NanoMeter

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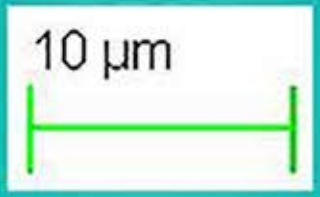
see page six for details!

The newsletter of the
Cornell NanoScale Facility
Winter 2018 • Volume 27 • Issue 2



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CNF Acknowledgements in Your Publications —

Note Change in Grant Number to "NNCI"

The National Science Foundation is beginning to count only properly acknowledged publications when considering our funding. So PLEASE use this language for ALL work product (publications, presentations, posters, patents) that benefits from CNF-related research.

This work was performed in part at the Cornell NanoScale Science & Technology Facility (CNF), a member of the National Nanotechnology Coordinated Infrastructure (NNCI), which is supported by the National Science Foundation (Grant NNCI-1542081).

If space is a concern, this can be shortened to:

This work was performed in part at Cornell NanoScale Facility (CNF), an NNCI member supported by NSF Grant NNCI-1542081.

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The NanoMeter cover and background image is from CNF Project # 2065-11 — the work of Prof. Jan Lammerding and Aaron Windsor, CNF staff — and used with their permission. The full report is online at http://www.cnf.cornell.edu/cnf_2018ra.html — "Design and Application of Microfluidic Devices to Study Cell Migration in Confined Environments"; page 30.

Most photographs in this issue were provided by the author or researcher. The director and annual meeting photos were taken by University Photography. Remaining photographs were taken by Don Tennant, unless otherwise noted.

The NanoMeter is formatted by Melanie-Claire Mallison. She welcomes your comments and corrections via email to mallison@cnf.cornell.edu. The NanoMeter is printed on 30% post-consumer content paper using soy based inks. Please reduce, reuse, and recycle!

Welcome to the 2018 Winter Edition of the CNF NanoMeter

We are very happy to introduce the latest edition of the Nanometer. This year (2018) has been an eventful one. We continue to implement our strategic plan for the next few years; including our new focus on heterointegration, a reinvigorated effort in nanobiotechnology, and an enhanced push into 2D materials. As part of this activity, we have acquired new tools including a new AlN deposition system, and we will be getting a flip chip bonder. It is our hope to acquire a new 3D printer with 2-photon lithography, nanoscale capabilities and an atomic layer etching (ALE) system. Our interest in nanobiotechnology is an ongoing one, and the merger of most of Nanobiotechnology Center (NBTC) into CNF gives us an opportunity to offer additional capabilities, many of which are located outside the cleanroom.

We are also working with other centers at Cornell and expect to do more in the near future. We are holding discussions with CHESS, the Cornell high energy synchrotron source to see how we can better work together. We will be collaborating with Cornell's Institute of Biotechnology to hold a workshop on "Revisiting Nanobiotechnology at Cornell: Themes and Opportunities" on Friday, January 25, 2019, in G10 Biotech (mark your calendars) and discuss how CNF can partner with the life science community to enable new discoveries. Finally, our partnership with PARADIM, the new NSF materials innovation platform (MIP) that offers theory, synthesis and characterization capabilities for 2D materials, provides unique nanofabrication expertise based on our long experience with 2D materials.

In October, Don and I also visited the House of Representatives and the Senate to share success stories of CNF and the NNCI along with other members of the NNCI network. In total, members of the NNCI teams at Georgia Tech, the University of Washington, Virginia Tech, NC State, the University of Louisville and the University of Kentucky all visited their senators and congressional delegation members at the same time. Our goal was to thank our representatives for their support of science and the NSF and to stress the importance of nanofabrication and nanoscience to such developing topics as quantum computing and artificial intelligence as well as other new areas of nanoscience.

In the lab we have ordered a new Filmetrics F40-UV and a new F40 thickness measurement microscope suite. These will enhance our thin film measurement capabilities for ultra-thin films such as those deposited in our atomic layer deposition (ALD) tools. We have also seen activity in developing new plasma etch processes for an expanded set of materials. See articles in this issue related to deep etching of germanium, and a reprovisioning of our metal etchers to handle aluminum, aluminum-silicon-copper, aluminum oxide, chrome, titanium, tantalum, niobium, molybdenum, molybdenum di-silicide, and titanium nitride. This is part of an overall scheme to allow a wider range of materials to be processed in the lab. Our plasma process team and CNF Fellows have done a great job of porting and vetting user processes to different etchers to allow us to redeploy our tools to meet this expanding need.

This year we had an excellent 2018 CNF User Meeting with a range of contributed and invited talks. Dr. Cyrus Modey, a science historian, talked about the pivotal role CNF played in establishing the nation's nanofabrication infrastructure. Another featured talk was the presentation by Dr. Susanne Arney, our first Nellie Whetten award winner. This award recognizes a commitment to scientific excellence, interdisciplinary collaboration, professional and personal courtesy and exuberance for life. The winners of this award have gone on to become leaders in the technology industry. Susanne, Senior Director, Bell Labs, Nokia, talked about the fusion of data with art and considered how data and data analysis can be interlinked with the human side. A number of the talks and posters earned awards sponsored by our member companies including Applied Materials, Corning Incorporated, Heidelberg Instruments, Huawei US R&D Center, Futurewei Technologies, NIL Technology ApS, and ReynoldsTech Fabricators, Inc. Remember to make plans to join us on Thursday, September 12th, for our 2019 annual meeting to learn more about the great things going on at CNF.

As always, we love to hear from you and welcome your comments.

Chris and Don

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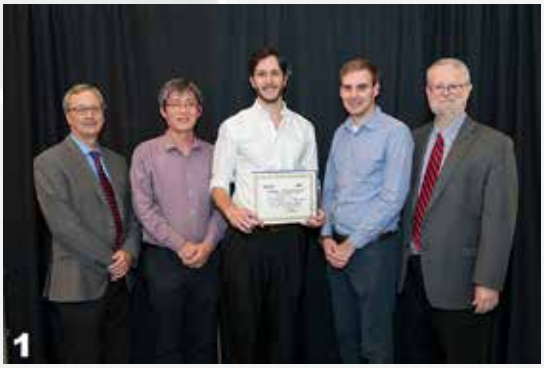
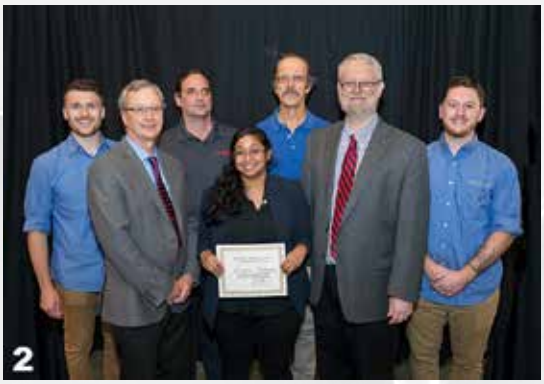
Cornell NanoScale Facility
2018 Annual Meeting Summary
http://www.cnf.cornell.edu/cnf_2018am.html





2018 CNF Annual Meeting Plenary Speaker

"Becoming a National Resource: CNF and Postwar American Academic Research." Prof. Cyrus Mody (C.C.M.), Faculty of Arts and Social Sciences, Maastricht University. Presentation abstract and video; http://www.cnf.cornell.edu/cnf_2018cnfam_mody.html

Corning Incorporated Best Paper Award (Photo #1)

Alejandro Cortese, Physics, Cornell University

CNF Best Paper Award (Photo #2)

Aseema Mohanty, Electrical Engineering, Columbia University

CNF Best Poster Awards (Photo #3)

Fangchen Liu, Biological and Environmental Engineering, Cornell University
Tanner Pearson, Applied and Engineering Physics, Cornell University
Alexander Ruyack, Electrical & Computer Engineering, Cornell University

2018 CNF Whetten Memorial Award Winner (Photo #4)

Samantha Norris, Physics, Cornell University

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2018 CNF Whetten Memorial Award Winner: Samantha Norris

Samantha Norris is a graduate student in physics, and is the 2018 recipient of the CNF Nellie Yeh-Poh Lin Whetten Memorial Award. This award recognizes young women whose work and professional lives exemplify Nellie's commitment to scientific excellence, interdisciplinary collaboration, professional and personal courtesy, and exuberance for life.

