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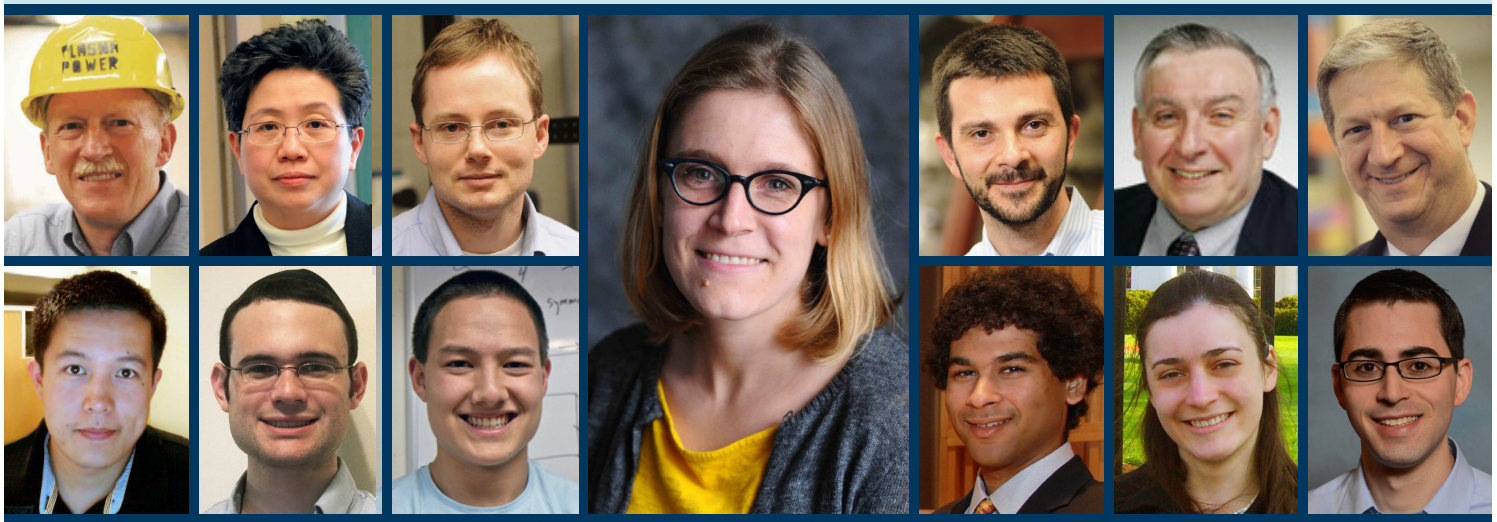
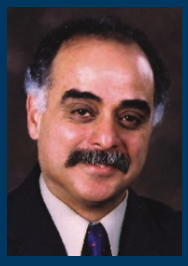
APAM NEWS

THE DEPARTMENT OF APPLIED PHYSICS & APPLIED MATHEMATICS

THE FU FOUNDATION SCHOOL OF ENGINEERING & APPLIED SCIENCE, COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK



APAM Award Winners: (large center photo) Tiffany Shaw, (small photos, top row) Michael Mauel, Siu-Wai Chan, Dirk Englund, Francesco Volpe, Ed Nickoloff, David Keyes, (bottom row) Nan Shi, Mordechai Kornbluth, Dillon Liu, Haris Durrani, Iva Vukicevic, and Eric Isaacs



Dear Alumni and Other Friends of APAM:

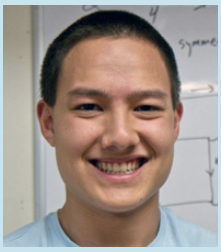
2012 has been yet another banner year for our department. Many of our faculty and students have been recognized with awards. Our Vice-Chair, Prof. Adam Sobel, who works on atmospheric and climate dynamics and tropical meteorology, has given interviews on all major networks about what can be done to predict storms like "Sandy". Our Plasma Physics Laboratory celebrated its golden (50th) anniversary. One of our seniors, Mr. Dillon Liu, SEAS '13, became the first Columbia Engineering student ever to receive a Marshall Scholarship. In the coming year we expect to work hard to achieve equivalent or greater success.

I would like to take this opportunity to express the thanks of the Department for all of the support we have received from alumni and friends in 2012. During the holiday season, our thoughts turn gratefully to those who have made our progress possible; and we wish all of the APAM family the *Best for the Holiday Season and a very Happy New Year!*

Best,

I. Cevdet Noyan
Chair, APAM

In This Issue



Liu Wins Marshall Scholarship by Holly Evarts (Originally published by *Columbia Engineering News*)

Dillon Liu, SEAS '13, is the first Columbia Engineering student ever to receive a prestigious Marshall Scholarship.

