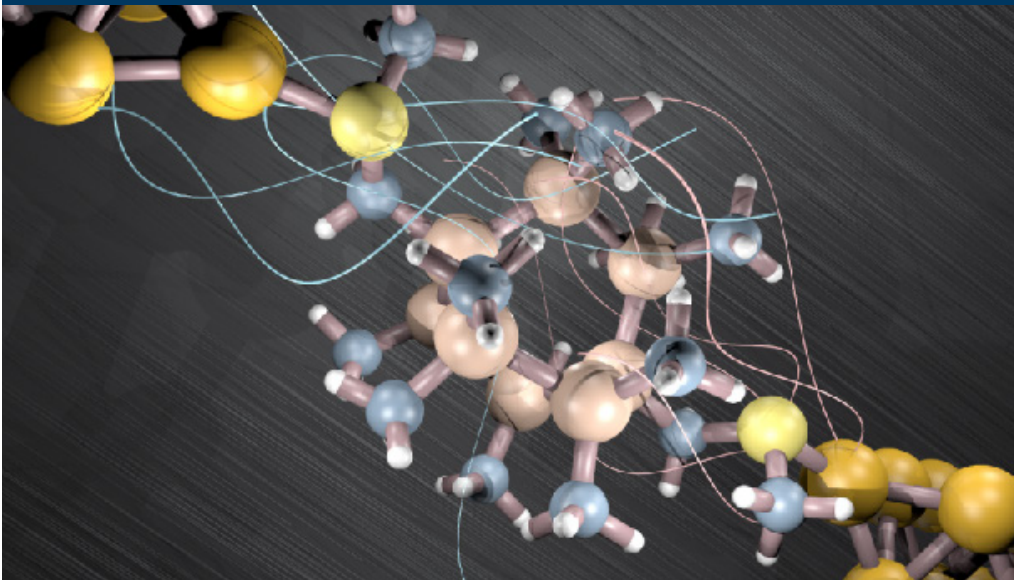


APAM NEWS

Applied Physics & Applied Mathematics Department
with Materials Science & Engineering
Columbia University in the City of New York



In a highly interdisciplinary collaboration, researchers across Columbia Engineering (including Prof. Latha Venkataraman and APAM alumnus, Dr. Haixing Li), Columbia University Department of Chemistry, Shanghai Normal University, and the University of Copenhagen have upended conventional wisdom, synthesizing the first molecule capable of insulating at the nanometer scale more effectively than a vacuum barrier. Their findings are published in *Nature*.

Image: An illustration of the silicon-based single-molecule device that functions as an efficient insulator through a sigma-based quantum interference effect from Prof. Latha Venkataraman's group. See page 5 for details.



Dear APAM Family,

As I return to the department chairmanship this academic year, I can see up-close the outcome of the wondrous events that have occurred in APAM in recent years. There has been growth in the faculty, strengthening of each of our academic areas and of our administrative staff, and the graduation of stellar sets of students who are now embarking on the next steps in their lives and careers. I can also see great things in our future, which starts with the new class of students who joined us in September. I warmly welcome them.

This issue brings you news of our applied physical and mathematical science activities across the full range of the department from the quantum interference affecting the conducting properties of single molecules, advances in ultrasmall/ultrafast optics and in new achromatic flat lenses, polymer coatings that enable building cooling, and the understanding and improving of battery performance, to the insightful recommendations for the future of burning plasmas and to field trips to acquire data for atmospheric and oceanic mathematical modelling.

We welcome Prof. Kui Ren who joined us this term in our Applied Mathematics Program. We also welcome Kristen Henlin as the APAM Career Placement Officer, the new department position established to help our students find jobs and internships. Numerous faculty and students have received major, highly-deserved recognitions. Alumni have embarked on exciting new phases of their careers. Also, our faculty have successfully relayed their science to the general public through various media outlets.

I wish all of you Joyous Holidays and a Wonderful New Year.

Best regards,

Irving P. Herman
Chair, APAM

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Polymer Coating Cools Down Buildings
Quantum Interference May Be Key to Smaller Insulators
Columbia Engineers Build Smallest Integrated Kerr Frequency Comb Generator
Lipson Wins 2019 IEEE Photonics Award

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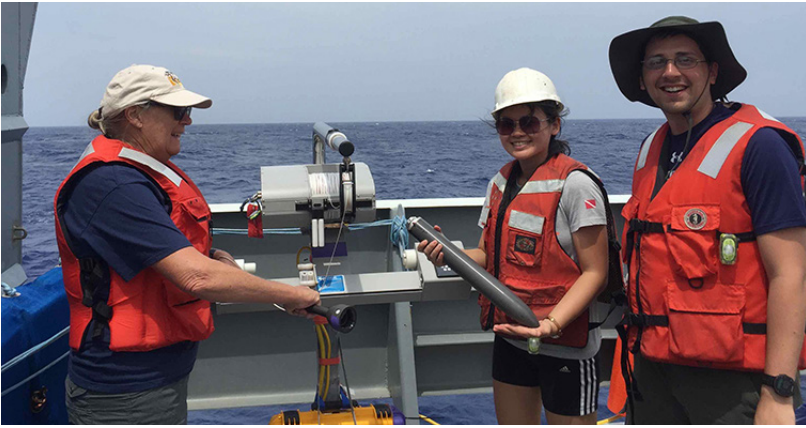
Billinge Featured in *Chemistry World*
Chan Elected APS Fellow
Du and Yu Win Columbia Engineering Research Awards
Gaeta Elevated to IEEE Fellow
Lipson Receives Honorary Doctorate from Trinity College
When Noise Becomes Signal

Mauel Co-Chairs National Academies Committee on Burning Plasma Research
New Applied Mathematics Faculty Member: APAM Alumn, Kui Ren
Stellarator Group Receives \$2M Simons Mathematical and Physical Sciences Award
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Department News

Zhou Wins Early Career Award
7th Annual SEAS Summer Research Symposium

Contact Us



Above: Dr. Janet Sprintall (left) from Scripps Institute of Oceanography, Socorro Rodrigo (center) from the University of the Philippines Diliman, and Zane Martin (right) prepare to practice launch a test-probe from the R/V Thomas G. Thompson as part of the PISTON field campaign, funded by the Office of Naval Research

Field Report from Zane Martin (Ph.D. Candidate)

Prof. Adam Sobel and I spent over three weeks at sea during our leg of the PISTON research cruise. Aboard the R/V Thomas G. Thompson, we stayed in close quarters and quite literally lived and breathed the weather we were studying.

Life on the ship provided a wholly unique and isolated environment: the Thompson had a stringent internet quota, little to no cell reception, and for the majority of the trip, the only interruptions to the expansive horizon were passing freighters or, in one case, another science vessel. Such an intense and all-encompassing experience lends a sense of perspective and focus to one's work which has been immeasurably beneficial to me as a scientist. My time on the ship deepened my intuition for the kinds of atmospheric and oceanic processes I think about in my research or learn about in the classroom. Through the experience of sitting outside and watching the weather, the water, and the sky, I found my curiosity and imagination excited and engaged in new ways: as the seemingly homogeneous ocean stretched out from all sides of the ship, why were there dotted storms in some places and not others? What set the height or base of the clouds? How did the rain coming out of storms interact with the ocean, or the wind whipping off the white caps feedback to the atmosphere? It gave a real sense of purpose and reality to work that can sometimes seem obtuse or abstract when viewed through the lens of a laptop screen. (continued on p. 10)

Alumni Reports

Justin Calamari (B.S. '18, Applied Physics), a former member of Prof. Simon Billinge's Group, participated in the prestigious and selective Google 2018 Summer of Code - a program which offers funding to students working on open source software projects.

Xin Chen (M.S. '17, Materials Science & Engineering): "After graduating, I went back to my country and started my career as a research analyst in the finance field. Though in finance field, my work is still related to engineering research."*

Xuan Gao (Ph.D. '03, Applied Physics), a former student of Prof. Aron Pinczuk and Prof. Andrew Millis, is now a full professor in the Physics Department at Case Western Reserve University. Prof. Gao's research centers on nanostructures or materials (quantum wells, nanoplates, nanowires, etc.) in which the quantum nature of particles (electrons, phonons, etc.) plays a fundamental role in their electrical, thermal, optical and magnetic properties. He seeks to understand and exploit the quantum physics in these nanostructures for novel device applications.