Samantha received her bachelor's degree in Physics from Illinois State University (Normal, IL) in 2016, where her research focused on developing computational methods to study electron-electron interactions in the presence of strong laser fields. In the fall of 2016, she joined the Ph.D. program at Cornell and began working for Prof. Paul McEuen. The McEuen Group is interested in "anything, as long as it's small", from two-dimensional metamaterials to wireless "microbots". Samantha's research focuses primarily on neural sensing and stimulation.

Her first project at Cornell and the Cornell NanoScale Facility involved working with graduate student Michael Reynolds studying the use of releasable graphene field-effect transistors (GFETs) to record neural signals *in vitro* in collaboration with Oregon State University. The mechanical strength and flexibility of graphene makes for a sensor that conforms to individual cell bodies without tearing, while the transparency of graphene means that electrical measurements can be made in conjunction with optical recording methods such as calcium imaging. In the case of a GFET adjacent to an electrogenic cell, changes in the cell's membrane potential modulate the gate voltage on the GFET which can then be detected by changes in current through the graphene device. This project is ongoing.

Another of Samantha's current projects involves fabricating wireless, implantable devices for electrical stimulation of neural tissue. Typical *in vivo* stimulation techniques require either genetic modification (e.g., optogenetics) or invasive electrode insertion (e.g., deep brain electrode stimulation). She is working with graduate student Alejandro Cortese to design devices consisting of silicon photodiodes connected in series. The photodiodes are connected to platinum electrodes at opposite ends of the device and then encapsulated in SU-8, leaving the electrodes protruding from the rest of the device. These devices can then be released in parallel to be free-floating in solution, and inserted into tissue with a custom injection method.

In the presence of incident light, current proportional to the photodiode area and light intensity flows between the protruding electrodes, stimulating nearby cells. The tuning of this current by the light intensity means that stimulation thresholds need not be known *a priori*, allowing dynamic *in vivo* testing. The voltage applied between the electrodes is proportional to the number of photodiodes in series, allowing the applied voltage and electrode spacing to be engineered specific to the application. She is working on optimizing these devices and she plans to perform *in vivo* experiments in collaboration with Prof. Jesse Goldberg's lab in the coming months.

Outside of research, Samantha enjoys amateur astronomy and spending time with her baby nephew, Addison, and her two cats, Melanie and Murphy.

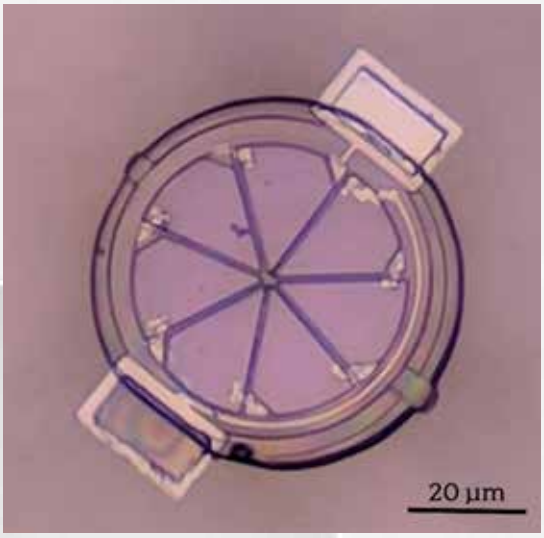


Figure 1: A wireless neural stimulator consisting of seven photo-voltaics in series released from the substrate and dried onto a glass coverslip.

CNF SHORT COURSE:

TECHNOLOGY & CHARACTERIZATION AT THE NANOSCALE

JANUARY 15 - 18, 2019

(REGISTRATION DEADLINE JANUARY 4, 2019)

This intensive 3.5 day short course offered by the Cornell NanoScale Science & Technology Facility, combines lectures and laboratory demonstrations designed to impart a broad understanding of the science and technology required to undertake research in nanoscience. TCN is an ideal way for faculty, students, post docs and staff members to rapidly come up to speed in many of the technologies that users of the CNF need to employ. Members of the high tech business community will also find it an effective way to learn best practices for success in a nanofab environment. Attendance is open to the general scientific community, but class size is limited.

CNF Cornell NanoScale Science and Technology Facility

For more information or to register visit:
http://www.cnf.cornell.edu/cnf_tcn_january_2019.html

Device to Corral Viable Sperm May Speed IVF Process

By Blaine Friedlander
September 10, 2018
Cornell Chronicle

For couples hoping for a baby via *in vitro* fertilization, chances have improved. A process that once took hours now takes minutes: Cornell scientists have created a microfluidic device that quickly corrals strong and speedy sperm viable for fertilization.

Conventional methods to separate vigorous, motile sperm is tedious and may take up to several hours to perform. "Trying to find the highly motile sperm has been difficult to do, but this improves the chances of insemination," said chemist Alireza Abbaspourrad, Cornell's Yongkeun Joh Assistant Professor of Food Chemistry and Ingredient Technology.

Taking advantage of sperm's ability to go against the flow — a process called rheotaxis — Abbaspourrad, Soon Hon Cheong, Ph.D. '12, assistant professor at Cornell's College of Veterinary Medicine, and Meisam Zaferani, a doctoral student in the field of chemistry, have devised a microfluidic channel through which the sperm swim. They added a microscopic corral — shaped like a "C" — that features a retaining wall that attracts the strongest swimmers.

"The older method is tedious, time-consuming and not efficient. It's the time that laboratory technicians and physicians expend that makes the process expensive," said Abbaspourrad. "With this method, it's five minutes instead of several hours."

The microfluidic device is simple to use: Rheotaxis is the key. "Here, we took advantage of sperm's natural tendency to redirect against fluid flow, once the sperm reach a certain velocity," said Cheong. "Once the sperm detect interference, they can use it to swim upstream. That's when we can trap them. We could separate the good sperm from the not-so-strong in a reasonably elegant way. We are able to fine-tune our selection process."

Zaferani said that these findings represent a broad range of applications beyond humans, such as using the device to separate motile bovine sperm for the dairy and beef industries. "The unprecedented efficiency of our device in comparison to previous studies and its benign, passive nature make it favorable for sperm separation," he said

The study, "Rheotaxis-Based Separation of Sperm with Progressive Motility Using a Microfluidic Corral System," published in the Proceedings of the National Academy of Sciences July 30. Production of the microfluidic channel was performed at the Cornell NanoScale Science and Technology Facility, which is supported by the National Science Foundation (NSF grant NNCI-1542081).

(Find video of bovine sperm swim upstream and enter the microfluidic corral online at http://news.cornell.edu/stories/2018/09/device-corral-viable-sperm-may-speed-ivf-process)

Scenes from 4-H Career Explorations

Alumnus David Duffield to be Honored by Engineering

A conversation with engineer, businessman, entrepreneur and philanthropist David A. Duffield '62, MBA '64, and presentation of the inaugural Cornell Engineering Distinguished Alumnus Award to him, was held Tuesday, Sept. 4th. President Martha E. Pollack introduced the event.

Duffield, in a conversation led by Lance Collins, the Joseph Silbert Dean of Engineering, spoke about his experience at Cornell and as founder of six companies, including two highly successful business software companies, PeopleSoft and Workday. He also talked about the importance of establishing a strong corporate culture and shared his thoughts on how students and alumni can distinguish themselves in today's competitive tech industry.

