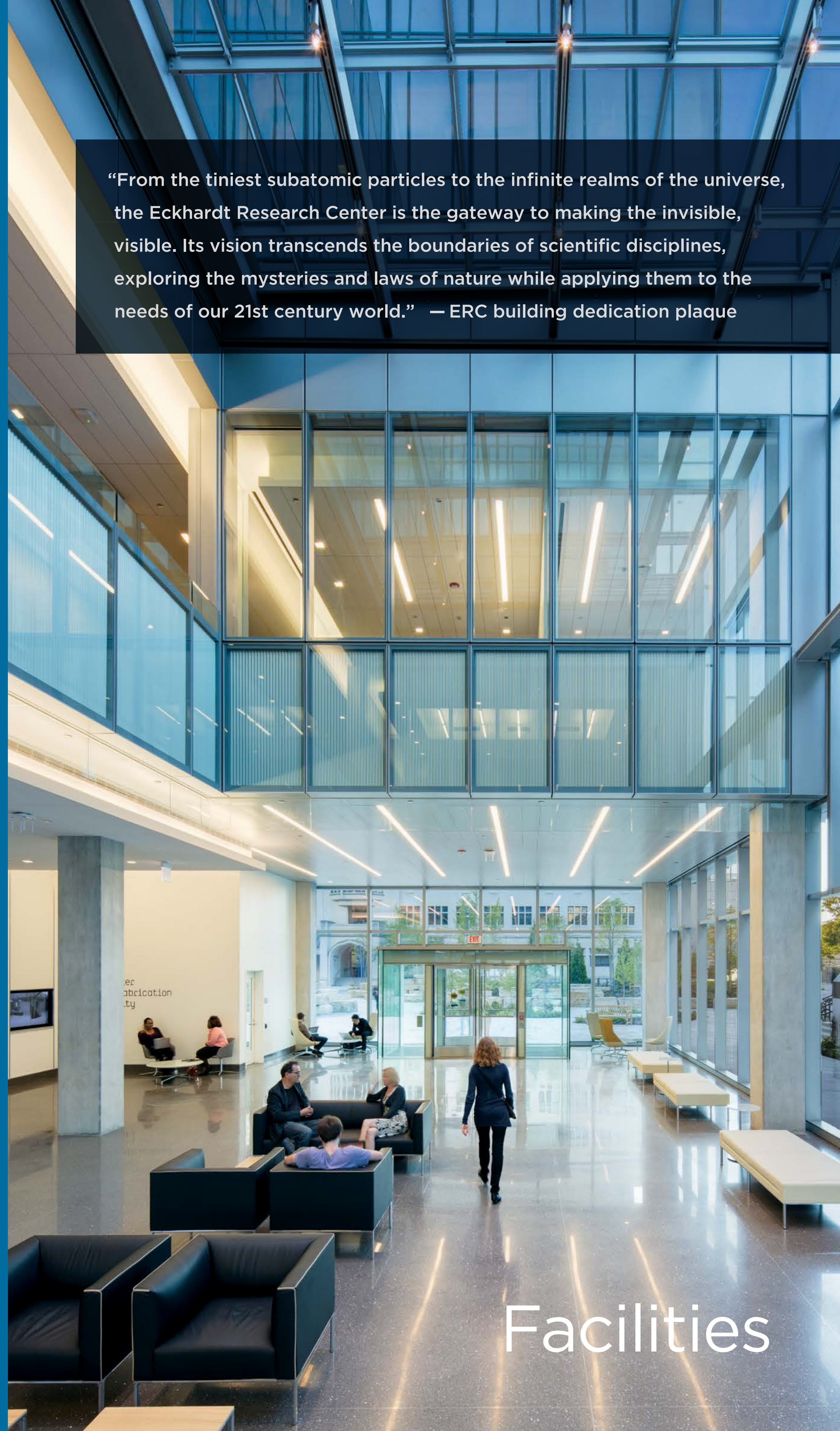
Savas Tay, Associate Professor in Molecular Engineering

Savas Tay is a systems biologist and bioengineer who uses engineering tools to manipulate cells and gene pathways to understand basic mechanisms in biology and disease. He was hired through a joint search between IME and the Institute for Genomics and Systems Biology in the Biological Sciences Division.

Tay is active in developing high-throughput and high-content single-cell analysis devices by integrating microfluidics and optics. He uses this technology to understand the role of molecular pathway dynamics in cellular information processing, pathogen sensing and recognition, and signaling.

Appointed in 2015, Tay will join the Institute for Molecular Engineering in the summer of 2016. He is currently an assistant professor of Bioengineering, Department of Biosystems Science and Engineering, Swiss Federal Institute of Technology (ETH Zurich), Basel.

"From the tiniest subatomic particles to the infinite realms of the universe, the Eckhardt Research Center is the gateway to making the invisible, visible. Its vision transcends the boundaries of scientific disciplines, exploring the mysteries and laws of nature while applying them to the needs of our 21st century world." — ERC building dedication plaque



Facilities

NEW FACILITIES MATERIALIZE IN 2015

A significant milestone in the Institute for Molecular Engineering's transition from its nascent stage to a fully-realized research and academic entity at The University of Chicago is its move into the 227,000 square foot, five-story William Eckhardt Research Center. However, the IME expanded into new spaces throughout 2015. From the Pritzker Nanofabrication Facility, to the Argonne National Laboratory facilities in Lemont, Illinois, to commercialization labs on 53rd Street, the IME has spread its wings and its researchers across the region—and their ideas around the world.

Making the Move to the William Eckhardt Research Center (ERC)

A glance at its new home—the William Eckhardt Research Center—dramatically confirms that the Institute for Molecular Engineering is no longer in start-up mode; the Institute has reached a turning point in its mission to realize a unique engineering vision.

Not only has the Institute for Molecular Engineering moved into a new building, it has entered a new phase in its mission to accelerate research discoveries, expand educational programs, and increase collaborations.

Logistically, this involved transferring offices, relocating labs, and equipping state-of-the-art facilities. Operationally, this established one home for administrative offices, specially-designed collaborative spaces, faculty and researcher offices, and new laboratories.

The 227,000 square foot, five-story Eckhardt Research Center not only houses the IME, but it contains several sections of the Physical Sciences Division (PSD), including the Astronomy and Astrophysics Department, the Kavli Institute for Cosmological Physics, and the Dean's Office (and two additional below-ground levels). The strategic combination was driven by the desire to create a global hub where boundaries between traditionally separate scientific pursuits are transcended. The structure is equipped with high-performance laboratories that allow researchers to translate quantum information science into new technologies, develop instruments that can detect planets orbiting distant stars, and much more. Rocky Kolb, Dean of the Physical Sciences Division, and Matthew Tirrell, Dean and Pritzker Director of the IME, worked closely with the architecture firm HOK and James Carpenter Design Associates to bring the project to fruition.

"A new building for astronomy and astrophysics has been in the works ever since I came to the University in the 1980s, maybe since the '60s," said Kolb (pictured below). "Planning for the Eckhardt Research Center itself started in at least 2005, when the idea of the IME did not yet exist. So having IME as part of the building, which wasn't in the original plan, really was a game changer, shifting the nature, size and functionality of the building, which will provide us great benefit."

"Molecular engineering can contribute to astronomy and astrophysics via fabrication of new detectors and other instrumentation," said Tirrell. "And IME will benefit from the PSD in terms of researchers with various backgrounds in the same location making connections with one another. We will literally span activities from the tiniest to the most gigantic."

The ERC is named for Chicago-based investment manager William Eckhardt, SM'70, in recognition of his gift to support scientific research at the University.

Dedication + Celebration

The William Eckhardt Research Center was formally dedicated on October 29, 2015. The special dedication celebration included a reception and digital presentation, tours, and remarks by University President Robert J. Zimmer, Provost Eric Isaacs, Dean of the Physical Sciences Rocky Kolb, and IME Pritzker Director and Dean Matthew Tirrell. Philanthropist William Eckhardt, for whom the building is named, was recognized for his generous support and consistent enthusiasm for science.

The Pritzker Nanofabrication Facility—Thinking Globally, Acting Locally at the Nanoscale

One of the first of its kind in the country, the Pritzker Nanofabrication Facility (PNF) inside the Eckhardt Research Center has been designed for fabrication of devices with unique nanoscale features. The advanced tools available in this facility will enable IME researchers to solve important technological issues with societal implications.

Andrew Cleland, the John A. MacLean Sr. Professor in Molecular Engineering Innovation and Enterprise, is the faculty director of the PNF. "The facility provides a unique research and development environment for the academic and industrial scientist interested in pursuing state-of-the-art micro- and nanoscale fabrication," Cleland said. "It provides a full suite of advanced lithographic tools, chosen to be compatible with a wide range of different materials and processes. We anticipate drawing researchers from the Chicago area, the Midwest, and the nation to this facility, both to use its resources and to establish collaborations with IME and UChicago researchers."

IME Pritzker Director and Dean Matthew Tirrell is confident that the Eckhardt Research Center is poised to become part of a new complex of buildings focused on applied science, signaling the University's efforts to concentrate on application, a departure from the traditional emphasis on pure, discovery-driven science and theory. This shift, combined with the advanced, but adaptable, infrastructure of the ERC, will allow the University to attract top talent interested in working in this advanced environment. ⬣

THE PNF DETAILS

The Pritzker Nanofabrication Facility is a multi-purpose 10,000 square foot, class 100/1000 cleanroom. Equipment presently planned for, and being installed in the PNF cleanroom includes:

- an advanced electron beam lithography system
- an I-line optical stepper
- contact aligners
- physical vapor deposition tools including sputtering systems for magnetic and non-magnetic materials, electron beam evaporators, and a thermal evaporator
- plasma etching systems configured for both chlorine and fluorine based etching
- inspection tools including
  - scanning electron microscopy
  - atomic force microscopy, and
  - high-performance optical microscopy
- profilometry, ellipsometry, and thin film interferometry
- a probe station
- precision dicing saw.

The facility will provide highly functioning advanced lithographic processing of both soft and hard materials. It will accommodate users interested in processing unusual types, shapes and sizes of substrates, as well as those doing more conventional wafer-based processing. All tools are configured to handle up to 100mm and 150mm wafers as well as pieces. Staff will be available to help train users and help develop specific processes.

New Facilities at Argonne Reinforce a Fundamental Partnership

From its inception, the IME has always been envisioned as an integral part of Argonne National Laboratory. Their collaboration and exchange of resources has been built into the IME's administration, faculty appointments, research, educational opportunities, and lab and facilities planning.

In 2015, IME's presence at Argonne took dramatic steps forward. The Institute moved into offices and 7,300 square-feet of laboratory space in the recently completed Energy Science Building (pictured above right) and Molecular Engineering Module (MEM). The spaces have been designed to enable groundbreaking research that will impact the fields of energy storage and harvesting, quantum information technology, and nano-patterning and nano-lithography.

Diana Morgan, who has been with IME since 2011, is now at Argonne as the full-time administrator and liaison for the Institute, providing "boots on the ground" to manage the ramping up of the activities of faculty, grad students, postdocs, and other scientists conducting research in the new offices and labs.

During 2015, the number of IME researchers working regularly at Argonne grew from a handful to 36, with an additional 34 students and postdocs conducting experiments and computational activities at various Argonne facilities, including the Advanced Photon Source (APS) and the Argonne Leadership Computing Facility (ALCF).

Three major Field Work Proposals (FWPs)—IME research programs funded by the U.S. Department of Energy—are underway with budgets totaling $5.9 million per year. One of the projects, investigating the assembly of complex polymeric materials, is conducted by Juan de Pablo, Liew Family Professor in Molecular Engineering, Paul Nealey, Dougan Professor in Molecular Engineering, and Matthew Tirrell, IME Pritzker Director and Dean, along with Argonne scientists Seth Darling and Wei Chen. A second project, focusing on quantum materials, is led by David Awschalom, Liew Family Professor in Molecular Engineering. The third FWP, the Midwest Integrated Center for Computational Materials (MICCoM) is directed by Giulia Galli, Liew Family Professor in Molecular Engineering, with de Pablo serving as deputy director. (See story p. 17)

(continued on next page)

SHyNE

NSF Award to Support Nanofabrication Infrastructure at UChicago's PNF and Northwestern University

The Pritzker Nanofabrication Facility in the Eckhardt Research Center has been selected to participate in a nationwide, $81 million NSF grant to establish a new National Nanotechnology Coordinated Infrastructure.

In partnership with Northwestern University, IME will receive a five-year, $5 million grant to establish a collaborative venture in nanoscale science, engineering and technology research. The Soft and Hybrid Nanotechnology Experimental (SHyNE) Resource of the two institutions will coordinate the integration of a diverse and open-access group of nanoscale fabrication and characterization facilities at Northwestern and UChicago for internal and external users, both academic and industrial.

"This award from the National Science Foundation will provide critical support for external users who want to develop nanostructure fabrication and characterization," said Andrew Cleland, the John A. MacLean Jr. Professor for Molecular Engineering Innovation and Enterprise. Cleland is the faculty director for SHyNE. The new venture will draw researchers from the Chicago area, the Midwest, and nationally to UChicago and Northwestern facilities. "Our facility provides a unique research and development environment for academic and industrial scientists interested in pursuing state-of-the-art, micro- and nanoscale fabrication," said Cleland.