Rosario Gerhardt, (M.S. '79, Eng.Sc.D. '83, Materials Science & Engineering / Earth & Environmental Science) who attended the 2018 SEAS alumni reunion, enjoyed Prof. Helfand's lecture, as well as walking around the campus, and seeing all of the changes that have taken place in the interim years. She has been a faculty member at the School of Materials Science and Engineering at the Georgia Institute of Technology since 1991, received tenure in 1997, and was promoted to full professor in 2001. Gerhardt received the 2017 ACerS Friedberg Award and lecture at the MS&T conference held in Pittsburgh in October 2017. She was named Goizueta Foundation Faculty Chair at Georgia Tech in 2015. In addition to conducting research in the materials field, she is also committed to helping younger generations become solid researchers to emulate her former thesis advisor, Prof. A.S. Nowick.*

Yuan He (Ph.D. '10, Applied Mathematics) joins APAM as an Adjunct Associate Professor and will be teaching *Introduction to Applied Mathematics* in Spring 2019. Previously, she was a Postdoctoral Research Fellow at the Institute for Computational Engineering and Sciences (ICES) and a Postdoctoral Instructor in Mathematics at the University of Texas, Austin; was a Research Fellow at the Institute for Pure and Applied Mathematics at UCLA; and returned to UT-Austin as a Lecturer in Mathematics.

Julio Herrera Estrada (B.S. '12, Applied Mathematics) : "I graduated from Princeton University with a Ph.D. in civil and environmental engineering. My thesis was about how droughts develop in North America, how they may be affected by climate change, and how they impact the electricity sector (e.g. through hydropower). I am now a Postdoctoral Scholar at Stanford University in the Department of Earth System Science, continuing my work on the impact of weather and climate extremes on the electricity sector. I am looking forward to connecting with other alumni in the Bay Area!"*

(continued on page 11)

Wright Receives NumFOCUS Award

Christopher James Wright, a doctoral student from Prof. Simon Billinge's lab, received a NumFOCUS award at the NumFOCUS Summit on September 22, 2018, and was among several award recipients who were recognized for their "substantial contributions to NumFocus projects, to the ecosystem, and to the open source scientific computing movement".

"Christopher (CJ) is one of the newest members of the conda-forge core team. However, in that short amount of time he has lead a revolution in the automation of conda-forge package updates and migrations. CJ, together with Justin Calamari, whom he mentored this summer, implemented what has become affectionately known as "The Bot," which is a feedstock modification framework capable of "topologically crawling" conda-forge's dependency graph. This tooling is now being used to solve one the panoply of challenges that face conda-forge on a daily basis. This includes the hardest task to-date: a complete rebuild of all conda-forge packages using new compilers in order to be ABI compatible with modern versions of C++. Thanks to CJ and the rest of the Bot team that worked with him, conda-forge will be able to complete this herculean task in just a few weeks, rather than the years it took to perform previous smaller, more benign migrations." wrote Gina Helfrich, the NumFOCUS Communications Director.

Revolutionary Ultra-thin “Meta-lens” Enables Full-color Imaging

by Holly Evarts, originally published by *Columbia Engineering*

Light of different colors travels at different speeds in different materials and structures. This is why we see white light split into its constituent colors after refracting through a prism, a phenomenon called dispersion. An ordinary lens cannot focus light of different colors to a single spot due to dispersion. This means different colors are never in focus at the same time, and so an image formed by such a simple lens is inevitably blurred. Conventional imaging systems solve this problem by stacking multiple lenses, but this solution comes at the cost of increased complexity and weight.

Columbia Engineering researchers have created the first flat lens capable of correctly focusing a large range of colors of any polarization to the same focal spot without the need for any additional elements. Only a micron thick, their revolutionary “flat” lens is much thinner than a sheet of paper and offers performance comparable to top-of-the-line compound lens systems. The findings of the team, led by **Nanfang Yu**, associate professor of applied physics, are outlined in a new study, published by *Light: Science & Applications*.

A conventional lens works by routing all the light falling upon it through different paths so that the whole light wave arrives at the focal point at the same time. It is manufactured to do so by adding an increasing amount of delay to the light as it goes from the edge to the center of the lens. This is why a conventional lens is thicker at its center than at its edge.

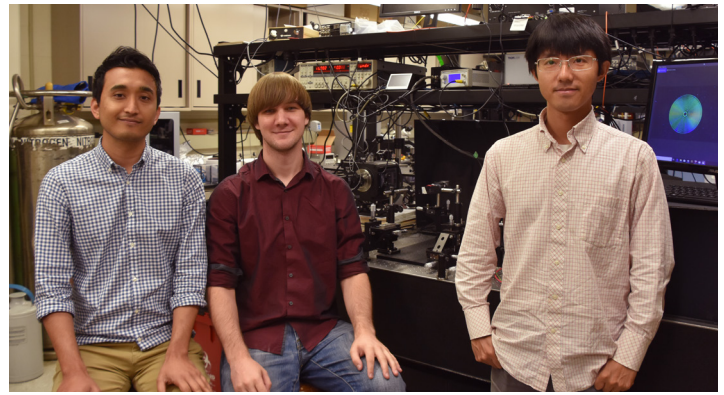
With the goal of inventing a thinner, lighter, and cheaper lens, Yu’s team took a different approach. Using their expertise in optical “metasurfaces”—engineered two-dimensional structures—to control light propagation in free space, the researchers built flat lenses made of pixels, or “meta-atoms.” Each meta-atom has a size that is just a fraction of the wavelength of light and delays the light passing through it by a different amount. By patterning a very thin flat layer of nanostructures on a substrate as thin as a human hair, the researchers were able to achieve the same function as a much thicker and heavier conventional lens system. Looking to the future, they anticipate that the meta-lenses could replace bulky lens systems, comparable to the way flat-screen TVs have replaced cathode-ray-tube TVs.

“The beauty of our flat lens is that by using meta-atoms of complex shapes, it not only provides the correct distribution of delay for a single color of light but also for a continuous spectrum of light,” Yu says. “And because they are so thin, they have the potential to drastically reduce the size and weight of any optical instrument or device used for imaging, such as cameras, microscopes, telescopes, and even our eyeglasses. Think of a pair of eyeglasses with a thickness thinner than a sheet of paper, smartphone cameras that do not bulge out, thin patches of imaging and sensing systems for driverless cars and drones, and miniaturized tools for medical imaging applications.”

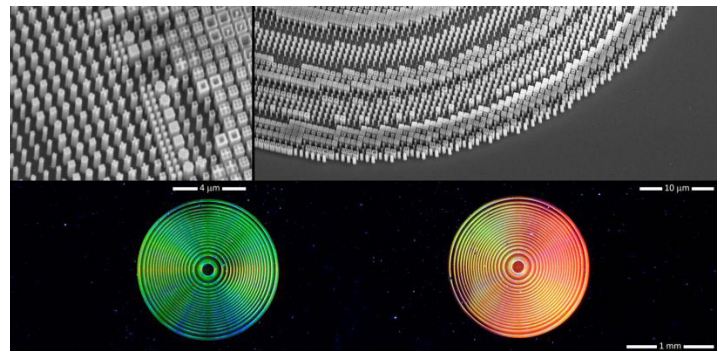
Yu’s team fabricated the meta-lenses using standard 2D planar fabrication techniques similar to those used for fabricating computer chips. They say the process of mass manufacturing meta-lenses should be a good deal simpler than producing computer chips, as they need to define just one layer of nanostructures—in comparison, modern computer chips need numerous layers, some as many as 100. The advantage of the flat meta-lenses is that, unlike conventional lenses, they do not need to go through the costly and time-consuming grinding and polishing processes.

“The production of our flat lenses can be massively parallelized, yielding large quantities of high performance and cheap lenses,” notes **Sajan Shrestha**, a doctoral student in Yu’s group who was co-lead author of the study. “We can therefore send our lens designs to semiconductor foundries for mass production and benefit from economies of scale inherent in the industry.”

Because the flat lens can focus light with wavelengths ranging from 1.2 to 1.7 microns in the near-infrared to the same focal spot, it can form



(left-right) Sajan Shrestha, Adam Overvig, and Prof. Nanfang Yu



Top panels: Scanning electron micrographs of sections of broadband meta-lenses. They are composed of silicon nanopillars with various cross-sectional shapes patterned on a glass substrate. Bottom panel: Photo showing two elements of a multi-element meta-lens imaging system.

“colorful” images in the near-infrared band because all of the colors are in focus at the same time—essential for color photography. The lens can focus light of any arbitrary polarization state, so that it works not only in a lab setting, where the polarization can be well controlled, but also in real world applications, where ambient light has random polarization. It also works for transmitted light, convenient for integration into an optical system.

“Our design algorithm exhausts all degrees of freedom in sculpting an interface into a binary pattern, and, as a result, our flat lenses are able to reach performance approaching the theoretic limit that a single nanostructured interface can possibly achieve,” **Adam Overvig**, the study’s other co-lead author and also a doctoral student with Yu, says. “In fact, we’ve demonstrated a few flat lenses with the best theoretically possible combined traits: for a given meta-lens diameter, we have achieved the tightest focal spot over the largest wavelength range.”