The Cornell Engineering Distinguished Alumnus Award has been created as the college's highest alumni honor, intended to recognize individuals who have demonstrated extraordinary leadership and vision – pushing traditional boundaries, transforming the world, and bringing pride and distinction to the college.

Duffield is one of Cornell Engineering's most successful and influential alumni. He is a visionary in the business management and higher education software industries, and has built companies that are icons in the tech industry. He is also a prominent global philanthropist, family man and deeply devoted Cornellian.

At Cornell, Duffield serves as a presidential councillor and is a foremost benefactor. His support enabled the construction of Duffield Hall, a critical facility for the college and university as a whole. Duffield Hall houses some of the world's most sophisticated research and teaching facilities for nanoscale science and engineering, and supports photonic, microelectromechanical and biotechnology research, as well as advanced materials processing via the Cornell NanoScale Science & Technology Facility, housed in Duffield Hall. Duffield also funded the Workday Atrium in Gates Hall and Workday Labs in Phillips, Rhodes and Sage Halls.

Duffield founded PeopleSoft in 1987, which grew into a public global enterprise software company before being acquired in 2005. That same year, he co-founded Workday, another public global enterprise software company developed on cloud technologies.

Duffield Receives Engineering's Highest Alumni Honor

By Blaine Friedlander
September 6, 2018
Cornell Chronicle

Cornell's College of Engineering presented David A. Duffield '62, MBA '64, with the inaugural Cornell Engineering Distinguished Alumni Award – its highest alumni honor – which recognizes extraordinary leadership, vision and bringing distinction to the college.

"The college has produced many extraordinary and talented engineers in its 150-year history. Graduates in my opinion have changed whole industries. … It's been a wonderful privilege as a dean to meet these

Lance Collins, the Joseph Silbert Dean of Engineering, right, awards David Duffield with the Cornell Engineering Distinguished Alumni Award – the college's highest alumni honor. Cornell Brand Communications

people," said Lance Collins, the Joseph Silbert Dean of Engineering, who presented Duffield the award Sept. 4.

An engineer, businessman, entrepreneur and philanthropist, Duffield founded six companies, including two highly successful business enterprise software firms, PeopleSoft and Workday.

Collins said that Cornell Engineering blends rigorous fundamentals with a sense of practical mission. "Dave, you embody the best of these ideals. It is really remarkable," said Collins. "You have a nose for [exploring] gaps in software, where there are opportunities … to fill those gaps with really interesting companies, with really interesting cultures.

"Most important is your sense of personal mission. You're trying to improve the lives of the millions of people who use your software and the thousands of people who work with you, and I admire both of those greatly – and I use those lessons in my own work," said Collins. "Thank you for being an incredible example to us all."

Duffield has a long history of giving back to the university. His naming gift for Duffield Hall enabled the construction of one of the top nanoscale facilities in the country and provides a location that is the heart and soul of the College of Engineering. He also funded the Workday Atrium in Gates Hall and Workday Labs and other named spaces in Gates, Phillips, Rhodes, and Sage halls. Duffield was named Cornell Entrepreneur of the Year in 1996. Duffield and his wife, Cheryl, founded Maddie's Fund, which supports companion animal welfare and promotes no-kill animal shelters across the country. Through this fund, the Duffields created and continue to support the Maddie's Shelter Medicine Program at Cornell's College of Veterinary Medicine, which has a strong partnership with the SPCA of Tompkins County.

David Duffield speaks with Lance Collins after receiving the Cornell Engineering Distinguished Alumni Award. Cornell Brand Communications

Before receiving the Distinguished Alumni Award, Duffield shared insights with the dean and the Phillips Hall audience, discussing his college days (which included playing varsity baseball and playing bass in a rock band) and his own career – which started at IBM in Rochester, New York, following graduation.

Duffield explained that his father, who did not attend college, instilled in him a love for aerospace engineering. But his career trajectory changed when Duffield took a computer programming class taught by Bill Maxwell, now the Andrew Schultz Jr. Professor Emeritus of Engineering. Duffield said he performed poorly in the class, but Maxwell gave him the chance to retake it. Maxwell and Duffield eventually became partners in one of Duffield's early business ventures, and Maxwell proudly sat in the front row when Duffield accepted his award.

Duffield also offered words of wisdom for budding engineers. "When you graduate, join a great company. I joined IBM. … Today it would be Amazon, Microsoft, Apple … and of course Workday is a great company," Duffield said, and smiled when mentioning his new venture Ridgeline, a software development company. "Ridgeline. Join our team. We've got another A Team."

More advice followed. "Be in sales. Be aware that it is important that your company sell its products, whether you're in administration or development – you have got to be in sales," he said. Duffield also emphasized the importance of innovation. "Go to this great company and look around for a problem to solve. Do it well, whether you're helping sell a new customer or helping to fix a customer problem," he said.

Finally, he said, hone communication skills, particularly writing and presenting. And "Work your tail off."

TINY Cancer Detection Device Proves Effective in Uganda Testing

By Tom Fleischman
September 11, 2018
Cornell Chronicle

Its name is an acronym used to convey its size, but researchers at Cornell Engineering and Weill Cornell Medicine are hoping their hand-held cancer detection device's impact in the developing world is anything but small. About half the size of a lunch box, the Tiny Isothermal Nucleic acid quantification sYstem (or TINY) has shown promise as a point-of-care detector of Kaposi sarcoma-associated herpesvirus (KSHV) in resource-limited settings such as sub-Saharan Africa. Early testing has resulted in about 94 percent agreement with traditional methods, with results being generated in a matter of hours instead of weeks.

Developed by a team led by David Erickson, the Sibley College Professor of Mechanical Engineering, and Ethel Cesarman, M.D., professor of pathology and laboratory medicine at Weill Cornell Medicine, TINY met its goals in the first round of funding from the National Institutes of Health. The team is planning expanded testing over the next several years.

Results of the team's field testing of the device in 2017 in Uganda are detailed in the paper, "A Portable Device for Nucleic Acid Quantification Powered by Sunlight, a Flame or Electricity," published Sept. 11 in Nature Biomedical Engineering. Ryan Snodgrass, doctoral student in the Erickson lab, and Andrea Gardner, researcher technician at Weill Cornell Medicine, are first and second authors.

Kaposi sarcoma (KS) is a cancer that develops in lymph or blood vessels, and usually appears as lesions on the skin, inside of the mouth or internally. There are four types of the disease; epidemic, or AIDS-associated, KS is the most common in sub-Saharan Africa and is AIDS-defining. That means when someone with the HIV virus is diagnosed with KS, they officially have AIDS.

Early detection leads to better outcomes, but that's not always possible in the developing world, where pathological testing can take one to two weeks. "There's a problem with being able to diagnose it there," Erickson said. "A number of things look like KS … and the time it takes for a traditional diagnosis, one to two weeks, makes it tough."

Doctoral student Ryan Snodgrass heats up the TINY diagnostic device using sunlight at the AIDS Healthcare Foundation-Uganda Cares Clinic in Masaka, Uganda, in 2017. The energy stored from the sun negates the need for electricity, which may be unreliable in such locations. Provided.

TINY has shown the ability to generate results in approximately 2½ hours.

Now in its third generation, TINY performs loop-mediated isothermal amplification (LAMP) for nucleic acid quantification. That requires heating the sample to 154 degrees, which necessitates a power source.

One of the main benefits of TINY: It can collect and store heat generated from electricity, the sun or even a Bunsen burner, and will function even during temporary power disruption, of which three occurred during testing in Uganda. TINY's power flexibility is important because in many sub-Saharan African countries healthcare facilities lack access to reliable electricity.