IME at Argonne

Staff	1
Scientists	2
Postdocs	10
Research Associates	8
Graduate Students	13
Visiting Scientists and Visiting Postdocs	3
APS Users	18
Joint PI Appointments	8

In a move to enhance the research capabilities at ChemMatCARS—a facility located at Sector 15 on Argonne's APS dedicated to chemistry and materials science research—the National Science Foundation in 2015 awarded a Major Research Instrumentation (MRI) award to Tirrell and two other co-principal investigators from the University of Illinois–Chicago and Argonne to support the acquisition and implementation of a state-of-the-art pixel array area detector. The new capabilities will aid in the work of characterizing nano-polymeric materials at the atomic level, advancing knowledge of possible structures to improve solar energy conversion and other processes and materials. One of IME's newest faculty members, Supratik Guha, was named Director of Argonne's Nanoscience and Technology Division in August, 2015, with office and lab space at Argonne. Together with the Awschalom group, Guha is establishing his labs in the just-completed MEM. Including Guha, eight faculty researchers have joint appointments at IME and Argonne.

As Tirrell looks forward to the next several years, he sees the potential to develop seamless processes that will enable scientists and students to carry out research programs on both campuses. In addition, researchers at the newly-established Pritzker Nanofabrication Facility at IME (see story p. 14) will work closely with those at its peer facility, Argonne's Center for Nanoscale Materials, to establish the premier research nanofabrication cluster in the country.

"Our work signals the University of Chicago's efforts to concentrate on application, a departure from the traditional, heavy emphasis on pure, discovery-driven science and theory," said Tirrell. "With our new facilities, our faculty and students are limited only by their dreams and imagination."

New Position at Argonne

In September 2015, Matthew Tirrell assumed a new position as Argonne's Deputy Laboratory Director for Science. As a scientific adviser to Argonne Director Peter B. Littlewood, Tirrell will be responsible for integrating research, development, science, and technology capabilities. He will develop and drive the strategy to support collaborating teams across divisions and disciplines, in support of Argonne's strategic initiatives. His dual roles—directing science at Argonne and directing IME at UChicago—will further strengthen collaborations between the two institutions.

New Center to Develop Software Tools to Simulate and Model Novel Materials

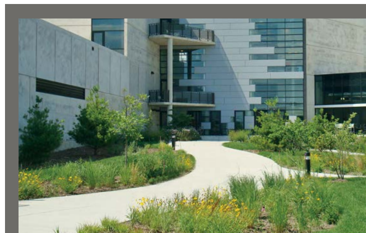
The Midwest Integrated Center for Computational Materials (MICCoM) has been established at Argonne National Laboratory through a four-year, $12 million grant from the Department of Energy. Giulia Galli, Liew Family Professor in Molecular Engineering at IME and a senior scientist at Argonne, will direct the center.

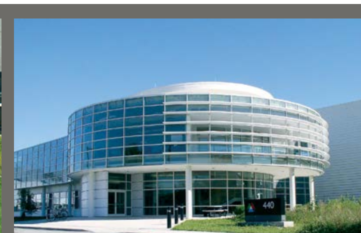
Charged with developing advanced, open-source software tools, MICCoM scientists will develop codes to simulate and model nanoscale and mesoscale materials, thus enabling scientists to predict the fundamental properties and behavior of materials for energy conversion, including metastable materials assembled outside equilibrium conditions.

"We will use sophisticated software to design entirely new materials with desired properties," said Galli. "In particular, MICCoM codes will be used to understand and predict the assembly of nano-sized materials into new, heterogeneous systems with targeted properties and functions."

Headquartered at Argonne, with co-investigators from several universities, including The University of Chicago, Northwestern, Notre Dame, the University of Michigan, and University of California, Davis, "MICCoM demonstrates the kind of exceptional resources a national lab such as Argonne can bring to bear on solving the nation's energy challenges," said Peter Littlewood, Director of Argonne. "The techniques that MICCoM will provide to forecast the behavior of these innovative materials will be critical to the next generation of energy solutions, such as efficient, low-cost solar panels to convert sunlight directly into electricity and battery materials that can't overheat."

In addition to Galli, the MICCoM team includes Juan de Pablo, Liew Family Professor in Molecular Engineering at IME, Argonne senior scientists Ray Bair and John Mitchell, and Francois Gygi, Professor in Computer Science at the University of California, Davis.





MICCoM's data management and computing will primarily use capabilities at the Argonne Leadership Computing Facility (above left). Testing and validating the materials-specific predictions generated by the new software tools will include experiments at the Center for Nanoscale Materials (above center) and the Advanced Photon Source (above right).

QUANTUM MEASUREMENT LABORATORIES

Built on three feet of concrete just a few inches above solid bedrock located nearly four stories below street level, a series of world-class precision measurement laboratories have been constructed in the Eckhardt Research Center.

Literally at the foundation of the ERC, the labs not only minimize vibrations, they are precisely temperature- and humidity-controlled, as well as electromagnetically shielded to enable extremely sensitive measurements at the level of single electrons and individual atomic nuclei.

The labs will house the Quantum Science and Engineering program in the IME, where dozens of students will collaborate with colleagues in the Physical Sciences Division on new research efforts in quantum information processing, communication, and sensing. "These laboratories are amongst the most impressive measurement facilities in the country," said David Awschalom, Liew Family Professor in Molecular Engineering. "They enable a new generation of exploratory experiments in a variety of materials with unprecedented sensitivities."

IME at CIE: Fostering Invention and Commercialization

The Doerr Fab Lab and Building at the Chicago Innovation Exchange (CIE) opened in 2015 as a new University of Chicago initiative to help scholars and entrepreneurs translate their ideas and new technologies into startup businesses and products. The Institute for Molecular Engineering occupies one dedicated office and rents additional incubator space in the new building.

The IME's spaces at Doerr Fab Lab enable faculty, staff, researchers, and students more direct communication and interaction with CIE staff and The University of Chicago entrepreneurial community. Additionally, the Doerr Building is the new home of IME's Innovation and Commercialization Fellows Program. (See story p. 22)

Leading the University's water resource management program, IME will use the new space to bring together partners from different divisions within the University, as well as from public and private sectors outside the University, to generate ideas and collaborate on projects. The recent Water Conference, held at the CIE Skydeck at the University's Harper Court building, included a breakout session on intellectual property procurement and the commercialization process led by IME graduate students (and IC Fellows) Yu Kambe, John Barrett, and Kevin Miao, along with Senior Associate Dean Sharon Feng. The discussion inspired active participation and yielded further patent inquiries for three projects.

IME is also involved in other CIE sponsored activities. In addition to their roles in the ICFP, graduate students Yu Kambe and John Barrett, and postdoctoral scholar John Colson serve as Associates at the Innovation Fund, CIE's $20 million early/seed-stage venture fund. Kambe and Barrett also serve as IME representatives to the CIE student advisory committee, providing input and direction for student-focused programming at the CIE.

The Chicago Innovation Exchange at The University of Chicago occupies two buildings at the intersection of 53rd Street and Harper Avenue in Hyde Park. The CIE fosters innovation and commercialization through business incubation spaces, cross-disciplinary connections, and community involvement.

"At many universities, programs evolve within existing school traditions, inheriting institutional and academic views and constraints. The IME is bringing together preeminent faculty and researchers who work with students across disciplines to solve real-world problems. Our students help define their experience—with exposure to innovative models of accessing information, communicating ideas, and developing applications." —Matthew Tirrell

Education

RE-ENVISIONING ENGINEERING EDUCATION

As the first engineering initiative in the 125-year history of The University of Chicago, the Institute for Molecular Engineering has shaped engineering at the institution. Rigorous inquiry and social impact—the tenants at the core of UChicago itself—became the IME's operating principles, embodied in its teaching pedagogy and laboratories at the forefront of technology.

IME's classrooms and teaching labs focus on scientific concepts and skills in concert with communications, innovation, and leadership. Students are trained to become impactful, engaged problem-solving leaders. A broad, innovative program of courses and unique opportunities for both undergraduate and graduate students ensures that students from the Institute for Molecular Engineering are prepared to make a difference in the world.

Undergraduate Major in Molecular Engineering Launched at the University of Chicago

Following a successful launch of the PhD degree and the molecular engineering minor degree in 2014, a Bachelor of Science degree in molecular engineering has been established at The University of Chicago, the first class for the major will be offered in Spring 2016.

Designed and delivered by the faculty of the Institute for Molecular Engineering, the program requires students in the College to master a strong foundation in mathematics, physics, chemistry, and biology. As part of this training, students are also challenged to find ways that engineering skills can be used to address societal issues, such as health care, energy, information technology, and water scarcity.

Undergraduates will be prepared for a wide variety of careers in technology-focused industries, as well as positioned for further post-graduate study in fields such as science, engineering, medicine, business, and law. The aim is to introduce invention and design, along with inquiry and discovery, as fruitful and complementary intellectual disciplines.

New courses will develop quantitative reasoning and problem-solving skills, introduce engineering analysis of physical, chemical, and biological systems, and address open-ended technological questions across a spectrum of fields.

Incoming students will be able to choose from two tracks: one aimed at engineering with a biological, chemical, and soft materials emphasis; and another geared toward applied physics. The applied physics track, offered in close collaboration with the Department of Physics, will be one of the first initiatives world-wide to formally educate quantum engineers at the undergraduate level.

IME Professor and Director of Undergraduate Studies Paul Nealey leads an orientation-week information session for incoming first-year students.

The program's capstone is a 300-unit design course, in which student teams will spend a quarter working with a faculty mentor to solve an open-ended problem. For example, students may analyze chemical and biological properties of cancer cells to develop new treatment and delivery vehicles, or harness the properties of electrons in materials to develop quantum information technologies.

> "What we're doing with undergraduate engineering education is completely different and completely new." —Paul Nealey

"What we're doing with undergraduate engineering education is completely different and completely new," said Paul Nealey, the Dougan Professor in Molecular Engineering and the Institute's Director of Undergraduate Studies. "One of the primary reasons we've attracted the faculty we now have was this opportunity to conceive of and implement a forward-looking curriculum to educate engineers for the next century."

COURSE PROFILE: MENG 20000: INTRODUCTION TO EMERGING TECHNOLOGIES

Dean Matthew Tirrell teaches the introductory course. In keeping with his commitment to training undergraduates to become creative, productive, and engaged participants in a technological society, Matthew Tirrell, IME Pritzker Director and Dean, teaches a course designed as an introduction to all undergraduates who are interested in either a major or minor in molecular engineering.

The non-degree introduction to molecular engineering provides a broad perspective on the field's areas of inquiry and relevance in today's society. Over the span of a quarter, "Introduction to Emerging Technologies" examines subjects such as stem cells in regenerative medicine, quantum computing, water purification, and new batteries. Topics covered include the basic science underlying emerging technology, and hurdles that must be addressed successfully to convert a good scientific concept into a commercial product that addresses needs in the market place.

In Autumn 2015, 70 students with majors in areas as diverse as economics, the humanities, and the social sciences, took the course, underscoring its interdisciplinary appeal. Their feedback was overwhelmingly positive:

"I have learned a lot about exciting new technologies and it has confirmed the exact direction of my desired career path. After taking this course I realize emerging technologies industry is an ideal fit for me as I have a propensity for the sciences and hope to continue my education in chemistry in the future." —Ryan Walsh

"The lectures were extraordinarily intriguing and very well put it together. This is doubtlessly my favorite course I've taken so far, and I look forward to what I encounter in future courses of the IME minor." —Pat Callahan

"This class—focused on bringing these technologies to market and encouraging us to think about the ways in which these scientific concepts could be used to transform the world as we know it—was truly eye opening." —Madeline Sovie

"I really enjoyed each of the emerging technologies we covered. It was also exciting to hear about the startups that are in those spaces." —Amutha Muthukumar

Partnering to Create the Innovation and Commercialization Fellowship Program

A student-led effort to link new discoveries and inventions with commercialization was established in 2015 as a partnership between the Institute for Molecular Engineering and the University's Chicago Innovation Exchange (CIE).

"We're building a culture of innovation at UChicago and here at IME."
—John Colson.

The Innovation and Commercialization Fellowship Program (ICFP) empowers graduate students and postdoctoral scholars affiliated with IME to engage with the UChicago innovation ecosystem to address the challenges associated with commercializing University technology. Graduate students Kevin Miao and John Barrett have been named inaugural fellows, along with ICFP co-founders Yu Kambe and John Colson, a post-doctoral researcher.

"We're building a culture of innovation at UChicago and here at IME," said Colson. "We started ICFP to encourage students, researchers, and faculty to 'get out of the building' and experience the impact their discoveries could have. We want to give them the skills to explore entrepreneurship."

In addition to maintaining an active portfolio of IME discoveries and intellectual property, the IC fellows will serve as ambassadors to organizations on campus, such as the Polsky Center for Entrepreneurship and Innovation, the Chicago Innovation Exchange, and UChicagoTech, the University's technology transfer office.

"We've received active support from UChicago-Tech, CIE, and the Polsky Center," said Kambe. "Since we launched in May, we've collaborated with IME professors and researchers in preparing several invention disclosures to UChicagoTech. And we successfully applied for funding through the Polsky Center's I-Corps program."

In addition, IC fellows participated in IME's Water Conference in August 2015, and they co-organized events, such as the Innovation Showcase and a Fab Lab 101 Demo Day at the CIE. The ICFP is housed in the new Doerr Building at the Chicago Innovation Exchange on 53rd Street in Hyde Park. The space enables faculty, researchers, students, and staff to have more direct contact with CIE staff and The University of Chicago entrepreneurial community.