Adds Univ. of Pennsylvania H. Nedwill Ramsey Professor Nader Eng-heta, an expert in nanophotonics and metamaterials who was not involved with this study: “This is an elegant work from Professor Nanfang Yu’s group and it is an exciting development in the field of flat optics. This achromatic meta-lens, which is the state-of-the-art in engineering of metasurfaces, can open doors to new innovations in a diverse set of applications involving imaging, sensing, and compact camera technology.”

Now that the meta-lenses built by Yu and his colleagues are approaching the performance of high-quality imaging lens sets, with much smaller weight and size, the team has another challenge: improving the lenses’ efficiency. The flat lenses currently are not optimal because a small fraction of the incident optical power is either reflected by the flat lens, or scattered into unwanted directions. The team is optimistic that the issue of efficiency is not fundamental, and they are busy inventing new design strategies to address the efficiency problem. They are also in talks with industry on further developing and licensing the technology.

Polymer Coating Cools Down Buildings

Columbia Engineers make white paint whiter—and cooler—by removing white pigment and invent a polymer coating, with nano-to-microscale air voids, that acts as a spontaneous air cooler and can be fabricated, dyed, and applied like paint.

by Holly Evarts, originally published by *Columbia Engineering*

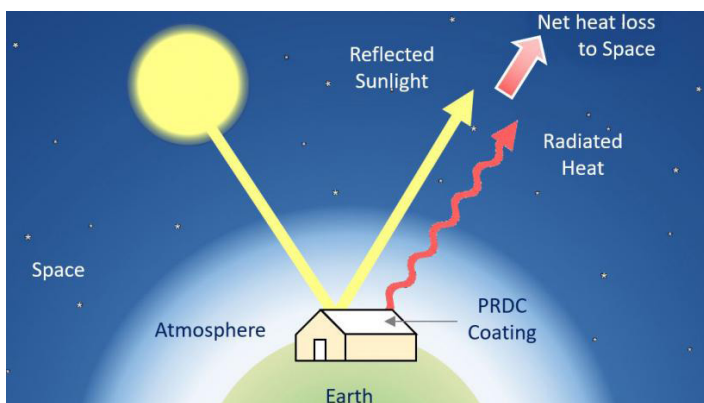
With temperatures rising and heat-waves disrupting lives around the world, cooling solutions are becoming ever more essential. This is a critical issue especially in developing countries, where summer heat can be extreme and is projected to intensify. But common cooling methods such as air conditioners are expensive, consume significant amounts of energy, require ready access to electricity, and often require coolants that deplete ozone or have a strong greenhouse effect.

An alternative to these energy-intensive cooling methods is passive daytime radiative cooling (PDRC), a phenomenon where a surface spontaneously cools by reflecting sunlight and radiating heat to the colder atmosphere. PDRC is most effective if a surface has a high solar reflectance (R) that minimizes solar heat gain, and a high, thermal emittance (ϵ) that maximizes radiative heat loss to the sky. If R and ϵ are sufficiently high, a net heat loss can occur, even under sunlight.

Developing practical PDRC designs has been challenging: many recent design proposals are complex or costly, and cannot be widely implemented or applied on rooftops and buildings, which have different shapes and textures. Up to now, white paints, which are inexpensive and easy to apply, have been the benchmark for PDRC. White paints, however, usually have pigments that absorb UV light, and do not reflect longer solar wavelengths very well, so their performance is only modest at best.

Researchers at Columbia Engineering have invented a high-performance exterior PDRC polymer coating with nano-to-microscale air voids that acts as a spontaneous air cooler and can be fabricated, dyed, and applied like paint on rooftops, buildings, water tanks, vehicles, even spacecraft—anything that can be painted. They used a solution-based phase-inversion technique that gives the polymer a porous foam-like structure. The air voids in the porous polymer scatter and reflect sunlight, due to the difference in the refractive index between the air voids and the surrounding polymer. The polymer turns white and thus avoids solar heating, while its intrinsic emittance causes it to efficiently lose heat to the sky. The study was published in *Science*.

The team—**Yuan Yang**, assistant professor of materials science and engineering; **Nanfeng Yu**, associate professor of applied physics; and **Jyotirmoy Mandal**, lead author of the study and a doctoral student in



Passive daytime radiative cooling involves simultaneously reflecting sunlight & radiating heat into the cold sky to achieve a net heat loss. The process, which is spontaneous, can cool down structures to sub-ambient temperatures.

Yang's group—built upon earlier work that demonstrated that simple plastics and polymers, including acrylic, silicone, and PET, are excellent heat radiators and could be used for PDRC. The challenges were how to get these normally transparent polymers to reflect sunlight without using silver mirrors as reflectors and how to make them easily deployable.

They decided to use phase-inversion because it is a simple, solution-based method for making light-scattering air-voids in polymers. Polymers and solvents are already used in paints, and the Columbia Engineering method essentially replaces the pigments in white paint with air voids that reflect all wavelengths of sunlight, from UV to infrared.

"This simple but fundamental modification yields exceptional reflectance and emittance that equal or surpass those of state-of-the-art PDRC designs, but with a convenience that is almost paint-like," says Mandal.

The researchers found their polymer coating's high solar reflectance ($R > 96\%$) and high thermal emittance ($\epsilon \sim 97\%$) kept it significantly cooler than its environment under widely different skies, e.g. by 6°C in the warm, arid desert in Arizona and 3°C in the foggy, tropical environment of Bangladesh. "The fact that cooling is achieved in both desert and tropical climates, without any thermal protection or shielding, demonstrates the utility of our design wherever cooling is required," Yang notes.

The team also created colored polymer coatings with cooling capabilities by adding dyes. "Achieving a superior balance between color and cooling performance over current paints is one of the most important aspects of our work," Yu notes. "For exterior coatings, the choice of color is often subjective, and paint manufacturers have been trying to make colored coatings, like those for roofs, for decades."

The group took environmental and operational issues, such as recyclability, bio-compatibility, and high-temperature operability, into consideration, and showed that their technique can be generalized to a range of polymers to achieve these functionalities. "Polymers are an amazingly diverse class of materials, and because this technique is generic, additional desirable properties can be conveniently integrated into our PDRC coatings, if suitable polymers are available," Mandal adds.

"Nature offers many ways for heating and cooling, some of which are extremely well known and widely studied and others that are poorly known. Radiative cooling—by using the sky as a heat sink—belongs to the latter group, and its potential has been strangely overlooked by materials scientists until a few years ago," says Uppsala University Physics Professor Claes-Göran Granqvist, a pioneer in the field of radiative cooling, who was not involved with the study. "The publication by Mandal et al. highlights the importance of radiative cooling and represents an important breakthrough by demonstrating that hierarchically porous polymer coatings, which can be prepared cheaply and conveniently, give excellent cooling even in full sunlight."

Yang, Yu, and Mandal are refining their design in terms of applicability, while exploring possibilities such as the use of completely biocompatible polymers and solvents. They are in talks with industry about next steps.

"Now is a critical time to develop promising solutions for sustainable humanity," Yang notes. "This year, we witnessed heat waves and record-breaking temperatures in North America, Europe, Asia, and Australia. It is essential that we find solutions to this climate challenge, and we are very excited to be working on this new technology that addresses it."

Yu adds that he used to think that white was the most unattainable color: "When I studied watercolor painting years ago, white paints were the most expensive. Cremnitz white or lead white was the choice of great masters, including Rembrandt and Lucian Freud. We have now demonstrated that white is in fact the most achievable color. It can be made using nothing more than properly sized air voids embedded in a transparent medium. Air voids are what make snow white and Saharan silver ants silvery."

Numerous media outlets, including sciencemag.org, mashable.com, smithsonianmag.com, fastcompany.com, dailymail.co.uk, chemistryworld.com, physics-world.com, newatlas.com, sciencedaily.com, europapress.es, business-standard.com, and phys.org, covered the *Science* paper, "Hierarchically Porous Polymer Coatings for Highly Efficient Passive Daytime Radiative Cooling," by J. Mandal, Y. Fu, A. Overvig, M. Jia, K. Sun, N. Shi, H. Zhou, X. Xiao, N. Yu, & Y. Yang.

Quantum Interference May Be Key to Smaller Insulators

Breakthrough could jumpstart further miniaturization of transistors

By Mindy Farabee, originally published by *Columbia Engineering*

Ever shrinking transistors are the key to faster and more efficient computer processing. Since the 1970s, advancements in electronics have largely been driven by the steady pace with which these tiny components have grown simultaneously smaller and more powerful—right down to their current dimensions on the nanometer scale. But recent years have seen this progress plateau, as researchers grapple with whether transistors may have finally hit their size limit. High among the list of hurdles standing in the way of further miniaturization: problems caused by “leakage current.”