For the study, Erickson's team collected biopsy samples from 71 patients in Uganda suspected of having KS and tested the samples with TINY as well as via quantitative polymerase chain reaction (qPCR), the current standard for nucleic acid quantification. Agreement between TINY and qPCR was 94 percent (67 of 71), and the team showed that all disagreement stemmed from assay limitations and not TINY capability.

Not only can TINY be carried to remote locations for point-of-care use, it could also be valuable in clinics and hospitals where electric power can be unreliable.

"Both applications can enable nucleic acid diagnostics to reach more of the population in [low- and middle-income countries]," the group concluded in its report.

"As a pathologist who knows how difficult it can sometimes be to diagnose KS," Cesarman said, "it is very exciting to collaborate with engineers that invented a brilliant new device that makes it so easy to support or discard a diagnosis of KS in less than three hours from the time a biopsy is taken."

Future work on TINY will include expanding testing to more locations in Africa, South America and the U.S., and developing a commercialization plan. The group has applied for patent protection through Cornell's Center for Technology Licensing.

Erickson and Cesarman began work on this device approximately five years ago. "Where we are now," Erickson said, "is beyond the best-case scenario I could have envisioned when I wrote the proposal."

And Snodgrass, who's been to Uganda twice testing TINY, said it's "very rewarding to build a device, take it there and see it used on real patients."

A portion of this work was done at the Cornell NanoScale Science and Technology Facility, which is supported by the National Science Foundation (NSF grant NNCI-1542081). Support also came from the NIH, the National Cancer Institute and the NSF Graduate Research Fellowship program.

New Study First to Demonstrate a Chip-Scale Broadband Optical System that Can Sense Molecules in the Mid-Infrared

Columbia Engineering system could lead to a spectroscopy lab-on-a-chip for real-time sensing in the microseconds

Article ID: 694989
Released: 23-May-2018 9:05 AM EDT
Source Newsroom: Columbia University School of Engineering

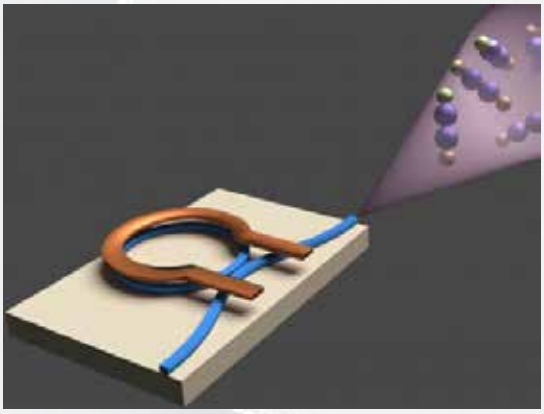
Newswise — Researchers at Columbia Engineering have demonstrated, for the first time, a chip-based dual-comb spectrometer in the mid-infrared range, that requires no moving parts and can acquire spectra in less than 2 μs. The system, which consists of two mutually coherent, low-noise, microresonator-based frequency combs spanning 2600 nm to 4100 nm, could lead to the development of a spectroscopy lab-on-a-chip for real-time sensing on the nanosecond time scale.

"Our results show the broadest optical bandwidth demonstrated for dual-comb spectroscopy on an integrated platform," said Alexander Gaeta, David M. Rickey Professor of Applied Physics and of Materials Science and senior author of the study, published May 14 in Nature Communications.

Creating a spectroscopic sensing device on a chip that can realize real-time, high-throughput detection of trace molecules has been challenging. A few months ago, teams led by Gaeta and Michal Lipson, Higgins Professor of Electrical Engineering, were the first to miniaturize dual-frequency combs by putting two frequency comb generators on a single millimeter-sized chip. They have been working on broadening the frequency span of the dual combs, and on increasing the resolution of the spectrometer by tuning the lines of the comb.

In this current study, the researchers focused on the mid-infrared (mid-IR) range, which, because its strong molecular absorption is typically 10 to 1,000 times greater than those in the visible or near-infrared, is ideal for detecting trace molecules. The mid-IR range effectively covers the "fingerprint" of many molecules.

The team performed mid-IR dual-comb spectroscopy using two Si nanophotonic devices as microresonators.



Schematic of silicon microresonator generating a frequency comb that samples molecules for chemical identification. Credit: Alexander Gaeta/Columbia Engineering.

Their integrated devices enabled the direct generation of broadband mid-infrared light and fast acquisition speeds for characterizing molecular absorption.

"Our work is a critical advance for chip-based dual-comb spectroscopy for liquid/solid phase studies," said Mengjie Yu, lead author of the paper and a PhD student in Gaeta's lab. "Our chip-scale broadband optical system, essentially a photonic lab-on-a-chip, is well-suited for identification of chemical species and could find a wide range of applications in chemistry, biomedicine, material science, and industrial process control."

The study is titled "Silicon-chip-based mid-infrared dual-comb spectroscopy." Authors are: Mengjie Yu (Columbia Engineering;Cornell University), Yoshitomo Okawachi (Columbia Engineering), Austin G. Griffith (Cornell University), Nathalie Picqué (Max-Planck-Institut für Quantenoptik; Ludwig-Maximilians-Universität München, Fakultät für Physik; Institut des Sciences Moléculaires d'Orsay (ISMO), CNRS, Univ. ParisSud, Université ParisSaclay), Michal Lipson (Columbia Engineering), and Alexander L. Gaeta (Columbia Engineering).

The study was supported from Defense Advanced Research Projects Agency (W31P4Q1510015), the Air Force Office of Scientific Research (FA95501510303), and National Science Foundation (ECS0335765, ECCS1306035). This work was performed in part at the Cornell NanoScale Facility, a member of the National Nanotechnology Infrastructure Network, which is supported by the National Science Foundation (NSF grant NNCI-1542081).

To Change a Catalyst's Electrochemical Properties, Just 'Shuffle'

By Tom Fleischman
October 2, 2018
Cornell Chronicle

A standard deck of playing cards will feature the same individual cards, no matter how much you shuffle it. But the card on top — along with the arrangement of the other 51 cards — is likely to change each time you shuffle. A research group led by Jin Suntivich, assistant professor and David Croll Sesquicentennial Faculty Fellow in the Department of Materials Science and Engineering (MSE), had an unexpected finding when it controllably "shuffled" the top layer of a well-known catalyst.

Manganese oxide (lanthanum-strontium-manganese oxide) catalyzes oxygen reduction reaction (ORR), a vital process for electrochemical energy technologies. As Suntivich and his group found, the atomic arrangement of the four components makes a huge difference.

They found that placing the highly reactive strontium just below the surface of the material optimizes ORR catalysis, even more so than by putting it on the surface, where it can cause an unwanted side reaction that actually hinders catalysis.

"The bulk material is nominally identical, but by changing just the organization of these materials, you see that the chemical properties changed," said John Eom, doctoral student in the Suntivich lab and first author of "Tailoring Manganese Oxide with Atomic Precision to Increase Surface Site Availability for Oxygen Reduction Catalysis," which published Oct. 2 in Nature Communications.

Also contributing was Darrell Schlom, the Herbert Fisk Johnson Professor of Industrial Chemistry in MSE, and Ding-Yuan Kuo, doctoral student in MSE.

Oxygen reduction is a fundamental reaction related to energy conversion, but the mechanism of the ORR on metal surfaces is not well understood. The Suntivich lab focuses primarily on identifying design strategies based on optics and electronic structure engineering to discover new materials and devices for sustainable energy and environmental technologies.

Traditionally in the pursuit of new catalysts, researchers will vary the bulk composition or structure, but the placement of each component is often left to chance and doesn't take into account how the location of the placement affects the material's property. By structuring the bulk material with thin films of each of the four components, using a process known as molecular beam epitaxy — a specialty of the Schlom lab — the team was able to precisely control the properties of catalyst while keeping its makeup the same.