Pictured are the IME Innovation and Commercialization Fellowship Program's Inaugural Fellows, Kevin Miao (right center) and John Barrett (right), with additional Fellows John Colson (left) and Yu Kambe (left center), and Sharon Feng, Senior Associate Dean and Advisor to ICFP at IME (center).

Learning to Communicate Science to a Wide Range of Audiences

While graduate students in the IME are working hard to discover new ways to address both scientific and societal challenges, they are also learning to communicate their ideas to diverse audiences, including the public.

Perhaps nowhere is this more visible than in a new program designed in collaboration with Chicago's Museum of Science and Industry (MSI). Through a series of workshops, students learn to present their own research in terms that are accessible to a general audience. Their work is displayed alongside exhibits at the museum, such as Robot Revolution and Body Worlds.

"We help them expand their comfort zones through exposure to innovative models of science communications."
—Juan de Pablo

The initiative is just one of the ways students in the IME go beyond acquiring knowledge and technical skills in their areas of focus.

Another is the STEM Writing Program, which teaches principles of effective science writing based on anticipating and shaping how readers respond to science. IME Workshops on Teaching Fundamentals, which support students

Helping to lead the IME's science communication program is Dr. Rabiah Mayas, Museum of Science and Industry Director of Science and Integrated Strategies.

to become teachers who encourage active learning and problem-solving in STEM classrooms, is another example of the supplemental training IME students receive.

"Our students learn more than science through their graduate school experience," said Juan de Pablo, Liew Family Professor in Molecular Engineering and Director of the PhD program. "We help them expand their comfort zones through exposure to innovative models of science communications."

POSITIONED TO MAKE A DIFFERENCE

IME Alumni Profiles

Christopher Arges

Gordon A. and Mary Cain Professorship, Assistant Professor in the Cain Department of Chemical Engineering, Louisiana State University

When Chris Arges first came to IME, his background was in polymer electrolytes and electrochemistry and he did not have any prior background in polymer physics or lithography. However, Paul Nealey, Dougan Professor in Molecular Engineering, was confident Arges could apply his expertise in the Nealey lab.

As a postdoctoral fellow at Argonne National Laboratory with the Nealey Group, Arges studied how the salient structural features of self-assembled block copolymer electrolytes alter the ion-conduction process in thin films. Polymer electrolytes are ubiquitous to a plethora of electrochemical cells, spanning batteries, fuel cells, electrolyzers, etc. Improving the conductivity of polymer electrolytes enables more efficient electrochemical cells.

"IME has contributed significantly to my growth as a scholar and the experience will undoubtedly make a difference in helping me launch a successful research enterprise at LSU," said Arges. "The diversity of research themes helped me develop a broader view of the engineering discipline. I now have a better sense of where it needs to go to address 21st century problems and realize emerging technologies."

Eun Ji Chung

Gabilan Assistant Professor of Biomedical Engineering University of Southern California

Eun Ji Chung came to the IME in 2012, joining Professor Matt Tirrell's research group to learn about self-assembly and nanoscale science, and diversify her background in biomaterials. However, in addition to expanding her skill set and learning about nano-level manipulation for biomedical applications, she also participated in the overall growth and development of the IME. The experience paved the way for her to become the Gabilan Assistant Professor of Biomedical Engineering at the University of Southern California.

Chung's first paper with Professor Tirrell and neuro-oncology collaborator, Dr. Maciej Lesniak, was accepted without revisions (other than formatting changes) and became one of the first collaborations between IME and the larger UChicago community.

"I remember during the 2014 AIChe Conference, Matt was standing in the back and I was sitting in the audience. I forwarded to him the email that I had just received from the NIH informing me that I had been awarded the K99/R00 'Pathway to Independence' grant. It felt like all our hard work had finally paid off, and I was really on my way to pursuing an academic career. The support from Matt, my lab colleagues and interns, as well as my collaborators has been invaluable," said Chung.

Gurdaman (Daman) Khaira, IME PhD '16

Software Development Engineer Mentor Graphics

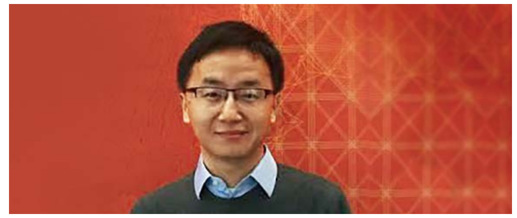
As a graduate student in the IME with the de Pablo group, Daman Khaira worked extensively on developing simulation methods to predict the properties of block copolymer mixtures under various process conditions. The materials are believed to be best for manufacturing very dense electronic circuits.

The research environment of IME, along with the people there, helped prepare Khaira for his current position designing simulation tools to manufacture the next generation of electronics. Khaira credits his successful IME experience to the influence of individuals ranging from Juan de Pablo, Paul Nealey, and Matthew Tirrell, to IME/Argonne administrator Diana Morgan, to IME postdoc Jian Qin, to IME Research Scientist Manolis Doxastakis.

"IME gave me the opportunity to pursue my research without being micro-managed," said Khaira. "I think that's very important for independent researchers."

Jian Qin

Assistant Professor in Chemical Engineering Stanford University



While working in the Institute for Molecular Engineering, Jian Qin's work exemplified the collaborative, interdisciplinary nature of the Institute. His research with the de Pablo Group focused on the development of theories and simulations of soft matters and polymers.

Qin used statistical mechanics as the major tool to understand the macroscopic, structural, physical, and morphological properties of soft materials by using molecular scale information. However, he worked closely with a number of experimental groups as well, including those of IME's Matthew Tirrell and Paul Nealey, and IME Fellow, Heinrich Jaeger.

"The opportunity to work in a big research group has exposed me to multiple research directions and certainly helped me grow intellectually," said Qin. "In addition to the IME faculty, I had the privilege of working with great people outside IME, such as Karl Freed and Tom Witten from the James Franck Institute."

First Science Writing Fellow

Stephanie Bi, a fourth-year undergraduate in the College, was named the IME's first-ever science writing fellow for the 2015–2016 academic year.

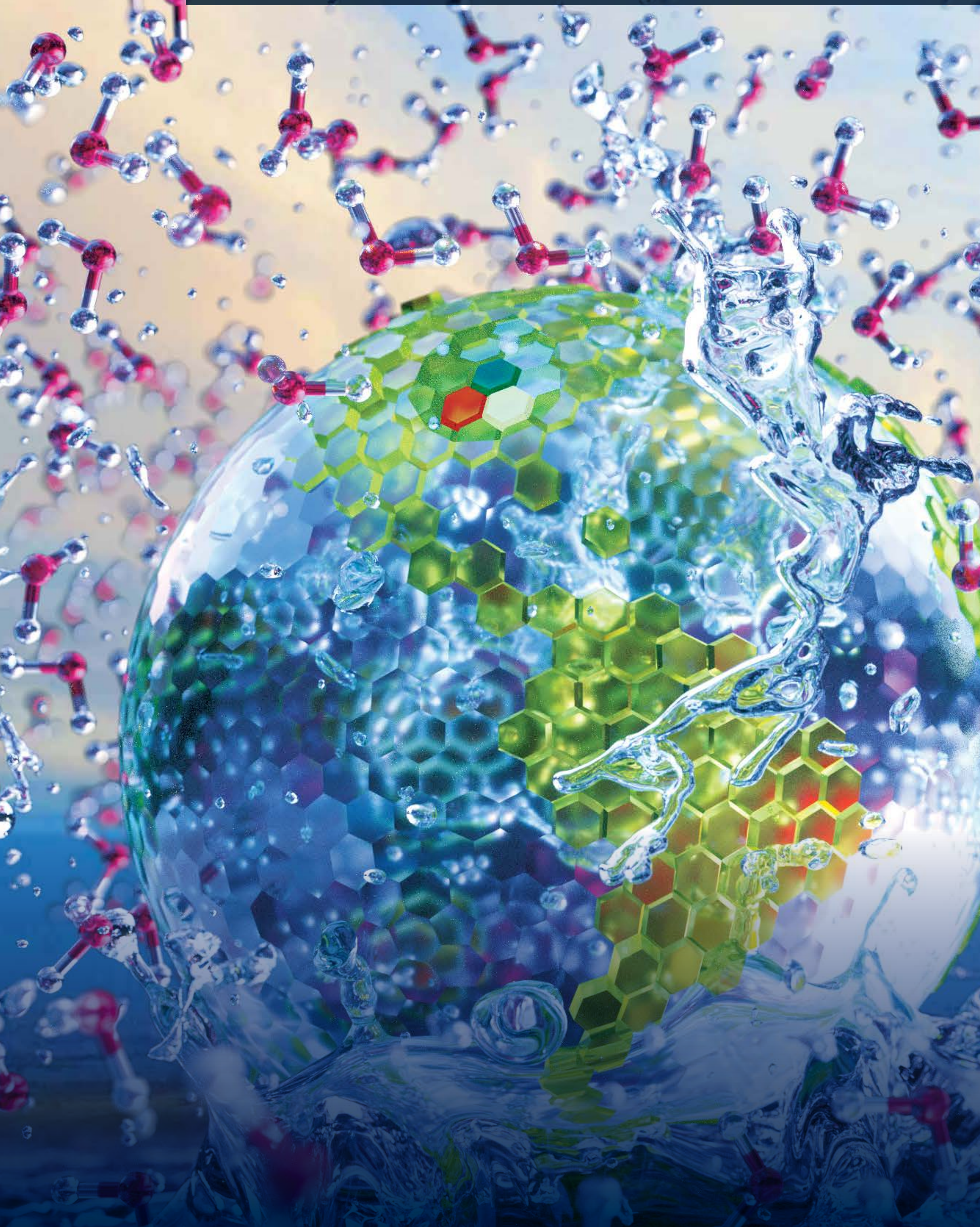
Bi will report on research and publications, new faculty appointments, and IME events. She is also a winner of the 2015 John Crerar Foundation Science Writing Prize for College Students.

The fellowship program is a component of IME's commitment to increasing the public's awareness of progress in science and engineering research through effective science communication.

Undergraduates Receive Astronaut Scholarship Foundation Award

In partnership with the Astronaut Scholarship Foundation, the IME has awarded the Astronaut Scholarship Foundation Award to Trevor Roberts, a fourth-year majoring in chemistry, and Olivia Stovicek, a third-year majoring in biochemistry and chemistry. Founded by Mercury 7 astronauts, the Astronaut Scholarship Foundation has awarded over $4 million in scholarships to more than 370 of the nation's top STEM students.

The Institute for Molecular Engineering explores a set of prominent research themes broadly aimed at concrete advances in important technology sectors. These themes were established through the leadership of IME's faculty and their collaborations. Each one addresses a major societal problem of global significance at the molecular level.



- Nano-Patterning and Nano-lithography
- Quantum Information and Technology
- Molecular Engineering of Water Resources
- Energy Storage and Harvesting
- Immuno-Engineering and Cancer

Collaboration and Impact

SOFT MATERIALS

Certain macromolecules self-assemble into regular morphologies and can be coerced into forming useful structures that are similar to those encountered in electronic circuits. Self-assembled nanostructures could reduce manufacturing costs and enable new generations of electronic, biomedical, and mechanical devices.

First International Scientific Symposium at the ERC: New Physics, Biology and Materials

The Eckhardt Research Center was the location for an International Scientific Symposium to address "Multivalent Interactions in Polyelectrolytes: New Physics, Biology and Materials," held in October 2015. Organized by Juan de Pablo and Matthew Tirrell from IME, Sheng-Lin Gibson and Vivek Prabhu from the National Institute of Standards and Technology (NIST), and Monica Olvera de la Cruz from Northwestern University, the symposium was attended by representatives from the Center for Hierarchical Materials Design (CHiMaD), the Institute for Molecular Engineering, NIST, and Northwestern.

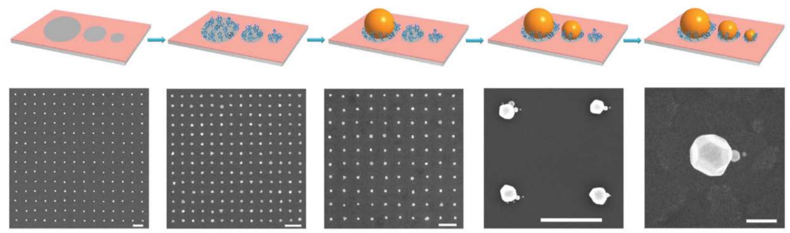
The three-day workshop explored the physical, biological and materials sciences that are possible when highly charged macro-molecules interact with multivalent species of the opposite charge. Important new structures, ranging from encapsulants to ordered block copolymer phases, to stress granules in biology, result from multivalent electrostatic assembly. ⬢

Photos from the international symposium "Multivalent Interactions in Polyelectrolytes: New Physics, Biology and Materials." The three-day event included a dinner celebration of Matthew Tirrell's 65th birthday, with a special 'This is Your Scientific Life' slide presentation given by Professor Claus Eisenbach.

Proving the Theory: IME Researchers Create Nanolenses

More than a decade ago, theorists predicted the possibility of a nanolens. This chain of three nano-scale spheres would focus incoming light down to a spot smaller than the light's own wavelength—much smaller than is possible with conventional microscopy. Such a device would open the way for extremely high-resolution imaging or biological sensing. But scientists had been unable to build and arrange many nanolenses over a large area.