"I am incredibly honored and humbled to be named a Marshall Scholar. Even a week after getting the phone call, it still hasn't fully sunk in," says Liu, who is majoring in applied physics and minoring in applied math. "I'm really fortunate to have been able to study at Columbia and be surrounded by so many amazing peers, advisers, faculty members, and opportunities in general."

Liu has been interested in physics and mathematics for as long as he can remember—he left high school after 11th grade to come to Columbia Engineering because he'd run out of challenging math and physics classes to take. He thinks physics and math "are really beautiful and mysterious, as well as powerful enough to encompass reality."

After graduation, Liu will attend the University of Oxford to earn a DPhil in theoretical physics. He plans to focus on condensed matter physics, the study of phases of matter, like solids and liquids, at length scales larger than atoms, but still small enough so that quantum mechanics, electromagnetism, and statistical physics are all interacting. He's especially interested in learning more about topological quantum computing and figuring out how to make it a reality.

Quantum computing would make solving certain problems much faster, challenges like factoring large numbers, critical in modern cryptography, or modeling very complicated systems, from designing better drugs to simulating climate change. Topological quantum computing, explains Liu, is a variant of quantum computing that would be resistant to decoherence, one of the main problems with quantum computing today.

"Topological quantum computing will provide hardware that is vastly more powerful than what exists today," Liu says. "Pursuing theoretical condensed matter and topological quantum computing at Oxford will quench my thirst for elegant physics, while also fulfilling my commitment to improving our world via applications to biology, neuroscience, economics, chemistry, climate science, and more."

Liu has worked for the Office of Residential Programs for 3 years and is the community advisor for East Campus Residence Hall. He is also a teaching assistant for the Departments of Physics and Mathematics, and hopes to continue being involved with science education and outreach in the UK.

A New Jersey native, Liu has never traveled out of the US, so he's very excited about going to the UK. He says that studying at Oxford on a Marshall Scholarship will help him pursue his studies in a way that he hopes will be "fruitful for solving problems in many different fields. My passion for physics runs parallel with a passion for making the world a better place, and I feel that the Marshall program really suits that alignment."

Durrani Wins APS Scholarship

Haris Durrani won an American Physics Society Scholarship for Minority Undergraduate Physics Majors.

Haris Durrani is an Applied Physics major and one of 12 Egleston Scholars in the Class of 2015. His advisor, Professor Michael Mauel, has been a huge help to him for the past few years. Since last March, Durrani has been working in Professor Peter Allen's Robotics Lab on a brain-controlled mobile manipulator project for people with full-body disabilities, part of a recently awarded five-year National Science Foundation grant project in assistive robotics. The team was recently named a Finalist for the 2012-2013 Cornell Cup USA presented by Intel. Durrani and his teammates will represent Columbia University at the national competition in Walt Disney World this spring.

Durrani sees robotics as an extension of his passion for applied physics—after all, medieval Arabs saw mechanical engineering as applied math! Since childhood, he competed in Dean Kamen's FIRST robotics programs. In high school, he founded and captained his local FIRST Tech Challenge (FTC) robotics team, which won 2nd, 3rd, and, in his senior year, 1st Place at the FTC World Championships. As a physics and robotics enthusiast, he is intrigued by the intersections between the fields as relates to applications in aerospace, in particular the monitoring and remediation of space debris.

An avid writer, Durrani is a fan of Columbia alumnus Dr. Isaac Asimov, who demonstrated in his life's work as a writer and biochemist the importance of an interdisciplinary worldview. Durrani is the youngest writer to be a two-time Semifinalist in the L. Ron Hubbard Writers of the Future Contest, which is judged by both prestigious writers and scientists. His work addresses environmental engineering, the physics of space debris, photosynthetic coherence, quantum evolution, and the near future of aerospace. He also was selected to work for Scholastic, Inc. and the Scholastic Art & Writing Awards as Editor for *The Best Teen Writing of 2012*, available on Amazon soon. Durrani helped develop a new award for the Scholastic Art & Writing Awards, "The Future New," sponsored by the engineering company 3D Systems. "The Future New" seeks to recognize works of art and writing which transcend creative boundaries by using cutting-edge elements of science, technology, engineering, and mathematics. Durrani is also a minor in the Department of Middle Eastern, South Asian, and African Studies, focusing on the cultural history of science.

Student Field Trips

Prof. Siu-Wai Chan and a group of twenty Materials Science and Engineering students visited the American Museum of Natural History on September 7. The event was sponsored by Columbia's Material Advantage and MRS Student Chapters.