"What we found is that if you take the same material, but just layer it differently, you get a catalyst with different properties," said Suntivich, a member of the Kavli Institute at Cornell for Nanoscale Science, as is Schlom.

"Think of a deck of cards: If you take a card from the top and put it on the bottom, you still have the same deck of cards, but how they're dealt is different. "That was what we found with this material," he said, "but the question was, why?"

The research team first built the material without strontium, then placed the strontium gradually closer to the surface of the material. They found that by placing it just below the surface, ORR catalysis was superior compared to when it was placed at the surface.

"That's when we realized that there must be another chemistry happening with the strontium at the surface,'" Suntivich said. That other effect: strontium at the surface can react with ambient air to create strontium oxide, which is detrimental to oxygen reduction catalysis. The ability to tailor this catalyst at the atomic scale —"painting" thin films of each component in a precise way — could open up a whole new way of thinking about catalyst design, Suntivich said. "Maybe catalysts that we once thought of as bad may behave differently if we can apply this approach," he said. "This could provide new design variables, which gives you greater ability to tailor and fine-tune the material."

Researchers from Stanford University, Drexel University and the Advanced Light Source at Berkeley National Laboratory in Berkeley, California also contributed.

Support for this work came from the U.S. Department of Energy Office of Basic Science. The researchers made use of the Cornell Center for Materials Research, which is supported by the National Science Foundation, and the Cornell NanoScale Facility (CNF), a member of the NNCI, which is supported by NSF Grant NNCI-1542081).

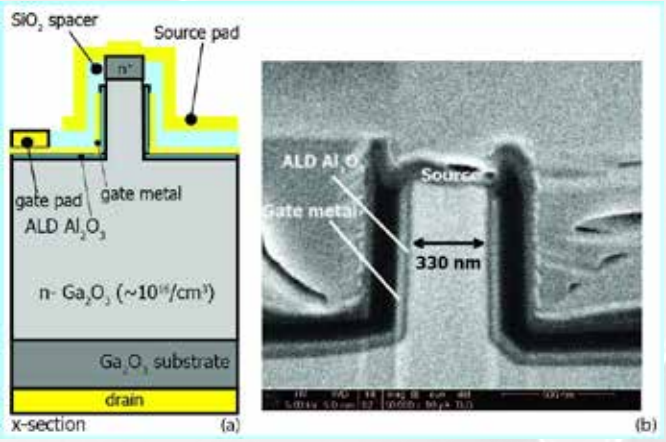





Scenes from Center for Excellence in Youth Education, Icahn School of Medicine at Mount Sinai

Vertical Gallium Oxide Transistor High in Power, Efficiency

By Tom Fleischman
June 5, 2018
Cornell Chronicle



A schematic, left, of a gallium oxide vertical power field-effect transistor, and a scanning electron microscope image, right, of the transistor, showing a 330-nanometer-wide by 795-nanometer-long channel. Transistor, Provided.

Cornell engineers have made a breakthrough in semiconductor transistor research that offers the potential for high-power electronic applications along with reduced power consumption.

The research has demonstrated metal-insulator-semiconductor field-effect transistors (MISFETs) with record performance using a new material. Gallium oxide has emerged in recent years as a desirable material for semiconductors in high-power applications. Its chief characteristics — a wide bandgap, more than four times that of silicon, and availability of large-area perfect crystals — make it an attractive alternative to silicon for high-power electronics.

Professors Huili (Grace) Xing and Debdeep Jena from the departments of Electrical and Computer Engineering and Materials Science and Engineering presented a series of these findings at the annual Compound Semiconductor Week held in Boston May 29-June 1. The record performance device results were published April 25 in IEEE Electron Device Letters, in a paper titled "Enhancement-Mode Ga_2O_3 Vertical Transistors with Breakdown Voltage >1 kV".

Zongyang Hu, a postdoctoral researcher in the Jena-Xing Group, is the lead author. Also contributing were research associate Kazuki Nomoto, doctoral students Wenshen Li and Nicholas Tanen as well as researchers from Hosei University, Tokyo, and Novel Crystal Technologies of Japan.

Enhancement-mode operation — the most desired switching characteristic in metal-oxide semiconductor transistors, in which the device is in the "off" state at zero volts — is attractive in power electronics applications to avoid catastrophic failure in the event of loss of control. A depletion-mode device is in the "on" state at zero volts, and more prone to failure than the enhancement-mode transistor.

The group used hydride vapor phase epitaxy to deposit a 10-micron layer of silicon-doped gallium oxide onto a gallium oxide single-crystal substrate. Their methods and measurements, detailed in the paper, produced a vertical power, enhancement-mode MISFET that featured breakdown voltages — the minimum voltage that causes a portion of an insulator to become electrically conductive — of greater than 1,000 volts, as well as an attractive on/off ratio (the difference between on-state current and off-state current).

According to the paper, gallium oxide's expected critical electric field exceeds that of silicon and gallium nitride. Xing said her group's MISFET could be good for harsh-environment electronics.

"Say you wanted to drill for oil," she said. "You want to have sensors right next to your drill bit to know the temperature, the mechanical stress where you're drilling. Your sensor needs to be able to handle the high temperature."

Xing was the technical program chair for the CSW conference, which was held at Massachusetts Institute of Technology. Jena was a member of the organizing sub-committee related to the gallium oxide focus session, at which seven members of their joint group presented their research results on a wide range of materials and devices.

Support for the published research came from the National Science Foundation and the Air Force Office of Scientific Research. This work was performed in part at the Cornell NanoScale Science and Technology Facility (CNF), a member of the National Nanotechnology Coordinated Infrastructure (NNCI), which is supported by the National Science Foundation (Grant NNCI-1542081).

Illumina to Acquire Pacific Biosciences for Approximately $1.2 Billion, Broadening Access to Long-Read Sequencing and Accelerating Scientific Discovery

November 01, 2018

BUSINESS WIRE

Brings Together Highly Accurate Short- and Long-Read Sequencing Technologies, Paving the Path to a More Perfect View of a Genome

Pacific Biosciences' Recent Advances with its Sequel SMRT® Technology, Combined with Illumina's Infrastructure, will Expand Biological Discovery and Clinical Insight

Long-Read Sequencing Market Opportunity Expected to Grow to $2.5B by 2022

SAN DIEGO & MENLO PARK, Calif.—

Illumina, Inc. (NASDAQ: ILMN) and Pacific Biosciences (NASDAQ:PACB) today announced they have signed an agreement for Illumina to acquire Pacific Biosciences at a price of $8.00 per Pacific Biosciences share in an all-cash transaction. This price represents a total enterprise value of approximately $1.2 billion on a fully diluted basis.

"Illumina and Pacific Biosciences have shared values and a commitment to innovation. Our complementary sequencing technology, once integrated, will offer customers a new standard of insight and understanding, opening new frontiers of genomic utility."

The agreement has been approved by the board of directors of Illumina and Pacific Biosciences. The acquisition complements Illumina sequencing solutions with accurate long-read sequencing capabilities to answer a set of complex genomic questions. While Illumina's accurate and economic short-read sequencing platforms address the majority of sequencing applications optimally, select applications, such as de novo sequencing and sequencing of highly homologous regions of genomes, are better addressed with accurate long-reads. With its acquisition of Pacific Biosciences, Illumina will be positioned to provide integrated workflows and novel innovations that bring together the best of both technologies to help researchers advance their discoveries faster and clinicians offer new tests economically.

"PacBio's unmatched accuracy mirrors that of Illumina's in short-read sequencing. Combining the two technologies positions us to reach more applications, accelerate the pace of genomic discovery and bolster our innovation engine which has been a hallmark of Illumina since our inception," said Francis deSouza, President and Chief Executive Officer of Illumina. "PacBio's relentless pursuit to improve sequencing accuracy, while driving down the cost, underscores the potential of long-reads to expand sequencing to new customers and applications."