"That's where we came in," says Xiaoying Liu, Senior Research Scientist in the Institute for Molecular Engineering. Liu and Paul Nealey, Dougan Professor in Molecular Engineering, have invented a way to build nanolenses in large arrays using a combination of chemical and lithographic techniques. This enables them to align three spherical gold nanoparticles of graduated sizes in the string-of-pearls arrangement needed to produce the focusing effect. The IME team worked with experts in nanophotonics at the Air Force Research Laboratory and Florida State University.



First, lithographic methods are used to make printed circuits that create a chemical mask. Liu's and Nealey's mask leaves a pattern of three spots of decreasing size exposed on a substrate such as silicon or glass that will not absorb the gold nanoparticles. Lithography allows for fantastically precise and delicate patterns. However, it cannot produce three-dimensional structures. So, the scientists use chemistry to build in three dimensions on top of the patterned substrate. They treat the spots with polymer chains that are then tethered to the substrate through chemical bonds. "The chemical contrast between the three spots and the background makes the gold particles go only to the spots," says Liu.

To get each of the three sizes of nanospheres to adhere only to its own designated spot, the scientists play with the strength of the chemical interaction between spot and sphere. "We control the size of the different areas in the chemical pattern and we control the interaction potential of the chemistry of those areas with the nanoparticles," says Nealey. "It's like the Goldilocks and the Three Bears story. We can put big ones on the big spots, but they won't stick to the smaller spots; then put the next-sized one on the medium spot but it won't stick to the small spot. By this sequential manufacturing, we're able to arrive at these precise assemblies of three different-sized particles in close proximity to one another."

The spheres are separated by only a few nanometers. It is this tiny separation, coupled with the sequential ordering of the different-sized spheres, that produces the nanolensing effect. "You get this concentration in the intensity of the light between the small and the medium-sized nanoparticles," says Nealey.

The scientists are already exploring using this "hot spot" for high-resolution sensing using spectroscopy. "If you put a molecule there, it will interact with the focused light," says Liu. "The enhanced field at these hot spots will help you to get orders of magnitude stronger signals. And that gives us the opportunity to get ultra-sensitive sensing. Maybe ultimately we can detect single molecules."

The method itself will have broad application for any process that requires precision placement of materials in proximity to the same or different types of materials. It will, Nealey predicts, "be part of the way that nanomanufacturing is done." ⬢

Discovering a New Glass Material

Unexpected outcomes lead to a materials science breakthrough.

Juan de Pablo's 20-year exploration of the unusual properties of glass began, oddly enough, with the microscopic animals known as water bears.

"When you remove the water, they very quickly coat themselves in large amounts of glassy molecules," says de Pablo, the Liew Family Professor in Molecular Engineering at The University of Chicago. His passion to understand how glass forms in such circumstances helped lead de Pablo and his fellow researchers to the unexpected discovery of a new type of glass.

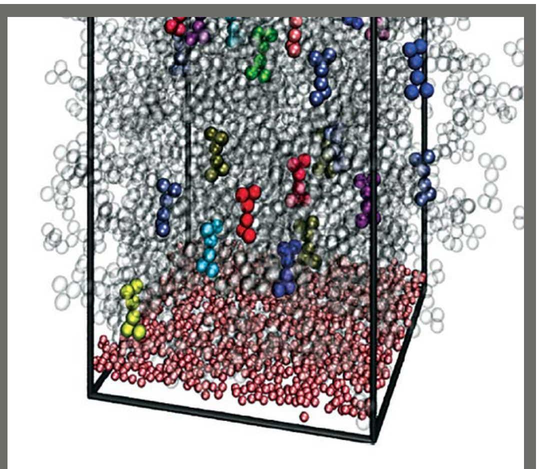
The team had thought there was a problem in their calculations when they saw unusual peaks in what should have been featureless optical data. But upon investigation, they found the peaks indicated molecular order in a material thought to be entirely amorphous and random.

"Randomness is almost the defining feature of glasses," de Pablo said. "At least we used to think so. What we have done is to demonstrate that one can create glasses where there is some well-defined organization. And now that we understand the origin of such effects, we can try to control that organization by manipulating the way we prepare these glasses."

Their results potentially offer a simple way to improve the efficiency of electronic devices such as light-emitting diodes, optical fibers, and solar cells. They also could have important theoretical implications for understanding the mysterious materials called glasses.

As they learned, the peaks were an indication that organic glasses deposited from the vapor phase, like those that form the active layer in a light-emitting diode or solar cell, can show a preferential molecular orientation.

The researchers can use high-throughput screening to show that the quality of this orientation can be tuned through control over the substrate temperature during deposition, which influences the molecular mobility at the surface. This ability may give a simple route to optimizing active layers in organic electronics, because the molecular orientation can affect light emission, charge mobility, and device lifetimes.



Inspired by nature: The water bear, also known as a tardigrade, can survive when exposed to extreme conditions by coating itself in glass-like molecules. Intrigued by this, researchers at UChicago and the University of Wisconsin-Madison have tested and simulated (at right) the deposition of ordered glass structures.

"Glasses are one of the least understood classes of materials," de Pablo said. "They have the structure of a liquid—disorder—but they're solids. So the fact that we can now control the orientation of these disordered materials is something that could have profound theoretical and technological implications. We don't know what they are yet—this is a new field of research and a class of materials that didn't exist before. But, we have a start."

In spring 2015, de Pablo and his collaborators at UChicago and the University of Wisconsin-Madison published their findings in the *Proceedings of the National Academy of Sciences.* News of the breakthrough went viral online, and became the UChicago news story with the greatest-ever number of web hits and was selected by *Science* as an Editor's Choice paper in materials science.

FOLLOW-UP GLASS RESEARCH POINTS TO POTENTIAL FOR MORE EFFICIENT PORTABLE ELECTRONICS, SOLAR CELLS

Delving deeply into the process for making organic glasses, chemists at the University of Wisconsin-Madison have discovered the key for controlling molecular orientation during manufacture. Their method is capable of imposing an ideal order on the molecules that produce glasses.

The process can be exploited to easily and routinely make organic glasses—the materials at the heart of some electronic displays, light-emitting diodes, and solar cells. The team, led by chemistry professor Mark Ediger, based their research on work conducted in partnership with IME's Juan de Pablo and Ivan Lyubimov.

The discovery is important because organic glasses are widely used in what are called organic light-emitting diodes, the active elements of the displays used in some portable consumer electronics such as cellphones. Perhaps more significantly, the finding by Ediger's team could help advance improved photovoltaic devices, such as solar cells, which convert light to electricity.

"We're thinking about the next generation of photovoltaics," says Ediger, noting that the use of organic glasses in things like solar cells has so far been limited. "That technology is commercially immature and improved control over material properties could have a big impact."

Liquid Crystals Show Potential for Early Detection of Neuro-degenerative Disease

Liquid crystals are detecting amyloid fibrils through a novel system developed by Juan de Pablo, the Liew Family Professor in Molecular Engineering, and his team of researchers.

Because amyloid fibrils contribute to the development of neuro-degenerative diseases, their work has implications for the early detection of conditions such as Alzheimer's, Huntington's, and Parkinson's. The novel approach promises an easier, less costly way to detect amyloid fibrils and to do so at a much earlier stage of their formation than has been possible before—the stage when they are thought to be the most toxic.

The scientists envision eventually being able to test small samples of blood or other body fluid using the new detectors, or for drug researchers to put the amyloid proteins in water, inject their drug, and study how the drug influences the growth of the aggregates over time.

"The de Pablo group took a completely different approach. They exploited the way a liquid crystal responds to a disturbance on its surface." —*ScienceDaily.com*

"It is extremely important to develop techniques that allow us to detect the formation of these so-called amyloid fibrils when they're first starting to grow," said de Pablo. "We have developed a system that allows us to detect them in a simple and inexpensive manner. And the sensitivity appears to be extremely high."

QUANTUM INFORMATION AND TECHNOLOGY

Quantum computing is thought to have the potential to accelerate the advance of computing power beyond Moore's law. Quantum engineering could also lead to "unhackable" communications through quantum cryptography and a new class of ultra-sensitive detectors for biological and chemical sensing.

Blink of a Quantum Dot

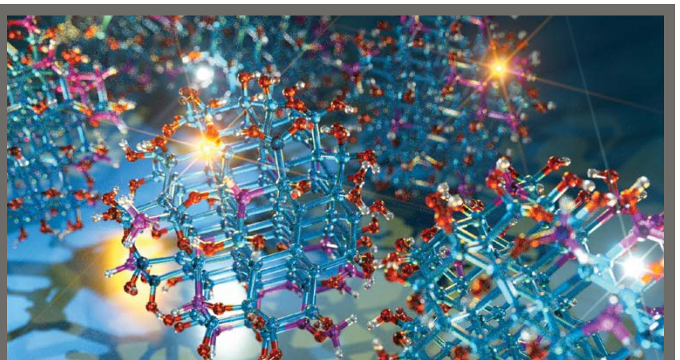
Using simulations to investigate the mysterious blinking process in silicon quantum dots—nanoparticles of semiconductor that can be tuned to glow in a rainbow of colors—researchers in the lab of Giulia Galli, Liew Family Professor of Molecular Engineering in Electronic Structure and Simulations, have produced the first reported *ab initio* calculations showing that dangling bonds on the surface of oxidized silicon nanoparticles can act as efficient non-radiative recombination centers. "Our findings provide an *a priori* validation of the interpretation of the role that dangling bond defects play in several photonic and optoelectronic devices," said Galli.

Moreover, the researchers' techniques can be used to tackle the effects of trapping in solar cells. "Trapping, the very same physical mechanism that causes blinking, can actually limit the efficiency of solar cells," said Márton Vörös, a postdoctoral researcher in the Galli group who co-authored the study.

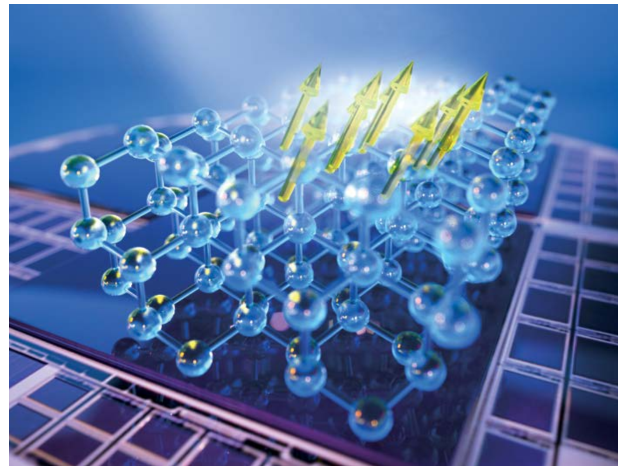
Since the discovery of quantum dots in the 1980s, the remarkable nanoparticles have held tantalizing prospects for new technologies, ranging from paint-on lighting materials and solar cells to quantum computer chips, biological markers, and even lasers and communications technologies—except that their blinking, or 'fluorescence intermittency,' as scientists call it, renders them unreliable. But the results found by Galli's team bring researchers a step closer to understanding—and possibly remediating—the problem.

To study blinking, the team used simulated silicon (Si) nanoparticles configured with various defects and coated with silicon dioxide. Starting with three different possible defect states, they used the Hopper supercomputer (a Cray XE6) at the Department of Energy's National Energy Research Scientific Computing Center (NERSC) to calculate the optical and electronic properties of the oxidized silicon nanoparticle with the scientific package called Quantum Espresso. "Now that we've tested this technique," Galli said, "we can apply it to nanocrystal solar cells, too."

Illustrated by IME resident artist Peter Allen, silicon quantum dots appear in various states of "blinking." The on crystals emit light (represented by a white dot) as an excited electron sheds excess energy as a photon. The off crystals are dark, because their electrons (yellow) are trapped in surface defects and siphon off energy through other paths, like heat or lattice vibrations.



Spintronics Advance Brings Wafer-Scale Quantum Devices Closer to Reality



A groundbreaking new technique that uses infrared light to align spins—or magnetization—of atomic nuclei to store and process information promises huge gains in performance over today's electron-based devices.

Getting spins to align in room-temperature silicon carbide brings practical spintronic devices a significant step closer to production. The material is already an important semiconductor in the high-power electronics and opto-electronics industries. Sophisticated growth and processing capabilities are already mature. So prototypes of nuclear spintronic devices that exploit the IME researchers' technique may be developed in the near future.

"Wafer-scale quantum technologies that harness nuclear spins as subatomic elements may appear more quickly than we anticipated," said David Awschalom, Liew Family Professor of Molecular Engineering in Spintronics and Quantum Information.

Nuclear spins tend to be randomly oriented. Aligning them in a controllable fashion is usually a complicated and only marginally successful proposition. The reason is that, "The magnetic moment of each nucleus is tiny, roughly 1,000 times smaller than that of an electron," explained Paul Klimov, a graduate student in the Awschalom group and co-author of the paper.

Using their new technique, the team aligned more than 99 percent of spins in certain nuclei in silicon carbide. Equally important, the technique works at room temperature—none of the previously required cryogenics or intense magnetic fields are needed. Instead, the research team used light to 'cool' the nuclei.