Leakage current results when the gap between two metal electrodes narrows to the point that electrons are no longer contained by their barriers, a phenomenon known as quantum mechanical tunnelling. As the gap continues to decrease, this tunnelling conduction increases at an exponentially higher rate, rendering further miniaturization extremely challenging. Scientific consensus has long held that vacuum barriers represent the most effective means to curtail tunnelling, making them the best overall option for insulating transistors. However, even vacuum barriers can allow for some leakage due to quantum tunnelling.

In a highly interdisciplinary collaboration, researchers across Columbia Engineering, Columbia University Department of Chemistry, Shanghai Normal University, and the University of Copenhagen have upended conventional wisdom, synthesizing the first molecule capable of insulating at the nanometer scale more effectively than a vacuum barrier. Their research, “Comprehensive suppression of single-molecule conductance using destructive sigma interference” was published in *Nature*.

“We’ve reached the point where it’s critical for researchers to develop creative solutions for redesigning insulators. Our molecular strategy represents a new design principle for classic devices, with the potential to support continued miniaturization in the near term,” said co-author **Latha Venkataraman**, Professor of Applied Physics and Chemistry, who heads the lab where researcher and APAM alumnus, **Haixing Li** (Ph.D. ‘17, Applied Physics), conducted the project’s experimental work. Molecular synthesis was carried out in the Colin Nuckolls Lab at Columbia’s Department of Chemistry, in partnership with Shengxiong Xiao at Shanghai Normal University.

The team’s insight was to exploit the wave nature of electrons. By designing an extremely rigid silicon-based molecule under 1 nm in length that exhibited comprehensive destructive interference signatures, they devised a novel technique for blocking tunnelling conduction at the nanoscale.

“This quantum interference-based approach sets a new standard for short insulating molecules,” said lead author Marc Garner, a chemist in the University of Copenhagen’s Solomon Lab, which handled the theoretical work. “Theoretically, interference can lead to complete cancellation of tunneling probability, and we’ve shown that the insulating component in our molecule is less conducting than a vacuum gap of same dimensions. At the same time, our work also improves on recent research into carbon-based systems, which were thought to be the best molecular insulators until now.”

Destructive quantum interference occurs when the peaks and valleys of two waves are placed exactly out of phase, annulling oscillation. Electronic waves can be thought of as analogous to sound waves—flowing through barriers just as sound waves “leak” through walls. The unique properties exhibited by the team’s synthetic molecule mitigated tunneling without requiring, in this analogy, a thicker wall.

Their silicon-based strategy also presents a potentially more factory-ready solution. While recent research into carbon nanotubes holds promise for industrial applications over the next decade or so, this insulator—compatible with current industry standards—could be more readily implemented.

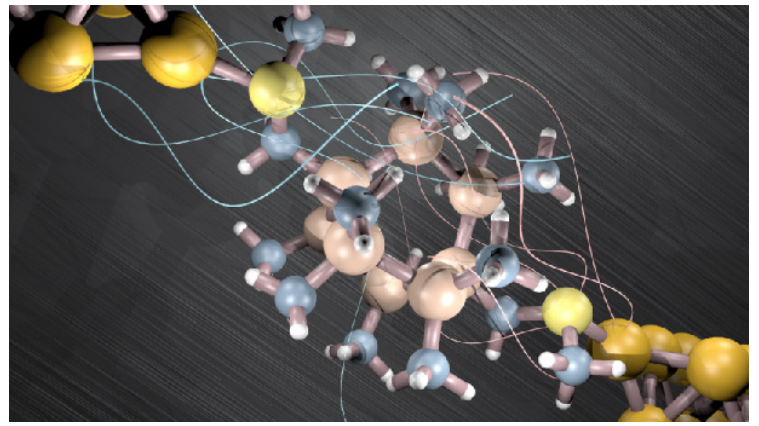
“Congratulations to the team on this breakthrough,” said Mark Ratner, a pioneer in the field of molecular electronics and professor emeritus at Northwestern University who was not involved in the study. “Using interference to create an insulator has been ignored up to this date. This paper demonstrates the ability of interference, in a silicon-based sigma system, which is quite impressive.”

This breakthrough grew out of the team’s larger project on silicon-based molecule electronics, begun in 2010. The group arrived at their latest discovery by bucking the trend. Most research in this field aims to create highly conducting molecules, as low conductance is rarely considered a desirable property in electronics. Yet insulating components may actually prove to be of greater value to future optimization of transistors, due to the inherent energy inefficiencies caused by leakage currents in smaller devices.

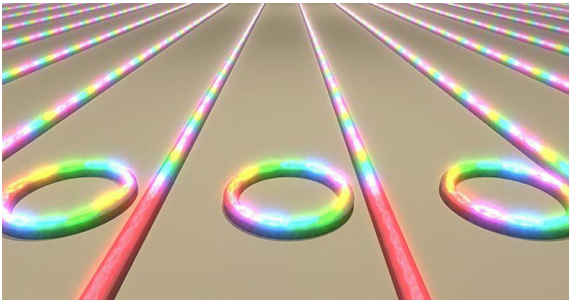
As a result, their work has yielded new understanding of the fundamental underlying mechanisms of conduction and insulation in molecular scale devices. The researchers will build on this insight by next clarifying the details of structure-function relationships in silicon-based molecular components.

“This work has been extremely gratifying for us, because in the course of it we have repeatedly discovered new phenomena,” said Venkataraman. “We have previously shown that silicon molecular wires can function as switches, and now we’ve demonstrated that by altering their structure, we can create insulators. There is a lot to be learned in this area that will help shape the future of nanoscale electronics.”

M.H. Garner, H. Li, Y. Chen, T.A. Su, Z. Shangguan, D.W. Paley, T. Liu, F. Ng, H. Li, S. Xiao, C. Nuckolls, L. Venkataraman & G.C. Solomon, “Comprehensive suppression of single-molecule conductance using destructive σ -interference,” *Nature*, Volume 558, 415–419 (2018)



A silicon-based single-molecule device that functions as an efficient insulator through a sigma-based quantum interference effect



Above: Illustration showing an array of microring resonators on a chip converting laser light into frequency combs.

Columbia Engineers Build Smallest Integrated Kerr Frequency Comb Generator

Low-power chip unites lasers and frequency combs for the first time and can be powered by an AAA battery, opening the door to portable devices for a wide range of applications from spectroscopy to optical communications to LIDAR.

By Holly Evarts, originally published by *Columbia Engineering*

Optical frequency combs can enable ultrafast processes in physics, biology, and chemistry, as well as improve communication and navigation, medical testing, and security. The Nobel Prize in Physics 2005 was awarded to the developers of laser-based precision spectroscopy, including the optical frequency comb technique, and microresonator combs have become an intense focus of research over the past decade.

A major challenge has been how to make such comb sources smaller and more robust and portable. In the past 10 years, major advances have been made in the use of monolithic, chip-based microresonators to produce such combs. While the microresonators generating the frequency combs are tiny—smaller than a human hair—they have always relied on external lasers that are often much larger, expensive, and power-hungry.

Researchers at Columbia Engineering announced in *Nature* that they have built a Kerr frequency comb generator that, for the first time, integrates the laser together with the microresonator, significantly shrinking the system's size and power requirements. They designed the laser so that half of the laser cavity is based on a semiconductor waveguide section with high optical gain, while the other half is based on waveguides, made of silicon nitride, a very low-loss material. Their results showed that they no longer need to connect separate devices in the lab using fiber—they can now integrate it all on photonic chips that are compact and energy efficient.

The team knew that the lower the optical loss in the silicon nitride waveguides, the lower the laser power needed to generate a frequency comb. "Figuring out how to eliminate most of the loss in silicon nitride took years of work from many students in our group," says **Michal Lipson**, Eugene Higgins Professor of Electrical Engineering, Professor of Applied Physics, and co-leader of the team. "Last year we demonstrated that we could reproducibly achieve very transparent low-loss waveguides. This work was key to reducing the power needed to generate a frequency comb on-chip, which we show in this new paper."

Microresonators are typically small, round disks or rings made of silicon, glass, or silicon nitride. Bending a waveguide into the shape of a ring creates an optical cavity in which light circulates many times, leading to a large buildup of power. If the ring is properly designed, a single-frequency pump laser input can generate an entire frequency comb in the ring. The Columbia Engineering team made another key innovation: in microresonators with extremely low loss like theirs, light circulates and builds up so much intensity that they could see a strong reflection coming back from the ring.

"We actually placed the microresonator directly at the edge of the laser cavity so that this reflection made the ring act just like one of the laser's mirrors—the reflection helped to keep the laser perfectly aligned," says Brian Stern, the study's lead author who conducted the work as a doctoral student in Lipson's group. "So, rather than using a standard external laser to pump the frequency comb in a separate microresonator, we now have the freedom to design the laser so that we can make the laser and resonator interact in new ways."