On October 12, eleven medical physics M.S. students and one applied physics senior enjoyed an all-day visit at Indian Point Nuclear Power Plant in Buchanan, NY. Michael Slobodien, from Entergy Nuclear, served as their host.

Graduate Student Fellowships

Edward Chen was awarded a 2012 NASA Space Technology Research Fellowship. He is a third-year graduate student working in the Quantum Photonics Group with Prof. Dirk Englund. He hopes to help nurture key quantum computation or biological sensing technologies that will play a critical for deeper scientific investigations in the coming century.

Eric Isaacs was awarded a 2012 DOE Computational Science Graduate Fellowship. It provides up to four years of support to students pursuing a doctoral degree in areas of study that focus on the use of high performance computing technology to solve complex problems in science and engineering. He is a Ph.D. candidate in Solid State Physics working with Prof. Chris Marianetti to compute the properties of complex materials from first principles, and his research focuses on designing materials for renewable energy applications such as photovoltaics and lithium ion batteries. He received a B.A. in Physics from the University of California, Berkeley and worked as a research assistant at the Lawrence Berkeley National Laboratory.

Mordechai Kornbluth won a Presidential Fellowship. He is a first-year M.S./Ph.D. track student, focusing on solid-state and optical physics. He received his B.A. with honors from Yeshiva University, with a major in physics and minors in mathematics and (just for fun) Semitic languages. Before Yeshiva, he studied Talmud at Yeshivat Kerem B'Yavneh in Israel. As an undergraduate at Yeshiva, he was awarded the Kressel Research Scholarship and an Honors Program scholarship. His past research has encompassed a variety of topics, including applied computer science, nanoscale friction, plasma physics, quantum mechanics, and nanoparticle heating. These led to an undergraduate Honors Thesis, two publications, and two more papers in progress. In the long run, Mordechai anticipates a career in physics research, probably in industry, exploring physics that can be applied practically.

Nan Shi was awarded a Columbia Optics and Quantum Electronics IGERT Fellowship. He is a Ph.D. candidate in Materials Science and Engineering who works with Prof. Chee Wei Wong.

Neil Tandon won the 2012 Bakhmeteff Award. He is a Ph.D. candidate in Applied Mathematics who works with Prof. Lorenzo Polvani.

Iva Vukicevic, a current Ph.D. candidate in Applied Mathematics, was awarded a Columbia Optics and Quantum Electronics IGERT Fellowship. Iva graduated from NYU with an honors degree in Mathematics and a minor in French Language and Literature. She works with Prof. Michael Weinstein on various problems involving partial differential equations. In the past couple of years they have focused on studying the mathematical properties of waves traveling through microstructures by analyzing the Schroedinger equation with spatially localized and highly oscillatory potentials. This particular problem can be interpreted as a quantum particle in a rapidly varying inhomogeneous medium or, in the paraxial approximation of the wave function, as guided and propagating waves in a dielectric medium. Currently they are also considering wave propagation through a background periodic medium with a spatially localized highly oscillatory perturbation. Upon graduation, her goal is to apply the skills that she has learned in an R&D setting.

Continuing graduate fellowship award winners include: **Arunabh Batra**, NSF Fellow; **Philip Chuang,** Learning through Ecology and Environmental Field Studies National Science Foundation GK-12 Fellowship; **John Dwyer,** NASA Fellowship; and **Clara Orbe,** NASA Fellowship.

Alumni News

Xuan Gao (Ph.D. '03, Materials Science and Engineering / '04 Simon Prize Winner) is currently an assistant professor of Physics at Case Western Reserve University. He writes, "At the beginning of this year, I received a CAREER Award from NSF. I was also awarded the Outstanding Young Researcher Award from the International Organization of Chinese Physicists and Astronomers, a prestigious recognition given to a young physicist/astronomer of Chinese ethnicity working in North America, Europe, or any other region outside Asia."

The following alumni updates are from *Columbia Engineering*, Fall 2012

Michael Hahn (Ph.D. '09, Plasma Physics) was selected as one of the postdoctoral winners of the New York Academy of Sciences's 2012 Blavatnik Awards for Young Scientists Competition. He received the award for his work using spectroscopy to constrain the mechanisms by which energy is carried into the solar corona, heating it to over a million degrees and driving the solar wind. Michael is currently an associate research scientist in the Columbia's Astrophysics Laboratory.

Tracy Hammond (B.S. '97, Applied Mathematics) received tenure last May and is now an associate professor at Texas A&M University. She was also recently awarded the 2011-2012 College of Engineering Faculty Fellow Award; specifically, she is the Charles H. Barclay, Jr. '45 Faculty Fellow.