While nuclei do not interact with light themselves, certain imperfections, or 'color-centers,' in the SiC crystals do. The electron spins in these color centers can be readily optically cooled and aligned, and this alignment can be transferred to nearby nuclei. Had the group tried to achieve the same degree of spin alignment without optical cooling, they would have had to chill the SiC chip physically to just five millionths of a degree above absolute zero (-459.6 degrees Fahrenheit).

"Our results could lead to new technologies like ultra-sensitive magnetic resonance imaging, nuclear gyroscopes, and even computers that harness quantum mechanical effects," said Abram Falk, recently a postdoc researcher in Awschalom's lab and lead author of the report on the work.

As part of the celebration of the opening of the University of Chicago Center in Hong Kong, Professor Awschalom co-organized the workshop "Quantum Technology: A New Frontier in Engineering." Topics included quantum computation and communication, as well as advanced sensing and imaging technologies. Also presenting were IME professors Giulia Galli and Andrew Cleland.

Quantum Entanglement Achieved at Room Temperature in Semiconductor Wafers

Despite previous theoretical debate, researchers in David Awschalom's group have demonstrated that macroscopic entanglement can be generated at room temperature and in a small magnetic field.

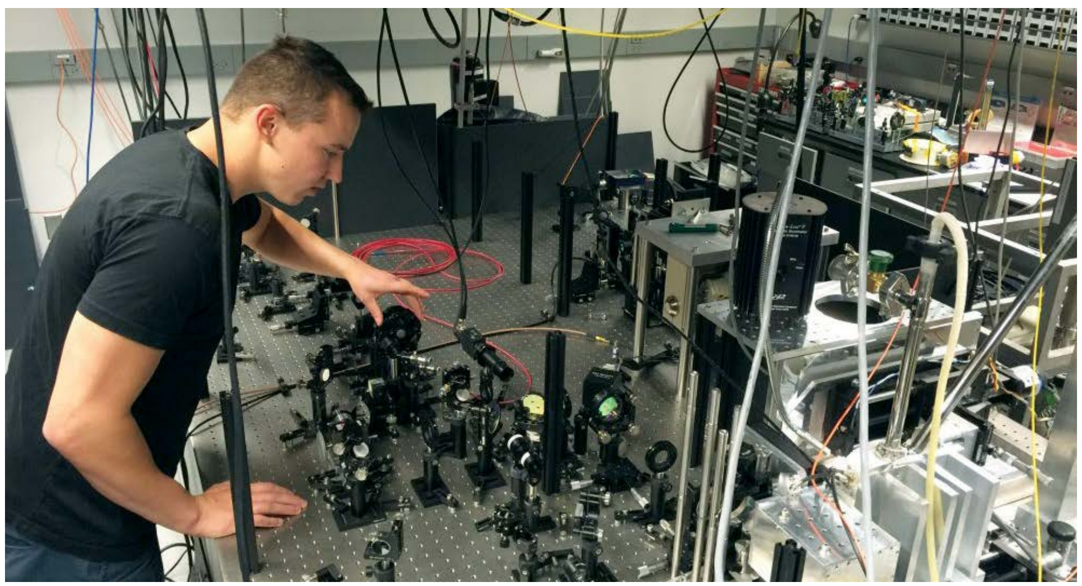
Entanglement, which underlies most of modern physics, says that two particles can be so inextricably connected that the state of one particle can instantly influence the state of the other, no matter how far apart they are. The phenomena is actively being explored as a resource for future technologies including quantum computers, quantum communication networks, and high-precision quantum sensors.

Producing entanglement between particles requires that they start out in a highly ordered state, which is disfavored by thermodynamics, the process that governs the interactions between heat and other forms of energy. This poses a particularly formidable challenge when trying to realize entanglement at the macroscopic scale, among huge numbers of particles. "The laws of thermodynamics generally prevent us from observing quantum phenomena in macroscopic objects," said Paul Klimov, a graduate student in Awschalom's lab and lead author of the new research on quantum entanglement.

Previously, scientists have overcome the thermodynamic barrier and achieved macroscopic entanglement in solids and liquids by going to ultra-low temperatures (-270 degrees Celsius) and applying huge magnetic fields (1,000 times larger than that of a typical refrigerator magnet) or using chemical reactions.

But the researchers in the IME study used infrared laser light to order (preferentially align) the magnetic states of thousands of electrons and nuclei and then electromagnetic pulses, similar to those used for conventional magnetic resonance imaging (MRI), to entangle them. This procedure caused pairs of electrons and nuclei in a macroscopic 40 micrometer-cubed volume (the volume of a red blood cell) of the semiconductor SiC to become entangled.

"We know that the spin states of atomic nuclei associated with semiconductor defects have excellent quantum properties at room temperature," said David Awschalom. "They are coherent, long-lived and controllable with photonics and electronics. Given these quantum 'pieces,' creating entangled quantum states seemed like an attainable goal."



In addition to being of fundamental physical interest, "the ability to produce robust entangled states in an electronic-grade semiconductor at ambient conditions has important implications on future quantum devices," Awschalom said. "We are excited about entanglement-enhanced magnetic resonance imaging probes, which could have important biomedical applications," said Abram Falk, a co-author of the research findings and a former postdoc in Awschalom's group who is now working in the IBM Thomas J. Watson Research Center.

Rewritable Quantum-Mechanical Circuits: Discovery 'Switched On' by Lab's Overhead Lights

A new way of using light to draw and erase quantum-mechanical circuits in a unique class of materials called topological insulators was serendipitously discovered when researchers realized that the low-energy fluorescent lights in the lab emitted ultraviolet light at just the right wavelength to polarize the surface of the experimental material they were using.

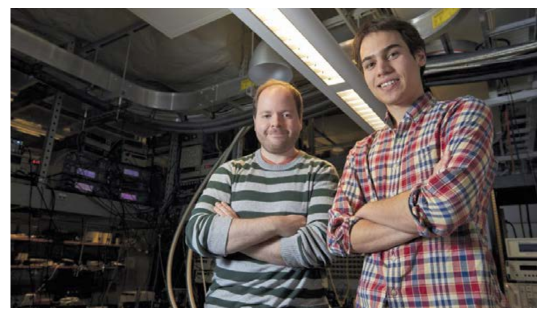
"To be honest, we were trying to study something completely different," said Andrew Yeats, a graduate student in David Awschalom's laboratory and lead of the research. "There was a slow drift in our measurements that we traced to lights. At first we were glad to be rid of it, and then it struck us—our room lights were doing something that people work very hard to do in these materials." Their process of discovery was reported in an October 9, 2015, *New York Times* article.

The new technique allows for rewritable 'optical fabrication' of devices, rather than using difficult and sometimes ineffective traditional semiconductor engineering processes. The finding is likely to spawn new developments in emerging technologies such as low-power electronics based on the spin of electrons or ultrafast quantum computers.

"This observation is one of those rare moments in experimental science where a seemingly random event—turning on the room lights—generated unexpected effects with potentially important impacts in science and technology," said Awschalom.

> "The insight could impact quantum computing and new types of precise sensors." — *New York Times*

The discovery of the optical effect allows researchers to 'tune' the energy of electrons in these materials using light—without ever having to touch the material itself. By intentionally focusing beams of light on their samples, the team 'drew' electronic structures that persisted long after the light was removed. They have used it to draw and erase p-n junctions—one of the central components of a transistor—in a topological insulator for the first time. "It's like having a sort of quantum Etch-A-Sketch in our lab. Instead of spending weeks in the cleanroom and potentially contaminating our materials, now we can sketch and measure devices for our experiments in real time. When we're done, we just erase it and make something else," said Awschalom.

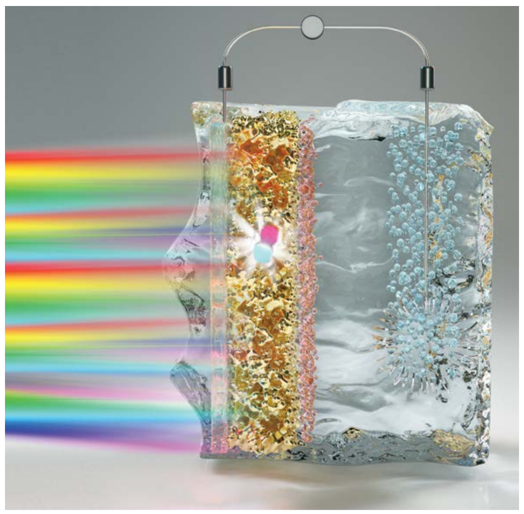


MOLECULAR ENGINEERING AND WATER RESOURCES

This broad-based research investigates all aspects of water utilization, including purification via membranes, biotechnology, and catalysis; efficient water use in agriculture; and efficient, distributed purification systems.

New Concepts Emerge for Generating Clean, Inexpensive Fuel from Water

An inexpensive method for generating clean fuel is one step closer, thanks to a research collaboration involving Giulia Galli, the Liew Family Professor of Molecular Engineering in Electronic Structure and Simulations at the IME. Working with Kyoung-Shin Choi, Professor in Chemistry at the University of Wisconsin-Madison, Galli provided critical theoretic simulations that helped reveal a more efficient way to use solar energy to split water into hydrogen and oxygen, and then harvest the hydrogen for use as fuel. Their work not only improves the efficiency of the key processes, it offers new conceptual tools that can be applied more broadly in the quest to split water with sunlight.



"Our study will encourage researchers in the field to develop ways to improve multiple processes using a single treatment," said Choi. "It's not just about achieving higher efficiency, it's about providing a strategy for the field."

While Choi and her team were able to increase efficiency by combining manipulations for increasing photon absorption and the movement of electrons in the material by heating an electrode made of the semiconducting compound bismuth vanadate while flowing nitrogen gas over it, they weren't sure how the nitrogen was facilitating the observed changes.

When they turned to Galli to see if her simulations of the system could provide new insight into the process, she and former graduate student Yuan Ping, now a postdoc at Caltech, were able to detect several ways the nitrogen was acting on the electrode. "Now we understand what's going on at the microscopic level," said Galli. "This enables others to use the concepts in other systems to try to improve efficiency." ⬣

Collaborative Water Research Initiative Moves Beyond Seed Grant Phase

After the molecular engineering of water resources emerged as one of the IME's major research themes, the Institute launched a competition to identify projects for initial seed funding. Five teams of researchers from the University of Chicago, Argonne National Laboratory, and Ben-Gurion University of Negev were selected.

"As the teams reach the end of the first phase of their seed grant funding, we are poised to take the next steps to grow this effort." —Steven Sibener

Over the past two years, the seed projects have applied the latest nanotechnological discoveries to create new materials and processes for making clean, fresh drinking water more plentiful and less expensive by 2020. Each project was headed by a BGU professor and a UChicago professor or Argonne scientist.

"These projects are making great strides," said Water Research Initiative director Steven Sibener, Carl William Eisendrath Distinguished Service Professor in Chemistry and the James Franck Institute. "And, as the teams reach the end of the first phase of their seed-grant funding, we are poised to take the next steps to grow this effort."

In August 2015, researchers from Ben-Gurion came to Chicago to meet their collaborators, participate in a two-day conference and workshop, and to map the path forward. This included exploring a National Science Foundation/United States-Israel Binational Science Foundation funding stream, and ways to seek private foundation funding. In addition, the IME Innovation and Commercialization Fellows worked with investigators to identify methods for commercialization.

"We have a great partner in Ben-Gurion University," said Matthew Tirrell, IME Pritzker Director and Dean. "We will build on our initial successes, and grow this effort in water research into one of the signature elements of IME and the campus at large." ⬣

Collaborative Water Research Conference: Photos from the two-day event held in August 2015. Nearly 100 participants attended from UChicago, Ben-Gurion University of the Negev, and Argonne National Laboratory.

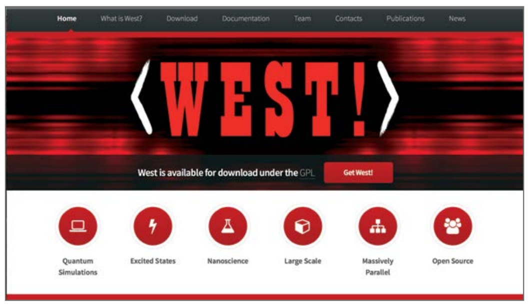
ENERGY STORAGE AND HARVESTING

In cooperation with Argonne National Laboratory, IME will develop a major Chicago-based hub for research on batteries, fuel cells, and other devices for storing energy to use with mobile, distributed, or intermittent energy sources, as well as energy harvesting via such molecular devices as photovoltaics and molecular devices.

Go WEST

Novel scalable software helps in silico discovery of materials for energy.

WEST, new software developed by researchers at Argonne and the Institute for Molecular Engineering in 2015, is already greatly improving the accuracy and efficiency of calculations of materials' properties from basic quantum principles. Available for free download, the open-source product is already in use by groups worldwide.



"We expect WEST to have a major impact in helping the prediction of new materials for energy conversion and storage," said WEST's lead developer Marco Govoni, a postdoctoral research scholar in the lab of Giulia Galli, Liew Family Professor of Molecular Engineering in Electronic Structure and Simulation, and a research associate at Argonne.

As scientific computing has become increasingly important in all scientific disciplines, software development has been critical to researchers' progress. The collection and interpretation of most experimental data are carried out using computers, which are also used to provide numerical solutions of physical models with various degrees of complexity and sophistication. Applications designed for high-performance computing are predicting and designing the fundamental properties of materials from numerical solutions of the basic laws of quantum mechanics.