All of the optics fit in a millimeter-scale area and the researchers say that their novel device is so efficient that even a common AAA battery can power it. "Its compact size and low power requirements open the door to developing portable frequency comb devices," says **Alexander Gaeta**, Rickey Professor of Applied Physics and of Materials Science and team co-leader. "They could be used for ultra-precise optical clocks, for laser radar/LIDAR in autonomous cars, or for spectroscopy to sense biological or environmental markers. We are bringing frequency combs from table-top lab experiments closer to portable, or even wearable, devices."

The researchers plan to apply such devices in various configurations for high precision measurements and sensing. In addition, they will extend these designs for operation in other wavelength ranges, such as the mid-infrared where sensing of chemical and biological agents is highly effective. In cooperation with Columbia Technology Ventures, the team has a provisional patent application and is exploring commercialization of this device.

B. Stern, X. Ji, Y. Okawachi, A.L. Gaeta & M. Lipson, "Battery-operated integrated frequency comb generator," *Nature*, Volume 562, 401–405 (2018)



Lipson Wins 2019 IEEE Photonics Award

Michal Lipson, the Eugene Higgins Professor of Electrical Engineering and Professor of Applied Physics, as well as a Columbia Nano Initiative Executive Committee member, was named the recipient of the 2019 IEEE Photonics Award for her outstanding achievements in photonics. Among IEEE's most prestigious honors, the Photonics Award is part of the IEEE Awards Program which, for nearly a century, has paid tribute to technical professionals whose exceptional achievements and outstanding contributions have made a lasting impact on technology, society, and the engineering profession. Lipson is the first faculty member from Columbia University to receive the award, which represents the highest honor bestowed by the IEEE Photonics Society. "This is such a great honor—I feel humbled and very grateful," says Lipson, one of the pioneers at the forefront of silicon photonics research.

Lipson investigates the physics and applications of nanoscale photonic structures and is particularly interested in light-confining structures that can slow down, trap, enhance, and manipulate light. "Nanophotonics can provide high bandwidth, high speed, and ultra-small optoelectronic components," she notes. "This is truly an exciting field to be working in as our technology can revolutionize telecommunications, computation, and sensing, connecting our worlds in all kinds of new ways." *By Holly Evarts, originally published by Columbia Engineering*

Faculty Updates

Billinge Featured in *Chemistry World*

Simon Billinge was featured in the article, “The luck of the materials scientist” by Clare Sansom in *Chemistry World*. “Billinge’s group uses techniques to tackle real world problems, improving the properties of advanced materials by subtly altering their molecular structures. These might be high temperature superconductors, batteries or photovoltaic cells, or, increasingly, pharmaceuticals. Many of the “failed” compounds on drug companies’ shelves are potent and selective inhibitors of their molecular targets but are too insoluble to enter the bloodstream. Reformulating by reducing the particle size can sometimes increase the solubility of a ‘brick dust’-like compound by as much as a thousand times.”

Chan Elected APS Fellow

Siu-Wai Chan was elected a 2018 Fellow of the American Physical Society (APS) “for observing and understanding the grain boundary dislocation motion in materials, providing a seminal impact on superconducting thin film boundary devices, and inventing a novel ecological synthesis technique of nano-crystals oxides for catalysis applications.”

Du & Yu Win Columbia Research Awards

APAM faculty proposals were selected to receive funding for interdisciplinary and translational research. Nanfang Yu (APAM) and Changxi Zheng (Comp. Sci.) will use advanced nanofabrication techniques to realize a number of flat optical designs that can have disruptive technological impact. Qiang Du (APAM) and Steve WaiChing Sun (Civil Eng.), whose proposal will be funded for a second year, strive to make robust, accurate, and reliable predictions for engineering applications related to porous media, such as hydraulic fracture, geothermal energy extraction, and nuclear waste disposal.

Gaeta Elevated to IEEE Fellow

Alexander Gaeta was elevated to IEEE Fellow in the 2019 Class “for contributions to quantum and nonlinear photonics”.

Lipson Receives Honorary Doctorate

Michal Lipson received an honorary doctorate for her pioneering work in silicon photonics from Trinity College, University of Dublin. Officiating at the December 7, 2018, ceremony was Dr. Mary Robinson, chancellor of the university and former president of Ireland (who received an honorary doctorate from Columbia). “This is an incredible honor,” says Lipson. “Trinity College is home to the AMBER Centre, on whose board I have had the privilege of serving. The center’s transformative research impacts science worldwide.” (*Electrical Engineering News*)

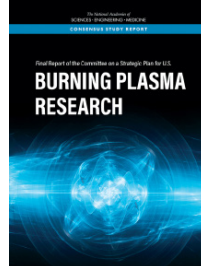
When Noise Becomes Signal

NOAA Research News highlighted a paper by Michael Tippett and Adam Sobel, along with Research Scientist, Shuguang Wang, and Alek Anichowski (B.S. ‘17, Applied Math). Their paper, “Seasonal noise versus subseasonal signal: Forecasts of California precipitation during the unusual winters of 2015–2016 and 2016–2017,” was published in *Geophysical Research Letters*. “Our study indicates that subseasonal to seasonal forecasts (S2S) made two weeks to 2 months ahead of time are highly valuable in this regard,” said Wang, lead author of the paper. “This is perhaps the first study showing that S2S forecasts can accurately predict high impact weather events.”



Mauel Co-Chairs National Academies Committee on Burning Plasma Research

The final report of the Committee on a Strategic Plan for U.S. Burning Plasma Research was released on December 13, 2018.



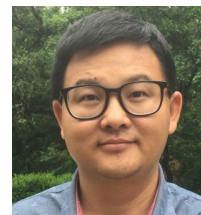
The National Academies press release stated, “Along with participation in the International Thermonuclear Experimental Reactor (ITER) project—a large, international burning plasma experiment—the U.S. Department of Energy should start a national program of accompanying research and technology to build a compact pilot plant that produces electricity from fusion at the lowest possible capital cost, says a new report from the National Academies of Sciences, Engineering, and Medicine. The report provides a strategic plan to guide implementation of the main recommendations.”

“We are seeing tremendous progress being made in the path to achieving fusion energy around the world,” said Prof. Michael Mauel, co-chair of the committee that authored the report. “Now is the right time for the U.S. to benefit from the investments in burning plasma research and take leadership in fusion energy.” (*National Academies of Sciences, Engineering, and Medicine press release*)

Online resources of the report are available at:

<https://www.nap.edu/catalog/25331>

New Applied Mathematics Faculty Member: APAM Alumn, Kui Ren



The Applied Physics and Applied Mathematics Department is proud to announce the appointment of a new Applied Mathematics faculty member. APAM alumn, **Kui Ren**, joins us as a new Professor of Applied Mathematics.

Prof. Ren received his B.S. from Nanjing University in China. He obtained his Ph.D. from the Applied Mathematics program in the APAM Department at Columbia University in May 2006 and was awarded the 2006 Robert Simon Memorial Prize for the most outstanding dissertation. Following his Ph.D., he moved to the University of Chicago in 2007, where he worked as the L. E. Dickson instructor. In Fall 2008, Ren joined the University of Texas at Austin as an assistant professor in the Department of Mathematics and the Institute for Computational Sciences, Engineering and Mathematics (ICES) and was promoted to Associate Professor in 2014.

Prof. Ren’s research involves several aspects of applied and computational mathematics. His recent work include theoretical and numerical analysis of inverse problems related to partial differential equations (PDEs) with applications in biomedical imaging, mathematical modeling and computation of the propagation of high frequency acoustic/electromagnetic waves in random media, numerical and mathematical studies of random graphs and networks, as well as numerical algorithms for kinetic modeling of electrostatics and charge transport in semiconductor devices.

Science

Oct 21, 2015

30 minute plasmas eventually

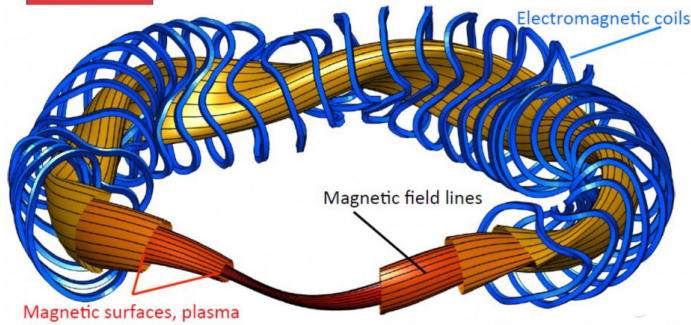


Image: The W7-X Stellarator

Stellarator Group Receives \$2M Simons Mathematical and Physical Sciences Award

Allen H. Boozer, Professor of Applied Physics at Columbia University, is part of a stellarator group that has received a Simons Mathematical and Physical Sciences Award of \$2M per year for four years. The Simons Foundation is particularly well known for funding applied mathematics and its applications to the fundamental sciences. Support for work as applied as the mathematical foundations of stellarators is noteworthy. The Foundation wants the title of the grant to clearly state the practical application, *Hidden Symmetries and Fusion Energy*.