In 2010, **Irina Kalish** (M.S./CVN '07, Materials Science and Engineering) and her family moved from Michigan to Washington, DC, following her husband's enrollment at Georgetown's law school. She left General Motors and is now a patent examiner with the US Patent and Trademark office, where she reviews patent applications in the area of single crystal growth.

In 1988, **Edl Schamiloglu** (M.S. '81, Plasma Physics) received his Ph.D. from Cornell University. This year, he is celebrating his 25th year anniversary as a professor of electrical engineering at the University of New Mexico. He was just awarded his third MURI grant and his sixth DURIP (Defense University Research Infrastructure Program) grant. Edl's daughter, Selin is currently a sophomore at Columbia College.

After graduating, **Di-Shi (Darren) Su** (M.S. '00, Materials Science and Engineering) joined TSMC (Taiwan Semiconductor Manufacturing Company) as the process integration engineering in wafer process development. He successfully qualified the first copper line in 0.13um poly/gate process. Since 2006, Darren has been a manager of foundry execution at LSI Corporation. He now has more than 12 years of experience in the semiconductor field and water fabrication with an emphasis in wafer process/yield improvement, reliability and SPICE evaluations, product-based performance optimization, and customer quality solutions. He was married in 2006 and currently lives in HsinChu with his wife, Kris Chen, and their 2 children.

While completing his M.S. degree, **Kyle Teamey** (M.S./CVN '12, Materials Science & Engineering) was also running a start-up, Liquid Light. His company is developing a technology for converting carbon dioxide to industrial chemicals. APAM Ph.D. candidate, **Theodore Kramer** (M.S. '08, M.Phil. '11) is one of Liquid Light's employees.

Alfredo Tognoni (M.S./CVN '10, Materials Science and Engineering) lives in Zurich and is a senior consultant/manager at Holcim, a world's leading supplier of cement, concrete, and aggregates.

Undergraduate Research Symposium: APAM students, Haris Durrani (AP), Julian Haimovich (AM), Prashanta Kharel (AP), Veronica Reynolds (MSE), and Kathleen Tatem (AP), participated in the Undergraduate Summer Research Symposium and Fair on September 27, hosted by the Office of Undergraduate Student Affairs and Global Programs and the Engineering Student Council. Read the abstracts and see photos online at: apam.columbia.edu/undergraduate-research-symposium

Shaw Wins Packard Fellowship

Tiffany Shaw, assistant professor of applied mathematics, has been awarded a Packard Fellowship in Science and Engineering, a prestigious honor given to a group of the most promising and innovative researchers who are at the beginning stages of their careers. Shaw, who has a joint appointment in Columbia's Department of Earth and Environmental Science, is one of 16 fellows named who will each receive an unrestricted grant of $875,000, distributed over five years.

Shaw studies the fluid dynamics of Earth's weather and climate, using a combination of theory, observations, and numerical models. Her research focuses on understanding how moisture is transported and how it interacts with large-scale flow patterns, such as the summer monsoon, and the impact of climate change.

"Receiving the Packard Fellowship is truly a great honor," says Shaw. "I am very grateful to the Packard Foundation for their support. [This] will provide me with a unique opportunity to pursue big and bold ideas that I might not otherwise pursue."

Shaw has always had a keen interest in the atmosphere, having grown up in a family of pilots and training to become a pilot herself. She recognized early on that atmospheric science combines the atmosphere, physics, and math—all subjects she was genuinely interested in and excelled in as a student.

Shaw is currently developing a theoretical basis for turbulent moisture transport. She hopes this can be used to understand the dynamics of the summer monsoon and their response to climate change.

"We are extremely pleased that Professor Shaw has been recognized as a talented young faculty member," says Donald Goldfarb, Interim Dean of Columbia Engineering and Alexander and Hermine Avanessians Professor of Industrial Engineering and Operations Research. "In giving her this significant honor, the Packard Foundation's Advisory Panel noted that her research has the ability to profoundly impact the lives of her students and all of us in the world at large. This is yet another confirmation of the superb quality of our faculty."

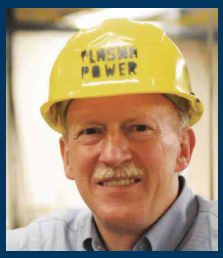
The Packard Fellowship in Science and Engineering is considered one of the most highly prized awards given to junior faculty conducting innovative research. The fellowship was established in 1988 to allow the nation's most promising researchers to pursue science and engineering research early in their careers with few funding restrictions.