"This field is growing and holds great promise," said Govoni, "especially in predicting materials for energy, where we need durable, inexpensive, non-toxic and disposable materials. In this case a quantum mechanical description of matter is of key importance, and a tight connection between laboratory experiments and numerical simulations will greatly help the design of advanced materials for sustainable energy technologies."

Using carefully crafted algorithms, WEST can predict properties arising from the interaction of materials with light, which requires a high-level of accuracy and implies a considerable computational cost. "We use high-performance computing architectures, in particular at the Argonne Leadership Computing Facility, a DOE Office of Science user facility. These can conduct large-scale quantum simulations that are aimed at understanding, predicting and designing materials properties," Govoni said. "WEST uses scalable algorithms that deal efficiently with these complex many-body interactions."

The novelty of WEST stems not only from efficiently parallelized workflows, but also from several algorithmic advances, such as the use of density-based linear response methods and the use of iterative matrix diagonalization techniques.

WEST was released in June 2015, 50 years after the original works of Lars Hedin on the equations that are now implemented in WEST; that work, also carried out at Argonne, revolutionized the description of electronic many-body interactions in materials. Now that WEST is public, researchers worldwide will have the means to exploit the accuracy of many-body perturbation theory through this powerful code.

For his work on WEST, Marco Govoni (left) received the award for scalable code at the 2015 Mind Bytes event, organized by the University of Chicago's Research Computing Center. Presenting the award (right) is H. Birali Runesha, Director of the Research Computing Center and UChicago Assistant Vice President for Research Computing.

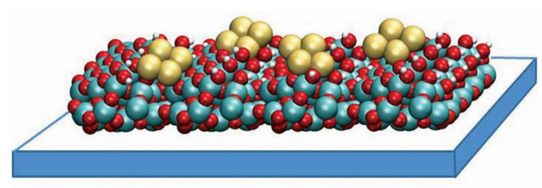
Copper Clusters Capture and Convert Carbon Dioxide to Make Fuel

A new catalyst for converting carbon dioxide into methanol has been identified by scientists at the IME and Argonne, in collaboration with researchers from the University of Freiburg and Yale.

Called copper tetramer, the catalyst consists of small clusters of four copper atoms each, supported on a thin film of aluminum oxide. This unique structure leaves most of its binding sites open, which means it can attach more strongly to carbon dioxide and can better accelerate the conversion. In this way, copper tetramer can capture and convert carbon dioxide in a way that uses less energy than previous catalysts.

"With our catalyst, there is no inside," said paper co-author Stefan Vajda, a senior chemist at Argonne and a fellow of The University of Chicago's Institute for Molecular Engineering. "All four copper atoms are participating because with only a few of them in the cluster, they are all exposed and able to bind."

The research helps address a solution to carbon dioxide emissions as an ongoing environmental problem. Once they are fully tested, copper tetramers could allow for the capture and conversion of carbon dioxide on a larger scale—reducing an environmental threat and creating a useful product like methanol, which can be transported and burned for fuel.



For this research, the team used Argonne's Center for Nanoscale Materials as well as beamline 12-ID-C of its Advanced Photon Source. The APS allowed the scientists to observe ultra-low loadings of their small clusters, down to a few nanograms, which was a critical piece of the investigation.

IMMUNO-ENGINEERING AND CANCER

In cooperation with the Biological Sciences Division, researchers are studying immunology at the interface with engineering, both to understand basic immunological mechanism and to use that mechanism to develop new therapeutic approaches. Foci include how tumors escape immune detection and how to use that knowledge to develop tumor immuno-therapies, more effective vaccines, and inverse vaccines to prevent or treat auto-immune disease.

Astellas and Anokion Partner in New Immune Tolerance Therapeutics Initiative

Biotechnology firm founded by IME professor Jeffrey Hubbell joins forces with pharmaceutical company in new R&D venture.

A new company, Kanyos Bio, Inc., has been created to develop unique new treatments for type 1 diabetes and celiac disease. The result of a partnership between Astellas Pharma Inc. and Anokion SA, the new initiative will be focused on products for antigen-specific immune tolerance.

Valued at approximately $760 million, including $16 million in equity financing, the deal includes R&D funding, option exercise, and milestone payments. Astellas, which will provide non-dilutive research funding to Kanyos, has the option to acquire Kanyos after reaching certain milestones.

Anokion, founded by Jeffrey Hubbell, Barry L. MacLean Professor in Molecular Engineering Innovation and Enterprise, is a biotechnology company that develops products based on proprietary technology for the induction of antigen-specific immune tolerance. Anokion's technology has demonstrated the ability to induce immune tolerance to protein drugs and autoimmune antigens in animal models. The creation of Kanyos will enable preclinical development of products. The collaboration will initially pursue solutions in the medical fields of type 1 diabetes and celiac disease.

"We are delighted that our partner Astellas is applying its resources and pharmaceutical development expertise to Anokion's platform of technology and immunology expertise. Our combined team has an opportunity to make a profound impact on patients' lives." — Jeffrey Hubbell

Kenji Yasukawa, PhD, Senior Vice President and Chief Strategy Officer of Astellas stated: "This collaboration is the newest piece of Astellas' strategy in immunology. Our goal is to provide innovative pharmaceutical products for type 1 diabetes and celiac disease, both of which represent significant unmet medical needs."

Center for Immuno-Engineering

As momentum gathers around the potential benefits of immuno-engineering, a research cluster grouped within a Center for Immuno-Engineering is in development in the Institute for Molecular Engineering.

"We want to generate completely new research that wouldn't have been done otherwise." — Melody Swartz

Driven by William B. Ogden Professor Melody Swartz, the concept is to facilitate collaboration between experts in immunology and molecular engineering to seek novel insights and approaches to drug development and disease treatment. Swartz hopes to build on existing partnerships, generate new collaborations between engineers and immunologists, and offer fellowships for postdoctoral, postbaccalaureate, and undergraduate research.

Another component of the center would be a designated collaboration space, where new innovation could incubate in a cross-disciplinary environment.

"The application of engineering principles within biological frameworks is a new frontier," said Swartz. "We see high potential for developing healthcare solutions that would have been impossible before the convergence of technology and science that we see today."

Collaboration to fight cancer

The Institute for Molecular Engineering and The University of Chicago Comprehensive Cancer Center participated in a symposium in August 2015 to generate cross-disciplinary interaction and collaboration. IME professor Melody Swartz organized this symposium which attracted more than 40 researchers.

The IME and the Grossman Institute Lay Groundwork for Collaboration

Organized by Melody Swartz, the IME and the Grossman Institute for Neuroscience, Quantitative Biology, and Human Behavior co-hosted a workshop in September that aimed to foster new collaborations and partnerships between researchers at the two UChicago organizations. Eight members of the IME faculty participated, sharing overviews of their research ranging from quantum bioimaging to nerve regeneration.

"This workshop was an exciting opportunity to seek research collaborations at the intersection of molecular engineering and medicine. In particular, it was aimed at identifying important problems in biology that might benefit from technological developments in the areas of submicron patterning, imaging, and sensing," said Professor David Awschalom.

ARTS, SCIENCES, AND TECHNOLOGY

The Institute for Molecular Engineering intentionally seeks unconventional opportunities that support its mission to bring new science to solve society's pressing challenges. This includes cross-fertilizing the arts and sciences. Not only do the arts offer alternative paths to insight, they provide opportunities to engage wider audiences.

On *STAGE*: Art and Science at the IME

As though preparing to open a newly-renovated, multifunctional performance space in early 2016 was not enough, Nancy Kawalek has also been a factor in the expansion of the IME on The University of Chicago campus. Kawalek, the founder and director of *STAGE* (*S*cientists, *T*echnologists and *A*rtists *G*enerating *E*xploration), is a Professor in the Institute for Molecular Engineering, and a Distinguished Fellow in the Arts, Sciences, and Technology. Kawalek introduced *STAGE* to campus when she came to the University in 2013 to create the theatre-science laboratory in the IME.

Since then, Kawalek has managed productions around the world from her new home in Chicago. She organized and directed the inaugural event of the 2013 Nobel Prize Week Festivities in Gothenburg, Sweden, and has partnered with professors in the social sciences on a conference in Paris.

In 2015, Kawalek began building her lab after adding postdoctoral scholar Melina Blees to the *STAGE* team in late 2014. Blees, an artist and physical scientist, and Kawalek have guest-curated a year-long rotating exhibition on the theme of memory at the Smart Museum of Art at The University of Chicago; their initial contribution focused on artificially engineering memories. They are also collaborating with a group of IME graduate students on a new theatre piece, *Bend, Fold, Break*, which connects principles of DNA folding with the art of kimono folding to tell a story about identity. Blees is working on the script, as well as on the set design of the play.

In addition, *STAGE* participated in the first Chicago Architecture Biennial, collaborating with the School of the Art Institute (SAIC) and architect David Benjamin in the Outside Design exhibition at the Sullivan Galleries in Chicago. Inspired by Benjamin's work, Kawalek and SAIC graduate students began creating a play exploring the evolving relationship between technology and biology. (Photo below)

Photo: Tony Favarula

While conducting research in Germany for a separate project, *Symmetry*, Kawalek met with Wolfgang Heckl, Director General of the Deutsches Museum in Munich, to discuss possible future collaborations with *STAGE* and the Institute for Molecular Engineering.

Going forward, Kawalek will debut the *STAGE* Lab with a production of *The Art of Questionable Provenance*. The Lab's space reflects *STAGE*'s interest in telling multilayered stories in new ways, including the integration of advanced digital technologies in the work.

"Stories about science and technology can be vivid and captivating; they do not have to be science lectures disguised as plays," said Kawalek. "*STAGE* generates emotionally engaging and entertaining theatre driven by scientific ideas." ⬢

Melina Blees and Nancy Kawalek, guest curators of an exhibition on memory at the Smart Museum

Photo: Mark Hereld

Graphene Kirigami: Art Inspires Science at the Nanoscale

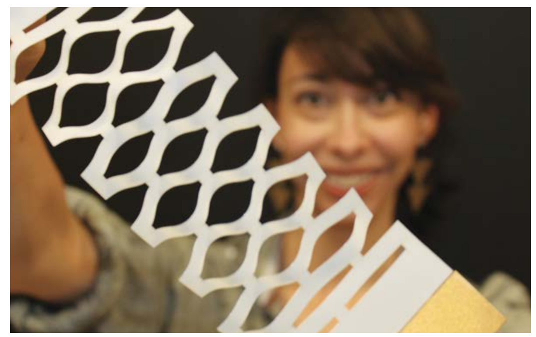
Kirigami—the ancient Japanese art of cutting paper into beautifully intricate, symmetrical designs—has been around for centuries. But IME postdoctoral scholar Melina Blees has found a new way to use it.

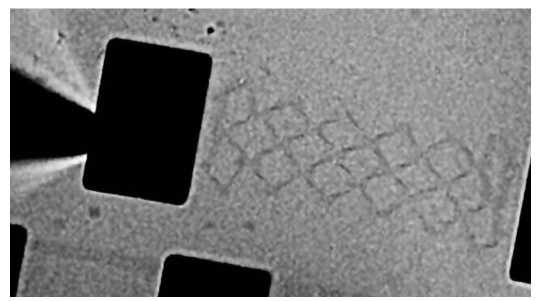
A postdoctoral researcher in the *STAGE* Lab, Blees' graduate work focused on materials such as graphene to learn how to produce nanoscale tools that work at the molecular level. In order to explore methods of construction, she began using kirigami to create paper models of the devices to be replicated in graphene, a durable, nanoscale material composed of a single sheet of carbon atoms.

Blees studied graphene kirigami as a PhD student at Cornell, where she wrote her dissertation on translating design principles from the traditional paper art of kirigami to graphene. Working with her advisors and collaborators at Cornell, Blees first bent, folded, and twisted graphene to learn its capabilities. Then the team created paper models and experimented with different patterns and designs. Finally, they began building mechanical structures with graphene, making pyramids, cantilevers, and hinges at the nanoscale level.

"It was really true exploration," Blees said of her work in graphine kirigami. "We were cutting things out of paper and playing with them, trying to imagine how a 'hanging kirigami mobile for kids' could become a nanoscale spring for measuring forces or interacting with cells."

Their work, published in the July 29th issue of *Nature*, demonstrates the value of art/science collaborations. As a postdoc in the *STAGE* Lab, Blees is expanding her paper arts techniques with graphene into large-scale art installations; she has been commissioned to contribute a kinetic sculpture for the set of *Bend, Fold, Break*, *STAGE*'s collaboration with graduate students in IME and the Biological Sciences Division. ⬢





UChicago Faculty Members Help Launch First Journal in Molecular Engineering

The Royal Society of Chemistry and the Institute of Chemical Engineers have launched the first journal in molecular engineering, *Molecular Systems Design & Engineering*. Among the contributors will be researchers from the Institute for Molecular Engineering and Argonne National Laboratory. "The interdisciplinary journal will help to shape and advance the field of molecular engineering for the future," said Juan de Pablo, who will serve as chair of the editorial board. David Awschalom was also named to the editorial board.

Molecular Systems Design and Engineering will be edited by Nicola Wise, executive editor at the Royal Society of Chemistry.