The primary institutions participating in this project are Princeton University, Australian National University (ANU), Cornell University, Max-Planck Institute for Plasma Physics-Greifswald (IPP-Greifswald), New York Uni-

versity (NYU), Columbia University, University of Colorado-Boulder, University of Maryland (UMD), University of Texas at Austin (UT Austin), and University of Warwick (Warwick). **Chris Hegna** (APAM alumnus, Ph.D., 1989, Plasma Physics), the Harry D. Spangler Professor at the University of Wisconsin, Madison, is a collaborator on this grant. **Amitava Bhattacharjee** (APAM faculty 1984-1993), who is the head of the Theory Department at the Princeton Plasma Physics Laboratory (PPPL) and a professor at Princeton, will serve as the director of the overall project.

Steady-state fusion of ionized deuterium (D) and tritium (T) for power production occurs at a temperature of 10^8 K a density of 10^{20} ions/m³ with an energy loss time of a few seconds. The simultaneous achievement of all three conditions is the objective of the ITER tokamak, which is under construction by a unique international collaboration in France. In tokamaks, the plasma has an axisymmetric toroidal (doughnut) shape with the pressure of the DT plasma balanced by a magnetic field. In stellarators, the plasma is confined in a non-axisymmetric torus, which allows many issues of tokamaks to be circumvented. These issues include sudden, possibly destructive, terminations of the plasma, called disruptions, steady-state maintenance of the magnetic field, and the reliability of computations of large changes in the plasma design.

The non-axisymmetry of the stellarator makes mathematical descriptions far subtler but paradoxically greatly enhances the reliability of computational design. In tokamaks, the properties of the magnetic field are in large part determined by a current carried by the plasma itself, which makes the system strongly non-linear and difficult to computationally predict. In stellarators the properties of the magnetic field are dominated by external coils and approximately ten times as many spatial distributions of magnetic field are available for plasma control than in axisymmetry.

The trajectories both of the charged particles that form a fusion plasma and of the magnetic field lines are given by Hamilton's equations of classical mechanics. Exact toroidal symmetry gives invariants for both the particles and the field lines that allow a simple but rigorous treatment. The practical constraints associated with these invariants can be lost when the symmetry breaking is less than a part in a thousand; stellarators break axisymmetry by tens of percent.

Prof. Boozer, together with a German colleague, Jürgen Nührenberg, received the 2010 Alfvén prize of the European Physical Society "for the formulation and practical application of criteria allowing stellarators to have good fast-particle and neoclassical energy confinement." This work, which was based on the adiabatic invariants of classical mechanics and the hidden symmetries they imply, led to the design of a radically different billion-Euro-class stellarator in Germany, W7-X. W7-X recently began operations, but has already demonstrated that non-axisymmetric design can give highly reliable results despite its subtleties.

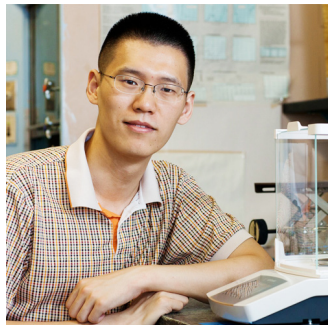
Although W7-X can demonstrate that much of the physics required for a fusion power plant can be achieved, it and the much smaller stellarator HSX at the University of Wisconsin need not be end points of computational design. Far more can be done with mathematics and simulations. It is this realization that led to the funding by the Simons Foundation.

Areas in which major advances are illustrated by recent work associated with Columbia University: (1) The coils for stellarators can be challenging, but Prof. Boozer has shown that all possible externally-produced spatial distributions of magnetic field in a torus can be ordered by their exponentially increasing difficulty of production. This allows stellarators to be optimized for less challenging coils by imposing a penalty for the use of fields that are difficult to produce. (2) The magnetic field lines should lie in toroidal surfaces across most of the plasma volume. Nevertheless, these surfaces should not be allowed to extend to the walls because their first point of contact would have an excessive heat load and would be inconsistent with the pumping of the plasma exhaust. Tubes of magnetic flux should carry the plasma from the plasma edge to appropriately localized locations on the walls, where divertor structures are located. A 2017 paper on which Prof. Boozer is a co-author shows that stellarator optimization for properties distinct from divertor requirements can give natural divertor solutions. With a colleague, Prof. Alkesh Punjabi of Hampton University, Prof. Boozer has developed a numerically efficient method based on concepts from Hamiltonian mechanics, cantori and turnstiles, for determining what types of divertor solutions are available and how they can be controlled. These and many other areas involving mathematics and simulation will be advanced by the Simons Foundation grant, *Hidden Symmetries and Fusion Energy*, which appears on the Simons Foundation website.

To read more about the grant, please see:

<https://www.simonsfoundation.org/collaborations/#mathematics-physical-sciences>

Looking Inside the Lithium Battery's Black Box



APAM material scientists, Yuan Yang & Qian Cheng, use Stimulated Raman Scattering microscopy to observe—for the first time—ions moving in liquid electrolyte; findings could lead to improving battery safety while also increasing next-generation energy storage

By Holly Evarts, originally published by Columbia Engineering

Lithium metal batteries hold tremendous promise for next-generation energy storage because the lithium metal negative electrode has 10 times more theoretical specific capacity than the graphite electrode used in commercial Li-ion batteries. It also has the most negative electrode potential among materials for lithium batteries, making it a perfect negative electrode. However, lithium is one of the most difficult materials to manipulate, due to its internal dendrite growth mechanism. This highly complex process is still not fully understood and can cause Li-ion batteries to occasionally short circuit, catch fire, or even explode.

Columbia University researchers announced that they have used Stimulated Raman Scattering (SRS) microscopy, a technique widely used in biomedical studies, to explore the mechanism behind dendrite growth in lithium batteries and, in so doing, have become the first team of material scientists to directly observe ion transport in electrolytes. They discovered a lithium deposition process that corresponds to three stages: no depletion, partial depletion (a previously unknown stage), and full depletion of lithium ions. They also found a feedback mechanism between lithium dendrite growth and heterogeneity of local ionic concentration that can be suppressed by artificial solid electrolyte interphase in the second and third stages. The paper, “Operando and three-dimensional visualization of anion depletion and lithium growth by stimulated raman scattering microscopy,” was published in *Nature Communications*.

“Using Stimulated Raman Scattering microscopy, which is fast enough to catch the quickly changing environment inside the electrolyte, we’ve been able to figure out not only why lithium dendrites form but also how to inhibit their growth,” says **Yuan Yang**, co-author of the study and assistant professor of materials science and engineering, department of applied physics and applied mathematics at Columbia Engineering. “Our results show that ion transport and inhomogeneous ionic concentration is critical to the formation of lithium dendrites on the lithium surface. The capability to visualize ion movement will help us improve the performance of all kinds of electrochemical devices—not just batteries, but also fuel cells and sensors.”

For this study, Yang collaborated with Wei Min, professor of chemistry at Columbia University and the study’s co-author. Ten years ago, Min developed SRS with colleagues as a tool to map chemical bonds in biological samples. Yang learned about the technique from Min’s website, and realized that SRS might be a valuable tool in his battery research.

“SRS is three to six orders of magnitude faster than conventional spontaneous Raman microscopy,” Yang noted. “With SRS, we can acquire a 3D image of resolution of 300 nm (1/300 of the diameter of human hair) in 10 seconds with a chemical resolution of approximately 10 mM, thus making it possible to image ion transport and distribution.”

The study revealed that there are three dynamic stages in the Li deposition process:

1. A slow and relatively uniform deposition of moss-like Li when ionic concentration is well above 0;
2. A mixed growth of mossy Li and dendrites; at this stage, Li⁺ depletion partially occurs near the electrode, and lithium dendrite protrusions start to appear; and
3. Dendrite growth after full depletion. When the surface ions are fully depleted, the lithium deposition will be dominated by “dendrite growth” and you will see the quick formation of lithium dendrites.