The figure above is of the weather-in-a-tank apparatus, which Tiffany Shaw uses to demonstrate atmospheric phenomena such as fronts, convection, the general circulation of the atmosphere, flow over a barrier and the flow in a hurricane. In the experiment illustrated here, Shaw has combined the two main ingredients that control the general circulation of the atmosphere, namely Earth's rotation and differential heating (warm equator, cold pole). The ice-water bath at the center mimics Earth's 'pole' and the water outside is at room temperature with the outermost region mimicking the warm 'equator.' The tank is slowly rotating creating a laboratory analog of the circulation in the tropical atmosphere. The purple dye shows the movement of water at the bottom of the tank in a southwest direction toward the 'equator,' which is consistent with the earth's trade winds. The green dye illustrates the movement of water in the interior, which forms an annular pattern. The dots on the surface show the movement of surface water, which rotates in a counter-clockwise direction and moves faster toward the pole.

Each year, the Foundation invites the presidents of 50 universities to nominate two early-career professors each from their institutions whose research is in the natural and physical sciences or engineering. An advisory panel of distinguished scientists and engineers review nominations and select the new class of fellows.

Shaw is the third professor in the Department of Applied Physics and Applied Mathematics to receive this honor, following Associate Professor **Latha Venkataraman,** who was selected a Packard Fellow in 2008, and Professor **Adam Sobel**, who received the fellowship in 2000. Six additional Columbians have received the fellowship, including three other SEAS faculty members: Ruben-Viele Professor Jingyue Ju of the Department of Chemical Engineering and T.C. Chang Professor Shree Nayar and Professor Kenneth Ross, both of the Computer Science Department.

The Packard Foundation, based in Los Altos, CA, was created by David Packard, co-founder of the Hewlett-Packard Company, and his wife, Lucille. This fellowship program arose out of David Packard's commitment to strengthen university-based science and engineering programs in recognition that the success of Hewlett-Packard derived in large measure from the research and development in university laboratories.



Mauel Receives $1.2 million, 3-year Grant (Columbia Engineering News)

Prof. Michael Mauel and scientists from MIT have received a $1.2 million, 3-year grant from the National Science Foundation and the U.S. Department of Energy Office of Fusion Energy Sciences to jointly develop and test models of space weather.

"We're really excited about this funding," says Mauel. "With this grant, we'll be able to test our understanding of how space plasma swirls and mixes by making careful measurements of hot plasma dynamics in the lab." Read more about the project at: engineering.columbia.edu/columbia-engineering-mit-new-joint-project-explore-space-weather

Faculty Updates

Prof. Guillaume Bal was featured in the article "Probing the Deep Mathematics of Nonlinear Inverse Problems" in the June 2012 issue of *SIAM News*. The article highlights his work on hybrid inverse problems, which lead to the Calderon Prize he received in 2011.

Prof. Simon Billinge was featured in *Columbia Engineering News*," New Technique Uses Electrons to Map Nanoparticle Atomic Structures." Billinge leads "a Brookhaven/ Columbia team of scientists, in collaboration with researchers at DOE's Argonne National Lab and Northwestern University; they have been working to develop nanocrystallography techniques that can be used in more ordinary science settings. They have shown how a powerful method called atomic pair distribution function (PDF) analysis can be carried out using a transmission electron microscope (TEM) — an instrument found in many chemistry and materials science laboratories. Their findings were published in the May 2012 issue of *Zeitschrift fur Kristallographie."*

Prof. Allen Boozer was featured in the Princeton Plasma Physics Laboratory press release "What a Cup of Coffee Tells Scientists about Solar Storms: A new theory asserts that a key astrophysical process parallels what happens at the breakfast table." His research was published in the September issue of *Physics of Plasmas*.

Prof. Siu-Wai Chan received the 2012 Avanessians Diversity Award. The award honors a faculty member whose actions encourage students from diverse backgrounds to become part of the engineering academic community. Chan, who has served as chair and member of several diversity committees in SEAS, was selected for being particularly instrumental in advising female students.

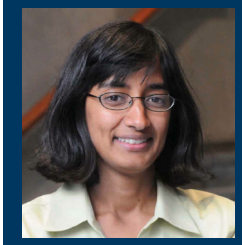
Dirk Englund, Assistant Professor of electrical engineering and of applied physics, won a DARPA (Defense Advanced Research Projects Agency) Young Faculty Award (YFA). He will receive $300,000 over two years to work on chip-integrated timing and inertial measurements.

Prof. Gerald Navratil hosted the 17th Workshop on MHD Stability Control and Joint US-Japan Workshop at Columbia University from Nov. 5-7. The series is organized jointly by Columbia, General Atomics, Princeton Plasma Physics Laboratory, and the University of Wisconsin.