"It's exciting to help create a new journal where researchers from different disciplines can share their findings within a broader scientific community and identify new opportunities for collaboration." — David Awschalom

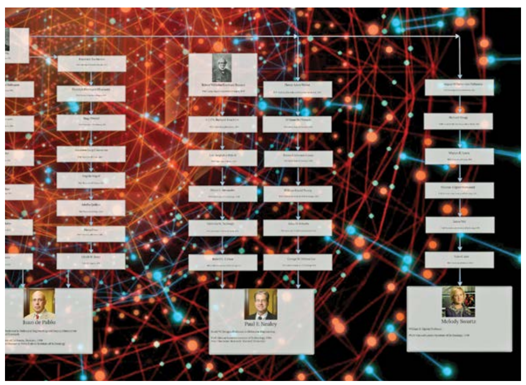
IME Gets a Look at Faculty's "Academic Genealogy"

Five graduate students in the University's Departmental Histories Fellowship Program, a pilot project initiated as part of UChicago's 125th anniversary celebration, have been charged with researching and documenting the histories of 17 of UChicago's 87 academic units. The anniversary themes of "inquiry and impact" shaped the students' approach as they conducted interviews and delved into archives about their assigned department or school.

"It is also interesting that there are several shared academic ancestors among our faculty members, as if the root of cross-disciplinary research can be traced back several generations." — Matthew Tirrell

Nabanjan Maitra, a fourth-year doctoral student in the Divinity School, created an academic family tree of sorts for the Institute for Molecular Engineering, tracing the lineage of its 10 faculty members and their advisors. Maitra says the genealogy highlights the department's "rich traditions of scholarship and interdisciplinary currents."

"The academic genealogy is fascinating," says Matthew Tirrell. "We have eight Nobel Prize laureates among our academic ancestors, including Pierre and Marie Curie, and Lord Rayleigh (John William Strutt). Perhaps surprisingly, we all go back to just three European countries: England, France, and Germany—an indirect reminder of how much more international the world of science and technology is now."



Link: www.uchicago.edu/features/tracing_universitys_intellectual_history

FACULTY: NOTABLE 2015 HONORS

Plenary and Keynote Lectures

David Awschalom

Francis G. Slack Lecturer, Vanderbilt University
Chapman Distinguished Lecture, Rice University
Plenary Lecture, 28th International Conference on Defects in Semiconductors, Aalto University (formerly Helsinki University of Technology), Helsinki, Finland
Plenary Lecture, German Physical Society Meeting, Berlin, Germany
Plenary Lecture, Physics FOM, Veldhoven, The Netherlands,

Juan de Pablo

Alumni Lectures, University of Massachusetts, Amherst
Keynote speaker, International Lithography Simulation Workshop, Frauenhofer Institute, Germany
Keynote speaker, International Molecular Modeling Conference, CCP5, Lancaster University, United Kingdom
Keynote speaker, International BioSoft Conference, Taiwan University and Academia Sinica, Taipei
Keynote speaker, International Conference on Bioinspired Materials, Doha, Qatar
Keynote speaker, International Congress of Physical Chemistry, Buenos Aires, Argentina

Giulia Galli

Plenary Lecture, Psi-K 2015 Conference, San Sebastian, Spain
Plenary Lecture, The Swiss Platform for Advanced Scientific Computing Conference, Zurich, Switzerland

Matthew Tirrell

Art Westerberg Lecture, Carnegie Mellon University
Kramer Memorial Symposium, UC Santa Barbara

Melody Swartz

Keystone Symposium, University of Texas Southwestern

Top Awards

Editor's Choice Paper in Materials Science, *Science* (Juan de Pablo)

Julius Edgar Lilienfeld Prize, American Physical Society (David Awschalom)

National Academy of Engineering (Supratik Guha inducted, Juan de Pablo elected)

Prize for Industrial Application of Physics, American Physical Society (Supratik Guha)

Thomson Reuters/ISI Highly Cited Researcher (David Awschalom)

Young Investigator Award, Cancer Foundation (Jun Huang)

Professional Services

David Awschalom

Editorial Board, *Molecular Systems Design & Engineering*, Royal Society of Chemistry
Advisory Board, *Nature Quantum Information*
Editorial Board, *Proceedings of the National Academy of Sciences*
Board of Reviewing Editors, *Science*, American Association for the Advancement of Science
Editorial Board, *Physical Review X*, Royal Society of Chemistry
Judge, Blavatnik Awards, New York Academy of Sciences

Juan de Pablo

Chair, Mathematical and Physical Sciences Advisory Committee, National Science Foundation
Chair, Committee on Condensed Matter and Materials Research, National Research Council
Founding Editor, *Molecular Systems Design and Engineering*, Royal Society of Chemistry

Supratik Guha

Evaluation Committee, ARPA-E

Jeff Hubbell

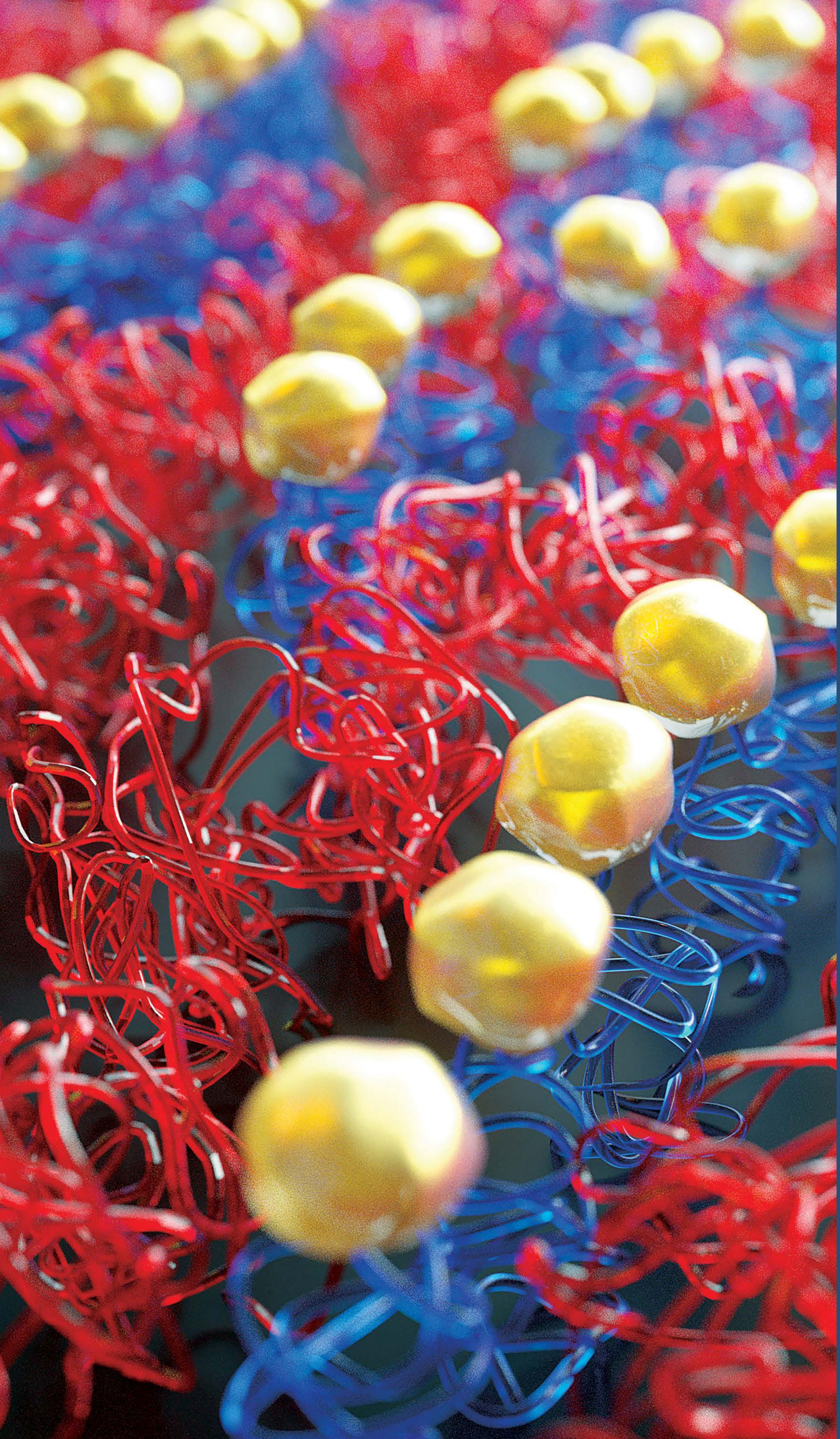
Associate Editor, *Journal of Biomaterials Science*, Polymer Edition
Board of Reviewing Editors, *Science*
Editorial Board, *Annals of Biomedical Engineering*
Editorial Board, *Acta Biomaterialia*
Editorial Board, *Biomacromolecules*
Editorial Board, *Cell Transplantation*
Editorial Board, *Journal of Controlled Release*
Editorial Board, *Journal of Polymer Science*
Editorial Board, *European Journal of Pharmaceutics and Biopharmaceutics*

Melody Swartz

Chair, American Association for Cancer Research Bi-annual Conference on Metastasis

Matthew Tirrell

Board of Directors, The Camille and Henry Dreyfus Foundation
Editorial Board, Royal Society of Chemistry, Book Series on Molecular Engineering



“2015 saw an increase in the Institute for Molecular Engineering’s organizational coherence and in its outreach activities. Most notably, in conjunction with the Physical Sciences Division of the University, we launched the Industrial Affiliates Program. And we established a Visiting Committee to provide expert advice and support.” —Sharon Feng

Outreach, Development, Arts

ESTABLISHING CRITICAL LINKS BETWEEN IME AND THE COMMUNITY

The IME and PSD Launch Industrial Affiliates Program

In partnership with the Physical Sciences Division, the Institute for Molecular Engineering has launched an Industrial Affiliates Program. The new initiative will facilitate the translation of knowledge gained in academic research into meaningful technological solutions, provide avenues for intellectual exchange between industrial and academic researchers, and provide access to talent from both the academic and industrial sectors.

This structure facilitates communications between partners, provides efficiency and speed in establishing a partnership and a specific point of contact, and streamlines administrative processes for developing master agreements and negotiating IP terms.

The program will further IME's efforts to convert scientific discoveries into useful technologies, enrich the Institute's intellectual environment by facilitating innovation partnerships, promote talent exchange channels, and provide access to first-hand market information that can help shape new research agendas.

An Industrial Affiliates Day co-hosted by PSD and IME kicked-off the program in August 2015. At the event, 16 industrial representatives from 14 companies were invited to hear overviews of faculty research, attend student poster sessions, and exchange information on topics of mutual interest.

In the Community: IME Outreach to Middle School Students

In 2015, two new programs to educate middle-schoolers on molecular science were developed by the Institute for Molecular Engineering.

"Juice for Juice," a day-long workshop sponsored by the NSF's Center for Chemical Innovation for Solar Fuels, was presented in March by IME postdoctoral researcher Juliana Morbec. Built around making a solar cell from blackberry juice, electrolytes, pencil graphite, and titanium oxide paste, the program demonstrated that science experimentation and research can be fun, engaging, and easy.

IME's Maroon Kids was launched in May 2015. An initiative of the Alumni and Friends of IME, a group organized by IME Visiting Committee member William L. Florida, AB'87, AM'87, Maroon Kids aims to inspire the next generation of molecular engineers through early exposure of cutting edge research to middle and high school students. In May, Maroon Kids participated in the World Science Festival by streaming a session called "What is Sleep?" from the WSF. In August, more than 40 students and their parents learned about the atomic scale by using mobile devices to view the light created by three sample chemical elements. Undergraduate Agnetta Cleland, graduate students Alex Crook, Peter Mintun, and Andrew Yeats created the seminar and led participants on a tour of IME's quantum engineering labs.

Harper Lectures Engage Diverse Global Audiences

The Harper Lectures bring faculty to selected cities around the world to discuss recent University of Chicago breakthroughs and discoveries, offering alumni and friends a chance to share ideas and conversation.

In April 2015, Juan de Pablo was a featured speaker in the Harper Lecture series in Mexico City. An expert in materials science, he discussed "The Promise of Self-Assembling Integrated Circuits."

While in Mexico City, de Pablo and Ian Solomon, UChicago's Vice President for Global Engagement, facilitated an agreement with CONACYT (Mexico's National Council on Science and Technology) to support a graduate student scholarship program, along with a student exchange program to bring highly qualified Mexican students to IME.

Giulia Galli was also a featured speaker in the Harper Lecture series. A leader in integrated computational and experimental science strategies, Giulia Galli, spoke about 'An Integrated Microscope for Water at Surfaces,' in San Diego in September.

TIRRELL BRIEFS U.S. CONGRESSIONAL STAFF AT "SCIENCE 2034: LIVE"

Named as one of six panelists from the Science Coalition—a nonprofit, nonpartisan organization of more than 50 of the nation's leading public and private research universities—Matthew Tirrell spoke at the "Science 2034: Live" meeting in Washington, D.C. He briefed the Senate and House Congressional staff on how nanoparticles are revolutionizing healthcare.