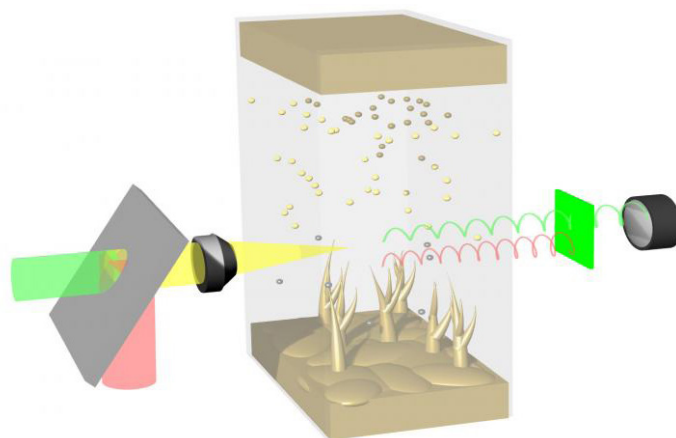
Stage 2 is a critical transitional point at which the heterogeneous Li⁺ depletion on the Li surface induces the lithium deposition to grow from “mossy lithium mode” to “dendrite lithium mode.” At this stage, two regions begin to appear: a dendrite region where lithium starts to deposit dendrites at a faster and faster rate, and a non-dendrite region where the lithium deposition slows down and even stops. These results are also consistent with predictions made from simulations carried out by Pennsylvania State University collaborators, Long-Qing Chen, professor of materials science and engineering, and his Ph.D. student Zhe Liu.

“The clever use of Stimulated Raman Scattering microscopy to visualize the electrolyte concentration within an operating electrode is a real breakthrough in the imaging of electrochemical systems,” says Martin Bazant, professor of chemical engineering and mathematics at the Massachusetts Institute of Technology. “In the case of lithium electrodeposition, the link between local salt depletion and dendritic growth was directly observed for the first time, with important implications for the design of safe, rechargeable metal batteries.”

Following up on their observations, the Columbia team then developed a method to inhibit dendrite growth by homogenizing the ionic concentration on the lithium surface at both stages 2 and 3.

“When we made the surface ion distribution uniform and mitigated the ionic heterogeneity by depositing an artificial solid electrolyte interface, we were able to suppress the dendrite formation,” says the study’s lead author **Qian Cheng**, a postdoctoral researcher in Yang’s lab. “This gives us a strategy to suppress dendrite growth and move on to improving the energy density of current batteries while developing next-generation energy storage.”

Min is very pleased that his SRS technique has become such a powerful tool for the materials and energy fields. “Without SRS microscopy, we would not have been able to see and validate such a clear correlation between the Li⁺ concentration and dendrite growth,” he says. “We are excited that more people in materials science will learn about this tool. Who knows what we will see next?”



A schematic illustration of a Li-Li symmetric cell under SRS imaging. Image credit: Qian Cheng/Columbia Engineering



Sobel: Hurricanes and Climate Change

Prof. Adam Sobel appeared on NBC's Today Show on Sept. 15 in the segment "Are hurricanes more powerful due to climate change?" and on Suzi Weissman's show, Beneath the Surface, on Sept. 24 on KPFK 90.7FM, Los Angeles, where he discussed the impact of Hurricane Florence on climate, politics, and public health. Sobel has also been featured in several articles, including "There's another weird tropical cyclone headed to the Middle East" by Brian Kahn on May 23 in the Science section of Earther.com; "The world has never seen a Category 6 hurricane, but the day may be coming" by David Fleshler on July 6 in the South Florida *Sun Sentinel*; "How global warming is turbocharging monster storms like Hurricane Florence" by Fred Guterl, Nina Godlewski, and M.L. Nestel on Sept. 25 in *Newsweek*; "Harvey, Florence, and the climate change connection" by Amanda Paulson on Sept. 27 in *The Christian Science Monitor*; "Climate change provided high octane fuel for Hurricane Michael" by Jeff Berardelli on Oct. 14 in *CBS News*; "Trump may not know what's behind warming, but scientists do" by Seth Borenstein on Oct. 15 in *AP News*; and "Climate scientists aren't in it for the money but for the truth" — a *CNN* op-ed published on Nov. 27.

Celebrating Faculty Excellence

APAM Department faculty members were recognized at the 2018 SEAS Faculty Excellence celebration this fall. Dean Mary Boyce welcomed new applied mathematics faculty members, **Kui Ren** and **Hadrien Montanelli**, and also recognized the achievements of several APAM professors.

Daniel Bienstock, who holds a joint appointment in IEOR and APAM, was named the Liu Family Professor of Industrial Engineering and Operations Research. **Simon Billinge**, Professor of Materials Science, won the 2018 Warren Award of the American Crystallography Association and was named the 2018 Busse Lecturer by the University of Wisconsin's School of Pharmacy. **Qiang Du**, the Fu Foundation Professor of Applied Mathematics, was elected a Fellow of the American Association for the Advancement of Science (AAAS). **Michal Lipson**, the Eugene Higgins Professor of Electrical Engineering (joint with APAM) won the 2019 IEEE Photonics Award and was named a "2017 Top 1% highly cited researcher in Physics" by Thomson-Reuters. **Gerald Navratil**, the Thomas Alva Professor of Applied Physics, was named the Chairman of the Board of Directors of Fusion Power Associates by the Professional Society of Fusion Research. **Michael Tippett**, Associate Professor of Applied Mathematics, received tenure. **Michael Weinstein**, Professor of Applied Mathematics and of Mathematics, was named SIAM's 2018 Martin Kruskal Prizer Lecturer. **Nanfeng Yu**, Associate Professor of Applied Physics, was recognized as the founder of MetaRe technology.

Qubits: How to Build a Quantum Computer

Undergraduate students of the applied physics majors participated in an undergraduate seminar titled "Qubits: How to Build a Quantum Computer." The seminar took place throughout the Fall semester and gave students a first hand look into the rapidly developing field of quantum computing. Applied physics students heard from **Professors Irving Herman**, **William Bailey**, **Alex Gaeta**, and **Michael Mauel** and also from Dr. Nick Bronn, an applied physicist in the Experimental Quantum Computing Group at IBM's T. J. Watson Research Center.

After learning how to make and manipulate states of quantum information, each member of the graduating class of 2018 prepared a lecture on a related topic of their choice. **Xin Chen** lectured on "Density functional theory's computational study of ferroelectricity;" **Christian Cruz Godoy** on "Quantum Biology: The origins of life explained through quantum mechanics;" **Shengyao Du** on "Verification of Quantum Computing;" **Roy Garcia** on "Trapping and Manipulating Ions in an Ion Trap Quantum Computer;" **Betty Hu** on "Josephson Junctions and SQUIDS;" **another** lectured on the topic of "Solving Laplace's equation and Schrodinger's equation;" **Rebecca Latto** on "Ghost imaging: a quantum optics topic;" and **Chengcheng Xin** presented a lecture on "Shor's algorithm." More information is available online at <http://sites.apam.columbia.edu/courses/apph4903x/>.

Field Report by Zane Martin, (continued from p. 2)

Despite being an atmospheric science student who typically works on numerical models, my role was to assist an oceanographic group out of Oregon State University, headed by chief scientist Jim Moum, gather data in the upper ocean. I spent many, many hours either dropping various probes or sensors off the ship or operating winches to pull them back up, and gained a new respect and understanding for the methodologies and challenge of gathering data in the field. Such work requires a unique blend of intense and meticulous planning and preparation, an ability to adapt on the fly and handle setbacks with humor and grace, a willingness to let curiosity sometimes dictate decisions, and above all else, a tenacity, a passion, and a desire to understand the natural world. Going outside my comfort zone and the neat confines sometimes placed on the discipline (between, say, oceanic or atmospheric research, or modelers and observationalists, or engineers and scientists) has helped give me a more well-rounded sense of my discipline as a whole and myself as a scientist. While it's a daunting experience to leave behind loved ones, familiarity, and the literal stability of dry land, I would highly recommend any student of atmospheric or oceanic science lucky enough to be afforded such an opportunity take advantage of it.

The experience left as large an impact on me personally as it did professionally. There is a sense of scope, both in terms of the size of the planet and the smallness of oneself, that is magnified and sharpened at sea, and the stark beauty of the natural environment—the texture and color and motion of the ocean and sky—was unlike anything I had experienced. The somewhat bruising work schedule (my shift was from 3 a.m. to 3 p.m. every day) nevertheless gave the days a sense of rhythm and routine, where meals with friends and colleagues became integral and eagerly anticipated parts of the day, and the sunrise, sunset, and stars at night became as familiar as the rooms and sounds of the ship. The friendships I forged aboard the Thompson are ones that will stay with me for life, born out of the close quarters and the common goals we shared. While I was very glad to return home, I think often and fondly of the time I spent aboard the Thompson and the people who were a part of the experience with me.