"Illumina continues to democratize the use of sequencing at an unprecedented rate. Through this combination, thousands of researchers will now have direct access to this technology," said Michael Hunkapiller, Ph.D., Chief Executive Officer of Pacific Biosciences. "Illumina and Pacific Biosciences have shared values and a commitment to innovation. Our complementary sequencing technology, once integrated, will offer customers a new standard of insight and understanding, opening new frontiers of genomic utility."

The transaction is subject to approval by the shareholders of Pacific Biosciences, as well as other customary closing conditions, including applicable regulatory approvals. Illumina expects to close the transaction in mid-2019.

About Pacific Biosciences

Pacific Biosciences of California, Inc. (NASDAQ:PACB) offers sequencing systems to help scientists resolve genetically complex problems. Based on its novel Single Molecule, Real-Time (SMRT®) technology, Pacific Biosciences' products enable: de novo genome assembly to finish genomes in order to more fully identify, annotate and decipher genomic structures; full-length transcript analysis to improve annotations in reference genomes, characterize alternatively spliced isoforms in important gene families, and find novel genes; targeted sequencing to more comprehensively characterize genetic variations; and real-time kinetic information

for epigenome characterization. Pacific Biosciences' technology provides high accuracy, ultra-long reads, uniform coverage, and the ability to simultaneously detect epigenetic changes. PacBio® sequencing systems, including consumables and software, provide a simple, fast, end-to-end workflow for SMRT Sequencing. Dr. Stephen Turner, Chief Technical Officer, founded Pacific Biosciences (formerly Nanofluidics) and in 2004 secured its Series A funding. He was awarded a Ph.D. in Physics by Cornell University in 2000, where he worked with Prof. Harold Craighead to study the behavior of biomolecules in nano-fabricated structures. Stephen was a Cornell NanoScale Facility user and or principal investigator from 2002 through 2010. He was a member of the project team at Cornell that developed the technology now employed by Pacific Biosciences and was co-author of the cover story in Science magazine (January 31, 2003) that introduced the technology to the scientific community. Dr. Turner's undergraduate work was at the University of Wisconsin, Madison, where he received a Bachelor of Science in Applied Mathematics, Electrical Engineering and Physics. He is the author of over 50 scientific papers in fields ranging from DNA sequencing technology and biophysics to genomics and epigenomics. He is listed as the inventor on over 50 U.S. patents and numerous published patent applications. Dr. Turner was recipient of the MIT Technology Review "TR100" Award in 2003 and the University of Wisconsin Madison Distinguished Young Alumnus Award in 2008. More information is available at www.pacb.com.

About Illumina

Illumina is improving human health by unlocking the power of the genome. Our focus on innovation has established us as the global leader in DNA sequencing and array-based technologies, serving customers in the research, clinical, and applied markets. Our products are used for applications in the life sciences, oncology, reproductive health, agriculture, and other emerging segments. To learn more, visit www.illumina.com and follow @illumina.

Héctor Abruña Elected to the National Academy of Sciences

By Tom Fleischman
May 2, 2018
Cornell Chronicle

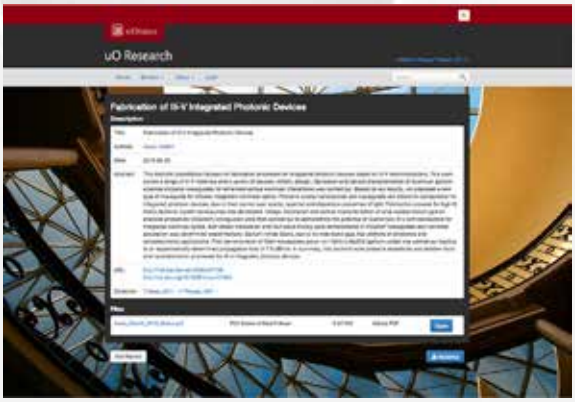
Héctor Abruña, the Emile M. Chamot Professor of Chemistry in the Department of Chemistry and Chemical Biology, and Susan McCouch, Barbara McClintock Professor of Plant Breeding and Genetics, School of Integrative Plant Science, are among 84 new members elected to the National Academy of Sciences, the academy announced May 1. The elections of Abruña and McCouch bring to 62 the number of Cornell professors past and present – including Nobel laureates Hans Bethe (physics), Roald Hoffmann (chemistry) and Harold Varmus (Weill Cornell Medicine) – who have been elected to the academy since its inception in 1863.

The Abruña group's interdisciplinary research addresses problems of electrochemical interest, with current emphasis on fundamental studies of battery and fuel cell systems to molecular electronics. The group uses standard electrochemical techniques in addition to x-ray and various microscopy methods and a variety of spectroscopic techniques.

The group also synthesizes novel, tailored inorganic complexes and organic battery materials to drive discovery of new chemical and electrochemical properties. Their latest work, "Direct Visualization of Sulfur Cathodes: New Insights into Li-S Batteries Via Operando X-Ray Based Methods," was published in January in Energy and Environmental Science.

Prof. Abruña has been the principal investigator for many active projects at the Cornell NanoScale Facility since 2003.

Scenes from the 2018 Cornell NanoScale Facility FIRST® LEGO® League Jr. Expo



Awan Thesis Available

Dear Melanie-Claire,

I am a CNF user and conducted most of my device fabrication at CNF. I recently defended my doctoral thesis and wanted to share my work with the CNF community, as I am hopeful that it will be helpful for anyone conducting similar fabrication and in extending the work further. Work is focused on fabrication of III-V integrated photonic devices, however, covers basics of plasma etching, e-beam lithography and also has some work on plasmonic metasurfaces and silicon photonic crystals.

Here is the library link:

https://ruor.uottawa.ca/handle/10393/37729

Best Regards,

Kashif Awan, University of Ottawa
Supervised by Profs. Robert Boyd,
Ksenia Dolgaleva, and Antonio Badolato

Transonic Kudos to CNF and Tom Pennell

Hi Don,

I'm not sure about the scope of contributions you're looking for under the heading: "Research Accomplishments Technical Report" — we use the facility (with the help of Tom Pennell) to produce components for our smaller transit-time ultrasound flowsensors.....

"Once more, Transonic Systems Inc., benefitted from the use of the Cornell NanoScale Facility for the manufacturing of production-grade sensor bodies for its chronically implantable transit-time ultrasound "nano probe" flow sensors."

--Cor

Cornelis J Drost
President & CEO
Transonic Systems Inc.
www.transonic.com

THE MEASURE OF BETTER RESULTS.

Lal Journal Cover

Persaud, A., Q. Ji, E. Feinberg, P. A. Seidl, W. L. Waldron, T. Schenkel, A. Lal, K. B. Vinayakumar, S. Ardanuc, and D. A. Hammer. "A compact linear accelerator based on a scalable microelectromechanical-system RF-structure." Review of Scientific Instruments 88, no. 6 (2017): 063304.

Activating Buried p-Type Gallium Nitride for Power Electronics

Thermal activation of buried p-type GaN is important for realizing advanced GaN vertical power devices, which has higher projected efficiency than Si and SiC-based counterparts. The power device team in Jena-Xing group has been investigating ways to better activate the Mg-acceptors in buried p-type GaN, which is passivated by the metal-organic chemical vapor deposition, a common way to grow the GaN layers. They found that successful activation can be achieved by the exposure of the p-type layer through etched sidewall. The work authored by Wenshen Li, et al., is published on Applied Physics letter and featured by Semiconductor-Today magazine.