Prof. Adam Sobel recently appeared on PBS Nova's "Inside the Megastorm" on Hurricane Sandy. Other recent media appearances included NBC Nightly News, ABC 20/20, Fox TV, The Weather Channel, Brian Lehrer Show, Channel 13 MetroFocus, All Things Considered, the Leonard Lopate Show, and the Forum with Michael Krasny.

Prof. Francesco Volpe won the 2012 Torkil Jensen Award. This award, given by General Atomics Fusion Energy Research, supports Volpe's research on cancer therapy with fusion neutrons, an experimental topic outside the areas usually covered by the DIII-D experimental program.

Read **Prof. Chris Wiggins's** article, "Applying Big Data Approaches to Biological Problems," in the special Fall 2012 issue of *Columbia Engineering*. Wiggins, an associate professor of applied mathematics, is a member of the executive committee of Columbia's newly created Institute for Data Sciences and Engineering.



Unraveling Intricate Interactions, One Molecule at a Time

by Holly Evarts (Originally published by *Columbia Engineering News*)

A team of researchers led by Associate Professor Latha Venkataraman has succeeded in performing the first quantitative characterization of van der Waals interactions at metal/organic interfaces at the single-molecule level.

In a study published online in *Nature Materials*, the team has shown the existence of two distinct binding regimes in gold-molecule-gold single-molecule junctions, using molecules containing nitrogen atoms at their extremities that are attracted to gold surfaces. While one binding mechanism is characterized by chemical interactions between the specific nitrogen and gold atoms, the other is dominated by van der Waals interactions between the molecule and the gold surface.

The team's research was in collaboration with Mark Hybertsen from the Center for Functional Nanomaterials at the U.S. Department of Energy's Brookhaven National Laboratory.

"A detailed understanding of van der Waals interactions is a key step towards design of organic electronic devices," says Sriharsha Aradhya, the study's lead author and a Ph.D. candidate working with Venkataraman. "Apart from the fundamental importance of these measurements, we are also excited about its applications. Understanding the effects of van der Waals interactions is tremendously important for creating and optimizing devices with organic building-blocks".

"Many proposals for future photovoltaic and flexible electronic devices are based on organic molecules because they are cost-effective," Venkataraman adds, **(continued on page 6)**

Adjunct & Affiliated Faculty Updates

David Keyes, Adjunct Professor, was named a member of the inaugural class of Fellows of the American Mathematical Society (AMS). The program recognizes members who have made outstanding contributions to the creation, exposition, advancement, communication, and utilization of mathematics.

Edward Nickoloff received the 2012 "Lifetime Achievement Award" from the Upstate New York Chapter of The American Association of Physicists in Medicine (AAPM). Nickoloff, Professor of Radiology and Chief Hospital Physicist at Columbia University and New York-Presbyterian Hospital, is a member of the Medical Physics faculty. Lawrence Rothenberg, also a member of the Medical Physics faculty, received this award in 2008.

Matthew Putman, Adjunct Assistant Professor of materials science and engineering and founder and CEO of Nanotronics Imaging, presented a TEDx Talk on Nanotechnology. Watch the video online at: **apam.columbia.edu/putman-presents-tedx-talk**

Steven Sabbagh, Adjunct Professor, presented the NSTX Physics overview talk at the 2012 International Atomic Energy Agency Fusion Energy Conference. He was also featured in the APS press release "Fusion Plasma Works Best Just Where You Least Expect It: Scientists measure a surprising increase in fusion plasma stability at high performance."

Plasma Physics Lab 50th Anniversary Celebration

Faculty, staff, students, alumni, and friends gathered on April 26, 2012 for the Plasma Physics Laboratory 50th Anniversary Celebration, which included some of the founding faculty of the plasma lab including Robert (Bob) Gross, C.K. (John Chu), and Amiya Sen.

The day began with a series of technical and personal reflections in Davis Auditorium. Event coordinators, Professors Gerald Navratil and Michael Mauel, welcomed the attendees and gave a brief overview of the 50-year timeline. Professor and Dean *Emeritus*, Bob Gross, joined in via Skype and spoke about the early days of the lab. Plasma physics alumni then took the stage to share their experiences and memories over each decade. Speakers included Don Spero (Ph.D. '68), Jay Kesner (Ph.D. '70), Don McNeil (Ph.D. '73), Richard Post (Ph.D. '73), Steve Paul (Ph.D. '81), Steve Sabbagh (Ph.D. '90), Dave Gates (Ph.D. '94), David Maurer (Ph.D. '00), and Oksana Katsuro-Hopkins (Ph.D. '07). New APAM plasma faculty, Andrew Cole and Francesco Volpe, concluded the talks by giving brief presentations on their current research and plans for the future.