For more photos and information, see: <https://apam.columbia.edu/field-report-prof-adam-sobel-zane-martin>

Zhou Wins Early Career Award

Dr. Zhi Zhou, a former postdoc in the Computational Mathematics and Multiscale Modeling (CM3) group led by **Prof. Qiang Du**, is now a faculty member at Hong Kong Polytechnic University (PolyU) and has won a highly competitive Early Career Award from the Hong Kong Research Grant Council (RGC), the research funding agency of Hong Kong SAR government.

Quoting from the PolyU media release, "Being a young scholar, Dr. Zhou has already displayed great potential in pushing the frontier of knowledge through his dedication and enthusiasm in applied mathematics and numerical analysis. We are glad that we have established seamless research collaboration with universities in the United Kingdom and the United States through this project. We have no doubt that this early career award give positive encouragement to Dr. Zhou to strive for new heights in his research endeavour for the benefit of mankind."

Applied Physics Alumni Win APS Awards



Two outstanding APAM alumni, Seth Davidovits (right) and John C. Wright (left), received awards at the Annual Meeting of the American Physical Society (APS) Division of Plasma Physics, which took place from November 5-9, 2018 in Portland, OR.

Seth Davidovits (B.S. '10, Applied Physics), received the 2018 APS Marshall N. Rosenbluth Outstanding Doctoral Thesis Award which recognizes "exceptional young scientists who have performed original thesis work of outstanding scientific quality and achievement in the area of plasma physics."

Davidovits, who was the SEAS class of 2010 valedictorian, earned his Ph.D. in plasma physics from Princeton University. He held a Department of Energy (DOE) Computational Science Graduate Fellowship from 2010-2014 and was named a 2018 Frederick A. Howes Scholar in Computational Science. Davidovits is now a postdoctoral research fellow in the Department of Astrophysical Sciences at Princeton, where he holds a DOE Fusion Energy Sciences postdoctoral fellowship. He is a member of the American Physical Society and was chosen as a 2018 Howes Scholar. Dr. Davidovits continues to pursue the compression of turbulent plasma, with applications in inertial-confinement-fusion experiments, Z-pinch experiments, and astrophysical plasmas.

John C. Wright (B.S. '91, Applied Physics) is a recipient of a 2018 APS Landau-Spitzer Award "for experimental verification, through collaborative experiments, of a novel and highly efficient ion cyclotron resonance heating scenario for plasma heating and generation of energetic ions in magnetic fusion devices."

"Dr. Wright is a principal scientist at MIT's Plasma Science and Fusion Center. He received his B.S. in applied physics from Columbia University in 1991 and his Ph.D. in astrophysical sciences from Princeton University in 1998. His research is in developing and applying new capabilities in radio frequency simulations that contribute to improved understanding of the theory and experiments in wave-particle interactions in plasmas. These physics advances have been accompanied by contributions in computer science, including advanced parallel linear algebra algorithms, integrated multi-physics simulation frameworks, and a Web-based approach to workflow, data, and provenance tracking. He is active in several international and multi-institutional domestic collaborations focused on improving the understanding of radio frequency actuators in tokamaks and stellarators." (Originally published on the APS website)

Alumni Reports (continued from page 2)



Photo: Larry Lagin (B.S. '73, Applied Physics) retired four years ago as deputy program manager in charge of the engineering team for the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory (LLNL). Since graduating Columbia, Larry spent over a 40-year career as a scientist and engineer, more than 32 years of which devoted towards fusion energy research at Princeton University and Livermore. While an undergraduate applied physics major at Columbia, he also took many courses liberal arts courses including painting and sculpting. Since retiring, Larry continued his art studies at UC Berkeley Extension, and has recently completed a graduate certificate program in visual arts specializing in painting there. He now is a resident artist and has a small art studio at the Bothwell Arts Center in Livermore, and has begun selling his art at local art fairs.*

Hening Liu (M.S. '18, Materials Science & Engineering) writes: "After graduation, I mainly worked under Professor Chan's research group. I just got a job offer from the company ASML in San Jose, California. I am excited!"

Hande Öztürk (Ph.D. '15, Materials Science and Engineering), a former student of Prof. I.C. Noyan, is a tenure-track assistant professor in the Mechanical Engineering Department at Özyeğin University in Istanbul, Turkey.

Manju Prakash (Ph.D. '85, Plasma Physics) writes: "My graduate studies at Columbia University prepared me for a career in academia both as an innovative researcher and an innovative educator. Currently, I am teaching physics courses at Hofstra University, New York and involved in outreach activities in nanoscience at Brookhaven National Laboratory (BNL). As a researcher, I am investigating the nonlinear dynamics and turbulence effects in gravitational-wave forms within the framework of Einstein's General Relativity. These gravitational waves were observed by LIGO and led to the 2017 Nobel Prize in Physics. I am also associated with Fermi National laboratory in the g-2 experiment designed to resolve the experimental and theoretical discrepancy between the values of the anomalous magnetic moment of a muon."*

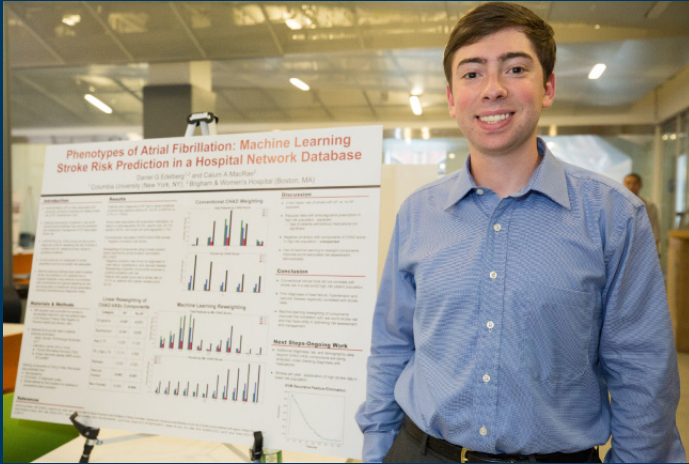
Edl Schamiloglu (B.S. '79, M.S.'81, Applied Physics) Distinguished Professor of Electrical and Computer Engineering, has been selected as associate dean for research and innovation at the University of New Mexico School of Engineering where he has been a faculty since 1988. He has also been appointed Special Assistant to the Provost for Laboratory Relations.*

Yuxiang Zhu (M.S. '18, Materials Science & Engineering) is pursuing a Ph.D. in Materials Science at the University of Houston.

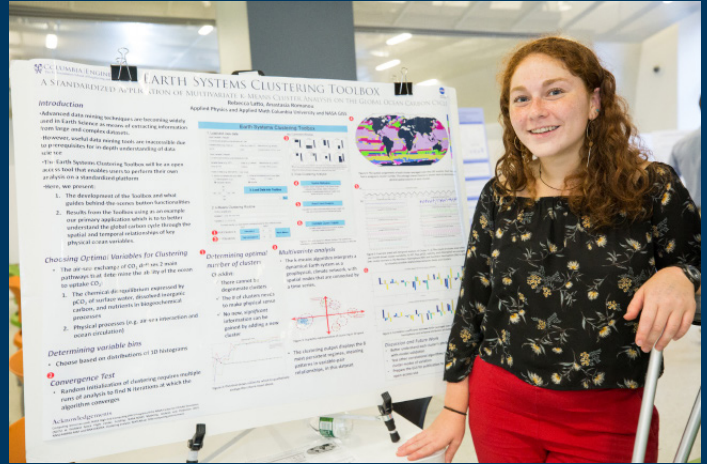
* originally published in *Columbia Engineering*

7th Annual SEAS Summer Research Symposium

APAM students participated in the 7th annual SEAS Summer Research Symposium on October 4, 2018, in Carleton Commons. The event, which was sponsored by the SEAS Undergraduate Student Affairs Office and the Columbia Undergraduate Scholars Program, featured over 30 undergraduate students who presented posters and talked to faculty and fellow students about their various summer research experiences.



Daniel Edelberg, Applied Mathematics '19
"Phenotypes of Atrial Fibrillation: Machine Learning Stroke Risk Prediction in a Hospital Network Database"




Rebecca Latto, Applied Physics '19
"Earth Systems k-Means Toolbox: A Standardized Application of Multivariate k-Means Cluster Analysis on the Global Ocean Carbon Cycle"

Contributing Authors: Applied Physics Society (APS) News; Allen Boozer; *Columbia Engineering*; *Columbia Magazine*; Holly Everts; Mindy Farabee; Gina Helfrich; Zane Martin; Michael Mauel; National Academies of Sciences, Engineering, and Medicines

Photos/Images: Applied Physics Society (APS) News; Eileen Barosso; Qian Cheng; *Columbia Engineering*; National Academies of Sciences, Engineering, and Medicines; Timothy Lee Photographers; Larry Lagin; Haixing Li; Jeffrey Schifman

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