URL: http://www.semiconductor-today.com/news_items/2018/sep/cornell_060918.shtml

Register for the CNF Short Course!
http://www.cnf.cornell.edu/

McGill Update

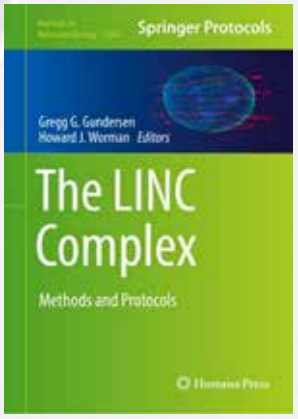
Hi Melanie,

I have graduated and am now a lecturer for the Department of Physics at the University of Florida. That's my update for the next Nanometer. ;-)

Best,

Dr. Kathryn L. McGill

Lammerding Windsor Publication



Assembly and Use of a Microfluidic Device to Study Cell Migration in Confined Environments

Jeremy Keys, Aaron Windsor, and Jan Lammerding

Part of the "Methods in Molecular Biology" book series (MIMB, volume 1840)

Citation: Keys J., Windsor A., Lammerding J. (2018) Assembly and Use of a Microfluidic Device to Study Cell Migration in Confined Environments. In: Gundersen G., Worman H. (eds) The LINC Complex. Methods in Molecular Biology, vol 1840. Humana Press, New York, NY

https://link.springer.com/protocol/10.1007/978-1-4939-8691-0_10

(Also see cover and this background image!)

LOCALLY SOURCED SCIENCE

Locally Sourced Science Features CNF

This past summer, the Cornell NanoScale Facility was featured on "Locally Sourced Science" -- a radio show on wrfi.org (88.1 FM). This particular podcast episode focused on the theme "From Micro to Nano" and included an interview with our very own Beth Rhoades, Amrita Banerjee, Tom Pennell, and Michael Skvarla.

WRFI's science podcast "Locally Sourced Science" is available at https://www.facebook.com/LocallySourcedScience/ and https://www.mixcloud.com/Locally_Sourced_Science/

Please give us a listen and enjoy!

Woll Journal Cover

S. Choudhury, D. N. Agyeman-Budu, A. R. Woll, T. Swanston, T. L. Varney, D. M. L. Cooper, E. Hallin, G. N. George, I. J. Pickering, and I. Coulthard, "Superior spatial resolution in confocal X-ray techniques using collimating channel array optics: elemental mapping and speciation in archaeological human bone," Journal of Analytical Atomic Spectrometry 32 (3), 527-537 (2017). doi: 10.1039/C6JA00297H

The CNF Cluster is Back!

The CNF Cluster is now available to users in a soft launch state — meaning not all the nodes are yet re-provisioned and we are still working on correcting some hardware failures.

What's new? We have added two new Dell PowerEdge R640 systems each with 256GB of memory and two Intel Xeon Gold 6136 processors — each processor has twelve cores and two threads for a total of 48 virtual CPUs per node. And we have a new Dell PowerEdge R740xd head node with 9TB of disk space for user job storage. The cluster OS has been updated to Scientific Linux 7 with an install of the OpenHPC project. We have also simplified login access especially for those users located on campus.

A few basic codes have been installed. Upon user request, we will install additional codes.

And the pricing model is the same as before ... a simple monthly charge for "all the bytes you can eat" for every month during which a user runs jobs on the cluster.

If users are interested in used the revitalized cluster, they should go through the usual CNF Project Proposal and New User Application process found at http://www.cnf.cornell.edu/cnf5_steps.html

Questions can be directed to:

David William Botsch
Programmer/Analyst
@CNFComputing
botsch@cnf.cornell.edu

New Tool Acquisitions at CNF

The CNF has recently made two new exciting tool acquisitions!

The first is the OEM Endeavor M1 aluminum nitride deposition system. This new tool will significantly improve on our ability to sputter high quality aluminum nitride films with a significantly higher deposition rate than standard sputter processes. This tool is currently in the clean room and the staff is actively engaged in the installation process.

The second acquisition is a new AJA Orion 8 sputter deposition system. This tool will replace the CVC sputter tool and will add several new capabilities to the CNF's metal deposition suite. The tool will include one magnetic materials gun, and the ability to cosputter multiple DC targets, along with an increased wafer bias potential for substrate cleaning and deposition of higher density films. The tool is expected to arrive at CNF this fall.

We are excited to introduce these new pieces of equipment to the CNF community.

Both of these new tools will be managed by Tom Pennell and Jerry Drumheller. Please contact them with any questions regarding capabilities, installation status, and training.

What Happens to Nanooze Magazines After They're Mailed Away?

By Beth Rhoades, Ph.D.
CNF Youth Outreach Coordinator

CNF surveyed subscribers of Nanooze, primarily educators, to assess the impact of the popular technology periodical for kids. Herein is a summary report on how respondents use Nanooze magazine and how useful the magazine is for teaching STEM, nanotechnology, and related careers.

Background

Nanooze is a website (www.nanooze.org), a magazine, and an exhibit at Disney's Epcot Center (see below). The website and magazine are written and edited by Professor Carl Batt at Cornell University with occasional contributions from Dr. Lynn Rathbun from the CNF.

The pilot issue (#1What is Nanotechnology) was published in 2007. At the time of our study there were 15 issues available, the latest on nanotechnology and the environment. Nanooze is written at a 5th-grade level, but with content that is fun, imaginative and engaging for all ages. The magazine and the website feature interviews with actual scientists, explore "cool" phenomena at the nanoscale, and they introduce readers to nanotechnologies and related careers. Many examples in the site and magazine are things that readers can relate to in their everyday lives.

We know that the reach of Nanooze magazine is immense. More than 1.1 million copies of issues #3 through #15 have been printed and distributed since 2010. In the first three months of 2018, the CNF mailed away 36,000 copies of the latest issue to classrooms and museums. Copies have also been distributed as PDF downloads from www.Nanooze.org or as print copies handed out at science, technology and education conferences by NNCI personnel.

Figure 1: Zip codes of 122 survey respondents from the Nanooze mailing list.

What we know less about, is the impact of Nanooze. We wanted to know how well the magazine is meeting the goals of NNCI's Education & Outreach Program — so we surveyed our Nanooze subscribers. Our goals were: (1) to understand how Nanooze magazine is used by educators and (2) to measure how well Nanooze enhanced STEM literacy and promoted and inspired the pursuit of nanotechnology-related careers.

137 subscribers completed our survey. We can't be certain whether the survey respondents were entirely representative of our entire subscriber pool, but their geographical distribution (Figure 1) and occupations suggested that survey respondents were representative. Their geographical distribution (and that of the entire mailing list) shows clustering in several areas (Georgia, Washington D.C/Virginia, and New York). These locations hold frequent conferences or workshops that teachers frequently attend. And Georgia and New York are local sites of outreach activity of two NNCI sites.

How Are Teachers Using Nanooze?

- 91% of teachers used Nanooze as a teaching tool in a teaching environment (classroom).
- A surprisingly large portion of teachers (58%) shared Nanooze with their colleagues.
- About 5% also shared Nanooze with library patrons, family or the general public.

Where Do Educators Use Nanooze?

- Most teachers (93%) used Nanooze in formal classrooms (Figure 2).
- 18% used Nanooze in after-school programs or day camps.
- 7% used Nanooze for special interest clubs (4-H, scouting, technology, etc.)
- Infrequent settings were libraries, professional development offices, or at home or community events.

How Many Students Are Taught With Nanooze?

Teachers estimated how many people they shared Nanooze with during the last year that they used the magazine.

- 7 % shared Nanooze with less than 10 people.
- 42 % shared Nanooze with 10 to 25 people.
- 32 % shared Nanooze with 26 to 50 people.
- 19 % shared Nanooze with more than 100 people.

If one does some (very loose) calculations, this group of 123 educators shared Nanooze with 4700 to 11,000 individuals in just one year, showing that Nanooze subscribers are a significant nexus for distributing Nanooze to a wide audience.

What Subjects Are Taught Using Nanooze?