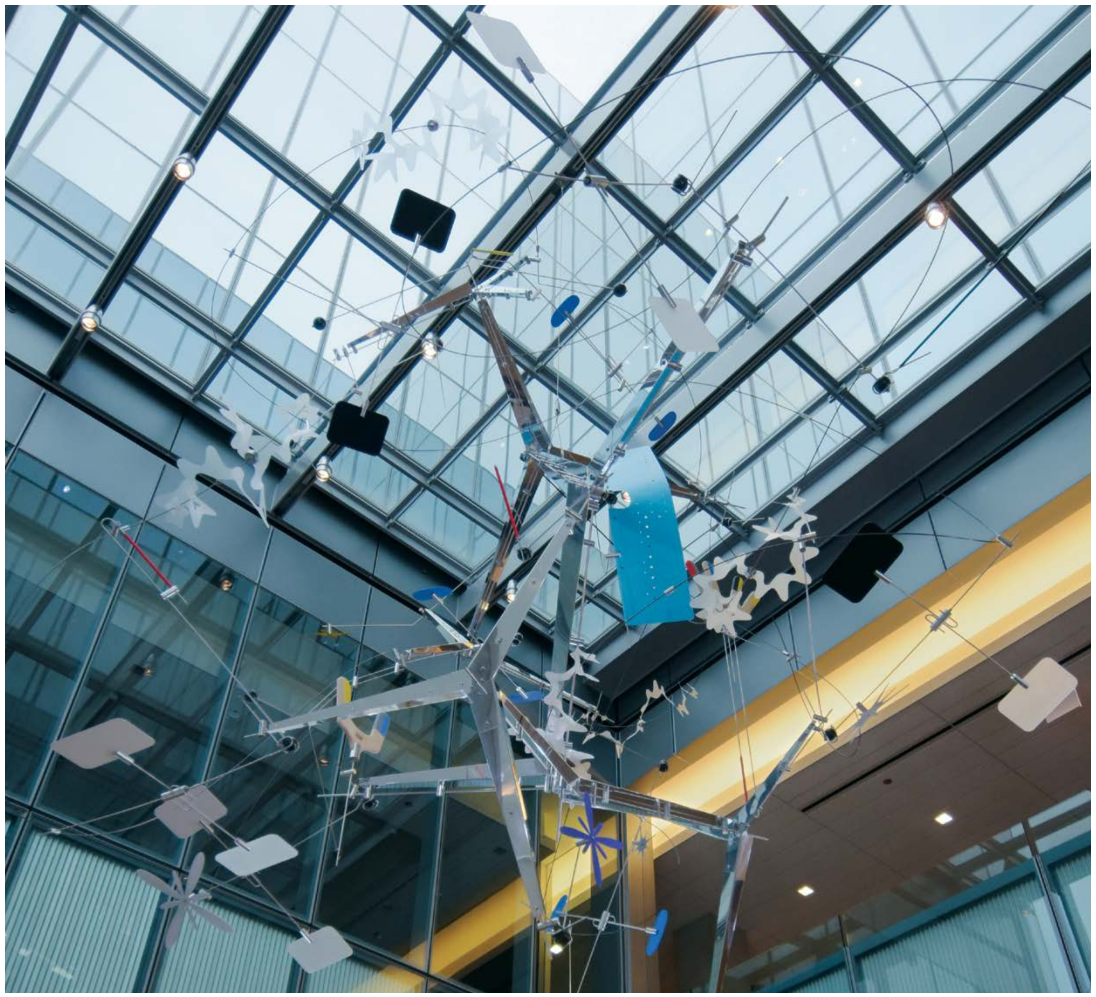
The Museum of Science and Industry Partners with IME on Art Installations for the William Eckhardt Research Center

As the physical structure of the William Eckhardt Research Center was being built, plans were also underway for an art collection to adorn its walls.

A team spearheaded by Patricia Ward, Director of Science and Technology at the Museum of Science and Industry, worked with faculty in the Institute for Molecular Engineering to identify installations that would reflect the history and promise of UChicago's Physical Sciences Division, as well the impact of science at the intersection of engineering. "It became clear that we had to find a common identity," said Ward. "How could we physically capture the common spirit of the PSD and IME?"

After nearly two years of consideration, Justus Roe, a Chicago painter and music producer, was commissioned in early 2015 to produce a mural for the glass-walled entry corridor on the ground floor of the ERC (photo at right). Its graphic multi-colored collection of shapes and imagery suggests improvisation, collaboration, and progress. The 200-square-foot mural is the largest by Roe to date.

For the main and south lobbies five kinetic sculptures by Mel Ristau were selected by the committee. Ristau, a sculptor based in Colorado, creates huge suspended sculptures for public display. His work exemplifies the ERC's transcending boundaries through the interplay of structure, movement, balance, and color.



LEADERSHIP

In the spring of 2015, the Institute for Molecular Engineering established a Visiting Committee (VC), a group of University of Chicago alumni and IME friends who support the Institute with professional expertise and philanthropic gifts.

Working in tandem with Matthew Tirrell, Pritzker Director and Dean of the IME, members of the Visiting Committee meet throughout the year to discuss the direction of the Institute, and serve as advocates to the University and Medical Center boards of trustees, and as ambassadors to external communities.

Barry MacLean, a supporter of the IME from its beginnings as well as a life trustee of University of Chicago Medicine, will chair the Institute's Visiting Committee.

Visiting Committee

Jack R. Bierig
Wayne L. Delker, SB'76
William Louis Florida, AB'87, AM'87
Karen Elizabeth Kerr, PhD'95
John Mihn Soo Liew, AB'89, MBA'94, PhD'95
Barry MacLean
Sylvia M. Neil, AM
Laura Elizabeth Niklason, PhD'88
Myrtle Stephens Potter, AB'80
Philip J. Wyatt, SB'52, BS'54

IME Executive Committee

Matthew Tirrell, Pritzker Director and Dean
David Awschalom, Deputy Director for Space, Infrastructure, and Facilities
Juan de Pablo, Deputy Director for Education and Outreach
Jeff Hubbell, Deputy Director for Faculty and Staff Affairs
Sharon Feng, Senior Associate Dean of Budget and Strategy
Rovana Popoff, Associate Dean of Education and Governance, Dean of Students

SUPPORT THE INSTITUTE FOR MOLECULAR ENGINEERING

Acknowledgments

We are very grateful to our donors, whose generosity supports and expands the vision of the Institute for Molecular Engineering. With your help, in the past five years the IME has grown to a faculty comprised of 14 research and scientific thought leaders from across disciplines and around the world. We have formed partnerships and collaborations with several universities, and with numerous corporate entities. In fall 2015, the IME moved into the new William Eckhardt Research Center, a truly collaborative space for scientific inquiry at all levels; and began utilizing new facilities and equipment at Argonne National Laboratories and the Chicago Innovation Exchange.

This report is filled with news of the IME's progress as it takes steps to tackle big issues, such as the availability of clean water, efficient energy harvesting and storage, improved cancer and medical treatment, and quantum solutions for data storage and security. The IME is developing new materials that open up possibilities for detecting diseases and delivering medicines, and exploring technologies and multidisciplinary approaches that promise to further harness the powers of material interactions at the smallest scales.

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Founding Gifts

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William R. Eckhardt, SM'70
Constance T. Keller and Dennis J. Keller, MBA'68
Serena J. M. Liew, U-High'85, AB'89 and John M. S. Liew, AB'89, MBA'94, PhD'95
Mary Ann S. MacLean and Barry L. MacLean
Agnes Mentre and Kenneth M. Jacobs, AB'80
The Pritzker Foundation

Supporting Gifts

Thomas F. Rosenbaum and Katherine T. Faber

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Eun Ji Chung
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Brady W. Dougan, AB'81, MBA'82 and Laura E. Niklason, PhD'88
Michael Einisman, AB'62, MBA'63
Lisa Farr
Sharon Feng and Zhe-Xi Luo
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The Institute for Molecular Engineering is a priority of The University of Chicago Campaign: Inquiry and Impact.

The first engineering program offered in the history of the University connects molecular-level science in chemistry, physics, and biology to determine what the disciplines can do together. The program is creating a "path from science to society… and putting what happens in the labs here into practice in the world," as IME Pritzker Director and Dean Matthew Tirrell explained.

A gift to the IME supports the inquiries of one of the most innovative scientific collaborations in the world, housed at The University of Chicago.

Your gift impacts a continually evolving set of solutions to problems that touch people's lives on a daily basis: water, health, energy, environment, and information.

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For more information about supporting the research and vision of IME, contact Carolyn Amadon, Director of External Affairs for the Institute for Molecular Engineering, at 773.834.4818 or amadoncaro@uchicago.edu.

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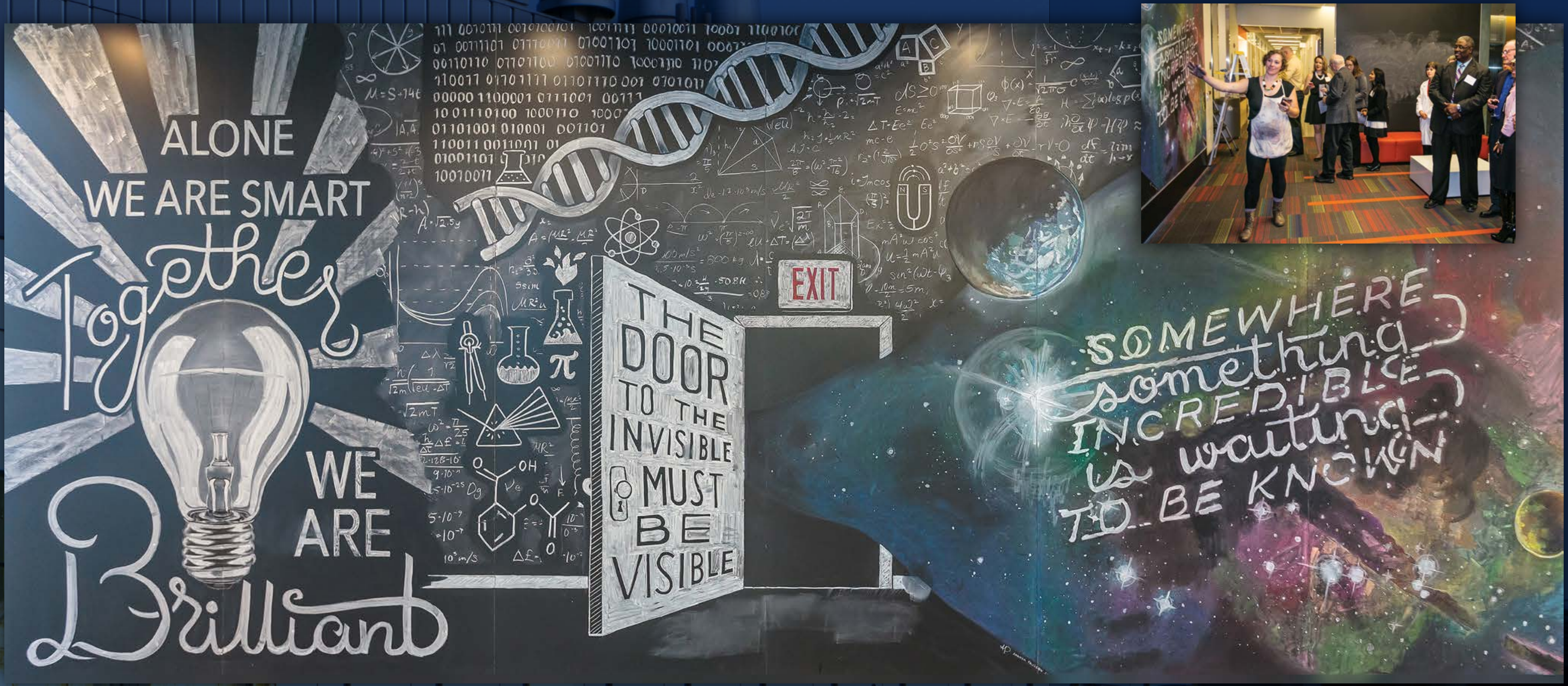

Above and top inset photo: To celebrate the IME's move into the William Eckhardt Research Center (ERC), artist Amanda Paulson was commissioned to create a 10' by 24' chalk mural in one of the second floor collaboration and study lounges.

Above and below: The atrium of the ERC building is the site of the September 2015 pizza party welcoming everyone to the new home of the IME and PSD.

Peter Duda, Technical Manager of the Pritzker Nanofabrication Facility, explains the cleanroom capabilities to IME researchers during the final stages of construction in the summer of 2015.

Autumn 2015 class of IME Graduate Students attends Opening Convocation.

In March 2015 the IME hosted its second admitted class of PhD students for recruitment. Students toured facilities at UChicago and Argonne, and met with faculty and researchers.

IME's first Molecular Mixer, held in February 2015, featured a "Camp IME" theme and included music, food, drinks, an innovative robo-skunk, and a light-emitting electronic campfire.

Middle-schoolers and their parents participate in the IME's Quantum Saturday event in August 2015.

IME students, staff and faculty enjoy the opportunity to interact during the June 2015 beach volleyball themed Molecular Mixer.

Mary Pat McCullough and Tierra Kilpatrick take care of registration at the IME holiday party in December 2015.

Above and left: A large and festive crowd of faculty, staff, researchers, students, and guests attended the IME 2015 holiday party

IME Professor Melody Swartz and her group of researchers and graduate students take a moment for a photo booth portrait during the 2015 holiday party.

Snapshot from the 2015 IME-sponsored international scientific symposium: IME alum Sarah Perry, IME/Argonne Business Administrator Diana Morgan, and IME Postdoctoral Researcher Lorraine Leon

Matthew Tirrell visits with incoming first-year students during orientation week in September 2015.

IME faculty network at the October 2015 Biomedical Engineering Society Annual Meeting.

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