The talks were immediately followed by a tour of the Plasma Physics Lab and a reception in the APAM Department. The day ended with dinner at Columbia's Faculty House, where the highlight of the evening was the presentation (via Skype) of a 50-year photo history of the lab with messages signed by Plasma Lab alumni, followed by more personal reflections and fond memories from various guests. **More photos are available on the back page and online at apam.columbia.edu/plasma-physics-lab-50th-anniversary-celebration**

Unraveling Intricate Interactions, One Molecule at a Time (continued from p. 5)

"and scientists need to have a deeper understanding of these van der Waals interactions. Our work opens up the possibility of measuring and characterizing the strength of interaction between a variety of molecules and metallic surfaces a single-molecule at a time."

The forces of attraction between atoms and molecules come in different varieties and strengths, Aradhya explains. One of the most ubiquitous forms of attraction in nature is the van der Waals force. In contrast to specific interactions arising from bonding between atoms, van der Waals interactions represent non-specific interactions with subtler underpinnings. While originally intended to explain the apparent continuity between gaseous and liquid phases of matter, these forces have come to be recognized as an important aspect in answering such diverse questions as how does water boil inside a pressure cooker? How are geckos able to climb walls vertically? Or how can you control the organization of molecules for an organic LED smartphone display screen?

As devices like the latter become increasingly common, there has been a good deal of renewed interest in van der Waals interactions, known to lie at the heart of the structure and functionality in such devices. These interactions between organic molecules and metallic surfaces are central to a diverse range of phenomena such as catalysis of reactions, molecular electronic architectures, and molecular self-assembly in nature and engineered material. However, van der Waals interactions remain challenging to characterize directly at the fundamental, single-molecule level both in experiments and in theoretical calculations.

For this Columbia Engineering study, the researchers used their custom-built conducting atomic force microscope to make simultaneous measurements of force and conductance in single-molecule junctions. They combined their measurements with theoretical calculations and simulations, carried out in collaboration with Hybertsen at Brookhaven, in order to provide a unique quantitative measurement of the relative importance of specific and non-specific interactions at the single-molecule level, in a regime where both are comparable.

"In simple terms, conductance of the junction acts as a fingerprint of the structure," explains Aradhya. "At the same time, the measured force—especially the force needed to rupture the junction—can be used to deduce its mechanical properties."

While similar studies have been reported by a few research groups around the world, such precise studies have typically required the measurements to be carried out at very low temperatures and in high vacuum. Venkataraman's and Aradhya's experimental setup was optimized for very high sensitivities even at room temperature and ambient conditions. This allowed the team to perform thousands of individual single-molecule measurements, resulting in statistically robust results. The researchers then performed extensive density functional theory calculations to help them understand the mechanisms underlying their measurements.

"Taken together, this unique combination of our state-of-the-art experimental and theoretical efforts has resulted in this major progress in quantifying van der Waals interactions," Venkataraman says.

Future research, she adds, will include trying to control the interplay of van der Waals non-specific interactions with chemical modifications, in order to "achieve interesting functionality at the single-molecule level, which is an active area of research in our lab."

"We're very excited about this," she says, "as our efforts towards developing a reliable way to simultaneously measure force and conductance are yielding exciting new opportunities to relate structure, mechanics, and electronics at the single-molecule level."

As Hybertsen notes, "The development and validation of efficient theoretical models for the van der Waals interaction is still in its nascent stage. We expect that our work will also have an impact on this theoretical effort underway among many research groups around the globe to develop accurate treatment of van der Waals interactions."

The experiments were conceived by Aradhya and Venkataraman. The experimental tools and large dataset analysis techniques necessary for this study were developed by Aradhya, along with Michael Frei, a recent graduate of Venkataraman's lab. The modeling of the interactions and the calculations were conceived and executed by Hybertsen at Brookhaven.

This research was funded primarily by NSF (Career Award CHE-07-44185) and the Packard Foundation. The computational efforts at the Center for Functional Nanomaterials at Brookhaven National Laboratory were supported by the U.S. Department of Energy's Office of Science.

In Memoriam: Stephen F. Paul, Ph.D. '81

"Stephen F. Paul, a PPPL Physicist for 30 Years, Dies at Age 58" by Jeanne Jackson DeVoe, with contributions from Michael Mauel and Michael Weinstein

Stephen F. Paul (1953-2012), a principal research physicist at Princeton Plasma Physics Laboratory who worked on many projects over a 30-year career, from the Poloidal Divertor Experiment (PDX) in the early 1980s to, most recently, the National Spherical Torus Experiment (NSTX), died on Saturday, Sept. 15, of pancreatic cancer. He was 58.