- Not surprisingly, the most commonly taught topics were in STEM (Figure 3).
- Nanotechnology subjects were taught by 16% of the teachers.
- Career topics were taught by 7% of the teachers using Nanooze.
- Occasional subjects included reading & literacy as well as society & ethics.

Figure 2: Settings where educators use Nanooze magazine.

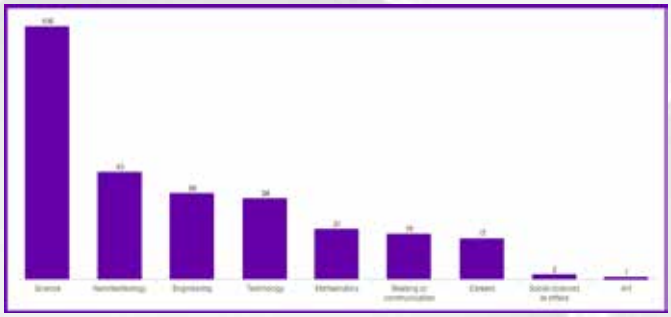


Figure 3: Distribution of the subjects that were taught using Nanooze.

How Well Does Nanooze Promote STEM Literacy & Nanotechnology Careers?

We wanted to know whether Nanooze magazine is a useful teaching tool. We couldn't directly test students who read the magazine so we surveyed the teachers who had regular contact with their students (71 of the survey respondents). We asked teachers to estimate how many of their students demonstrated evidence of learning. There are different levels of learning, so we asked several questions. For instance, we asked how many students asked for more issues of Nanooze as a way to assess how well Nanooze engaged student interest. We asked teachers to estimate how many students used Nanooze content later and used it correctly as a way to assess how well Nanooze increased STEM and nanotechnology literacy. We asked similar questions to assess how well Nanooze taught about nano-related careers.

People will estimate differently. To standardize the teachers' estimates, we gave a set of ranges to select from on the survey. The options were: none of students, 1-25%, 26-50%, 51-75% or 76-100% of students. We averaged the teachers' responses to come up with the portion of students in a class who demonstrated learning. The averages had a range of plus or minus 12.5% due to the 25% ranges that we supplied on the survey.

STEM & Nanotechnology Literacy

- 42% of students were engaged by Nanooze. They asked for more issues.
- 50% recalled Nanooze content. They mentioned it in weeks following a lesson.
- 66% demonstrated increased STEM literacy. They used Nanooze content correctly after lessons.
- 50% demonstrated deeper learning about STEM. They applied Nanooze content to other lessons or projects.

Nanotechnology Career Awareness

- 66% showed increased awareness of nano-related careers by talking about careers outside of the lesson.
- 47% were inspired to seek out more information on nano-related careers.
- 23% sought out scientists or other professionals to learn more about nano-related careers.
- 30% of students changed their ideas or opinions about nano-related careers.

What Are The Broader Impacts of Nanooze?

We asked the survey respondents to tell us their stories. Here are some inspirational accounts that show the value of Nanooze magazine.

"Nanooze inspired a whole course on nanotechnology for high school students."

---Teacher @ Indian Lake School District, Indian Lake, NY

"I had a gifted student travel to the Argonne National Lab during the summer to tour and meet with a scientist. The student became interested in nanotechnology after receiving the magazines."

--- Teacher @ Hickman County Elementary School, Clinton, KY

"Six years ago, I shared Nanooze with my students in 5th grade. As a junior in high school, one of the students came to see me. When I asked how my class impacted him, he immediately responded that reading Nanooze was his favorite thing that we had done. He said that reading the magazine helped to re-awaken his love for school and for science. He hoped that I still use the magazine (which I do) because it was the best part of his entire 5th grade."

--- Teacher @ Baldwin Elementary School, Hope Mills, NC

"After using Nanooze in our 4th-grade nanotechnology unit, a 5th-grader said to me at a random time during class, 'Mrs. D, do you know what I'm going to be? A nanotechnologist.' A discussion followed with the whole group about the sciences in which they could concentrate and 'do nanotechnology'."

---Teacher @ Elkton Elementary School, Elkton, VA

"Nanooze was the basis and sparked an interest in my students which led me to create a project about colonizing on another planet in our solar system. We have, since reading Nanooze, had a materials engineer come to speak for us, and I am in the process of planning a field trip to a local lab that does failure rate testing for NASA.

---Teacher @ Spokane International Academy, Spokane, WA

"Several students have brought an issue up to me to show me something that interested them and sparked their interest. To me this shows that they are deeply interested in the science, careers and the content. And, this is DEFINITELY content they will not see in their science textbook. Unless I bring the content to them as their teacher, it's unlikely they would learn about such cutting edge & interesting technologies."

--- Teacher @ McAuliffe Middle School, Boynton Beach, FL

"My students and I adore Nanooze. I teach a Nanotechnology and Deadly Disease Unit which incorporates art … They research on Nanooze.org and use the stack of magazines I have in my fine arts classroom. … They are learning real-life applications … Georgia Tech also has a Nanotechnology Department, and through them I learned that the NSF estimates that in the fields of nanotechnology & nanoscience, there will be a need for 7 million workers world-wide by 2018…. so Nano has incredible career opportunities that I want to expose my students to."

--- Art Teacher @ Stonewall Tell Elementary, College Park, Ga.

Conclusions & Future Directions

Our survey of educators has verified that Nanooze is being used to supplement lessons in cutting edge nanotechnology and STEM topics. It is being used in less-traditional ways in reading and art classes. Nanooze magazine is definitely not gathering dust in the windowsills of school classrooms. The magazine is read, and re-read, and shared and sometimes fought over. It is a valuable resource for teachers. And it is engaging the minds and imaginations of all ages.

We have a very enthusiastic group of subscribers that are willing to help with more assessments. Some have offered to assess their students directly. And others have suggested how we could survey with magazine inserts, for instance. The educators' enthusiasm and appreciation has spilled over on other forms. We have dozens of helpful comments and suggestions about the magazine as well as other ways that teachers could use our help. The CNF plans on using this opportunity to do additional impact assessments as well as begin to consider other ways that our Education & Outreach program can help educators and students.



2018 CNF • CNF iREU • CTECH • KEP • PARADIM REU • PARADIM CU
Research Experience for Undergraduates (REU) Programs


We had a very successful summer working with a total of 27 Research Experience for Undergraduates (REU) interns across seven programs, listed on the right. From civil engineering to process characterization at the nanoscale, from system evaluation to atomic layer deposition, we did our best to provide an exciting, satisfying, and ultimately productive research project for each intern. But as Albert Einstein said, "If we knew what it was we were doing, it would not be called research…" Still we hope we instilled the skills and understandings that will draw our interns to join us in research!

Find their final reports and the information on next year's programs at the URLs below.

Cornell NanoScale Facility (CNF)

CNF International Program (CNF iREU)

Center for Transportation, Environment & Community Health (CTECH)

Keeping the Ezra Promise (KEP)

Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials (PARADIM)

Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials for Cornell (PARADIM CU)

PARADIM at Johns Hopkins University (PARADIM JHU)

http://www.cnf.cornell.edu/cnf_2018reu.html
http://www.cnf.cornell.edu/cnf5_reuprogram.html



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CNF NanoMeter • Winter 2018 • Volume 27 • Issue 1 •
Your comments are welcome!

The Cornell NanoScale Science & Technology Facility (CNF) has been serving the science and engineering community since 1977. The CNF is supported by the National Science Foundation, the New York State Office of Science, Technology & Academic Research (NYSTAR), Cornell University, Industry, and our Users.

To be added to our CNF NanoMeter mailing list or to correct a mailing address, please send your request via email to: information@cnf.cornell.edu. You will also find the NanoMeter in PDF on our web site at: http://www.cnf.cornell.edu