APAM alumnus, Philip Efthimion (Ph.D. '77, Plasma Physics), Head of PPPL's Plasma Science and Technology Department, said Paul would be remembered for bringing "enormous energy and enthusiasm to whatever he did." He noted that Paul was collaborating with Columbia University while he was getting chemotherapy treatments. "The illness couldn't diminish his spirit or his passion for his research and work," Efthimion said.

Paul grew up in Cranford, N.J. and lived in Princeton for 20 years before moving to West Orange about a decade ago.

After earning a bachelor's degree in applied physics from Cornell University, he went on to earn his Ph.D. in plasma physics (under the supervision of Prof. Bob Gross) from Columbia University in 1981, the year that he joined PPPL. He worked on the S1 Spheromak and later worked on the PDX, the PBXM (the Princeton Beta Experiment Modification) and the TFTR (Tokamak Test Fusion Reactor). He worked on a diagnostic to measure the velocity of the plasma on the NSTX and was working on plasma spectroscopy and radiated power measurements before NSTX shut down for an upgrade in November of 2011.

"He was fully involved in fusion and very passionate about what we do here," said Brent Stratton, head, Diagnostic Development Division, who worked with Paul since the late 1980s.

Paul's specialty was plasma spectroscopy, which involved looking at the radiation emitted by ions in the plasma to find impurities that could interfere with the plasma's performance in fusion experiments.

"He was one of the brightest, best informed and thoughtful persons about a vast area of knowledge in the Lab," said Lewis Meixler, head, Technology Transfer and Applications Research.

While working at PPPL, Paul spent his time off developing an alternative motor fuel made from organic material found in municipal and agricultural waste, such as food waste, paper, leaves and grass clippings. He named it P-Fuel to accentuate his link with Princeton University. The material was patented in 1997 by Princeton University. Paul established a company, The Trenton Fuel Works, based in an abandoned municipal waste processing plant in Trenton, N.J., to produce the fuel. The company is still in operation and is being run by Paul's partner.

Despite being ill for the past two years, Paul managed to collaborate with Columbia University's High-beta Tokamak program on optical diagnostics as part of PPPL's Off- Site University Research Program. "Steve was an outstanding scientist and very much loved by everyone in the plasma lab," said Michael Mauel, Professor of Applied Physics at Columbia University, and co-head Columbia's tokamak program. "Steve patiently guided our graduate students and helped several design and install a new plasma diagnostics."

"Steve was a close personal friend for over 15 years," said Michael Weinstein, Professor of Applied Mathematics at Columbia University. "I feel lucky to have known him. He was a kind, generous, warm and caring individual. In addition to being a superb scientist, he had a vast and deep knowledge of diverse fields. Steve so enjoyed engaging in discussion over important issues and I've never met anyone more intellectually honest."

Paul was also very active in his synagogue, B'Nai Shalom, in West Orange. He was devoted to his family and is survived by his wife Gilda, of West Orange, who works in Princeton University's Office of the Dean of the Faculty, and three grown children: Jordana Paul, Aaron Paul and Rachel Paul Yogev, along with her husband, Dean.

Funeral services were on Sept. 16. Donations in Paul's name can be made to Memorial-Sloan Kettering Cancer Center to support the pancreatic cancer research of Dr. Eileen O'Reilly or to the American Technion Society to support the Technion-Israel Institute of Technology. The family would welcome cards and emails, which can be sent to gilda@princeton.edu or to 61 Howell Drive, West Orange, N.J. 07052.

Postdoc News: Daehyun Kim & Sarbajit Banerjee

Daehyun Kim (a former postdoc in Adam Sobel's group) won the 2012 James R. Holton Award from the American Geophysical Union (AGU) for "outstanding scientific research and accomplishments of early-career scientists in the field." Dr. Kim's research focuses on diagnosis, modeling and parameterization of tropical convection, with a specialization in intraseasonal variability and the Madden-Julian oscillation.

Sarbajit Banerjee (a former APAM postdoc in Prof. Irving Herman's group) was selected by MIT Technology Review as one of 2012's "35 Innovators Under 35." Dr. Banerjee is currently an Associate Professor in the Department of Chemistry at the University at Buffalo, The State University of New York.

Staff News: Dina Amin, the APAM Department Administrator, received the Egleston Distinguished Administrator Award on May 25, 2012. The award, presented by the Fu Foundation School of Engineering and Applied Science, was given "in recognition of exceptional achievement, leadership and contributions to the excellence of the School." Dina joined the APAM staff in July 2008 after serving as the Assistant Director of the Center for Iranian Studies. She was inducted into the Columbia 25-Year Club in Fall 2009.









Photos from the Plasma Physics Laboratory 50th Anniversary Celebration on April 26, 2012

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