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NQPI
OHIO UNIVERSITY

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J. Chen Fine-tunes Nanoscale Imaging Procedure

NQPI member and Chemistry & Biochemistry professor Jixin Chen has developed a new method to optimize the fluorescence imaging of DNA structures. Although fluorescent imaging techniques are nothing new, Chen's formulation will enhance the resolution of fine images at the nanoscale.

Among the techniques used to illuminate particles at the nanoscale, fluorescence is the emission of light from atoms or molecules excited by a photon. For Chen, the molecule of interest is a dye called YOYO-1, a particle capable of resolving fine DNA images below 250 nanometers.

Since this level of measurement is lower than the diffraction limit of visible light, the resolution of an entire image in Chen's study must be constructed one dye at a time.

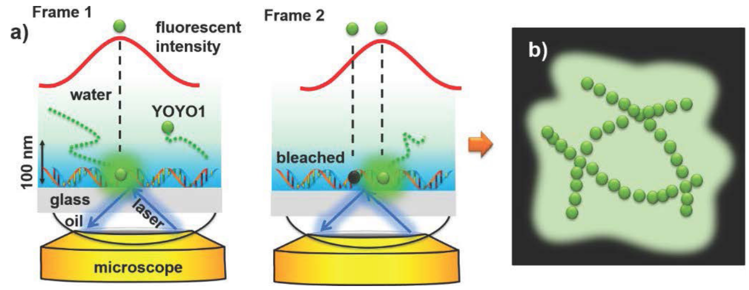

Diagram of point accumulation for imaging in nanoscale topography used for YOYO-1 dye molecule (Illustration: Beilstein Journal of Nanotechnology*)*

YOYO-1 is not fluorescent before binding to the DNA structure, and after binding, it remains fluorescent until photobleached – or "turned off."

"We need to find a balance," Chen said. "Where is the balance between the bleaching and the absorption?"

In an article published in the *Beilstein Journal of Nanotechnology*, Chen produced individual frames of excited YOYO-1 molecules using a method called point accumulation for imaging in nanoscale topography (PAINT). This process involves adding together the individual frames of excited YOYO-1 molecules along the range of the DNA measured. As a

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Accelerator Enhances Collaborative Materials Research

Ohio University's Edwards Accelerator Laboratory sits tucked away within the walls of an unobtrusive brick building that extends some way into the hillside at the center of the main campus. This facility blends in with surrounding buildings, yet it attracts researchers from some of the most prestigious institutions across the country and around the world.

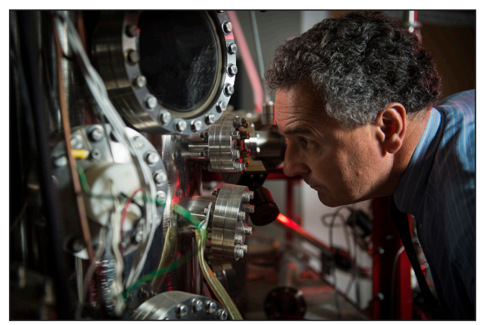
The laboratory is managed through the Department of Physics & Astronomy and is part of the Institute for Nuclear and Particle Physics. Although this accelerator has traditionally been used for the study of nuclear reactions, Physics & Astronomy chair and NQPI member David Ingram said the accelerator has numerous applications for material science, including analysis of electronic materials and archaeological samples. For example, the accelerator has recently been used to characterize samples of coal-derived graphene films with Chemical & Biochemical Engineering Distinguished Professor and NQPI member Gerri Botte.

Ingram partners with numerous OHIO faculty, including many NQPI members – Arthur Smith, Saw-Wai Hla, Marty Kordesch, Jason Trembly, Wojciech Jadwisienczak – and their students, as well as researchers from across the country.

The accelerator functions through a high-voltage power supply that propels particles at high speeds within a concentrated beam. This technique allows researchers to characterize properties of targets including atomic composition, nuclear energy levels and resistance to radiation damage.

Because OHIO's accelerator produces a greater current than most other accelerators, it can be used in a broad range of applications. These working conditions can help mitigate background noise in analysis of data. In addition, the accelerator is housed in a well-shielded building that minimizes background radiation.

The facility has been maintained entirely



David Ingram in Edwards Accelerator Laboratory (Photo: Robert Hardin)

by OHIO staff and faculty since its induction in 1971. Ingram credited the facility's success to its late founder, Roger Finlay, noting that OHIO's accelerator has remained a viable asset due to its unique capacity to produce a remarkably high current.

"Accelerators around the country have shut down, but this one is kept going," Ingram said. "Choosing the right accelerator design was critical to this place being sustainable."

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Director's Corner

Dear Colleagues,

Springtime at Ohio University in Athens is a time for new beginnings, and that is certainly the case for NQPI and the Condensed Matter and Surface Sciences program.

The arrival of President Duane Nellis at the leadership of OHIO presented an opportunity to strengthen the university's research profile. Following the suggestion made by the interim Provost and the Vice President for Research and Creative Activities, a proposal was submitted to President Nellis outlining a broad university-level investment in these programs. We are very happy to report that this request has been approved, demonstrating a strong vote of confidence and commitment by OHIO to continuously support successful research activities.

The proposal jointly drafted by Sergio Ulloa (acting director of CMSS) and myself outlined a combined vision that will support core research and education missions, open new opportunities for strategic investments and streamline administrative duties. Additionally on July 1, 2018, the oversight of CMSS/NQPI will be transferred from the College of Arts & Sciences to the office of the Vice President for Research & Creative Activity, reflecting the truly multi-disciplinary composition of our membership.

We deeply value the support from the President, Provost, Vice President for Research, and the Deans of Arts & Sciences and the Russ College in this venture. We will continue to work to advance the education and research missions recognized by peer institutions around the world.

Allow me to take this opportunity to introduce NQPI's newest members, Dr. Keerti Kappagantula, a faculty member in Mechanical Engineering, and Dr. John Staser, a faculty member in Chemical & Biomolecular Engineering. Dr. Kappagantula's research focuses on material processing techniques and their optimization for diverse applications. Dr. John Staser works on electrochemical solutions to industrial and health-related problems. I invite you to learn about their interests and expertise highlighted in this issue.

Sincerely,

Eric Stinaff, NQPI Director

NanoBytes

- NQPI member and Distinguished Professor of Chemistry & Biochemistry Tadeusz Malinski received national media attention on his Vitamin D3 study published in the *International Journal of Nanoscience*.
- Honored for his work at Argonne National Laboratory, NQPI member and Physics & Astronomy professor Saw-Wai Hla received the 2017 Samuel D. Bader Prize for Exceptional Achievement.
- Bishal Bhattari, a Ph.D. condensed matter physics student working with NQPI member and Distinguished Professor of Physics David Drabold, was awarded the Vishwa S. Shukla Memorial Scholarship.
- NQPI invited alumnus Ph.D. Greg Petersen for the series Bring Back OUr Alumni on April 26 to lead a discussion on building networks, career experience and finishing college.
- Eight NQPI members who authored 24 abstracts participated at the 2018 March Meeting of the American Physical Society.

New NQPI Member John Staser: Nano-materials Engineer

New to NQPI, Chemical & Biomolecular Engineering professor John Staser is no stranger to Ohio University. Staser became a professor at OHIO in 2013, and now he's bringing his research on carbon quantum dots to a new audience.

"Along the lines of NQPI's mission, we're using these nanoscale materials to make new types of electrochemical materials," Staser said.

With chemical engineering degrees from Case Western Reserve University (B.S.) and the University of South Carolina-Columbia (Ph.D.), Staser has been integrating carbon quantum dots with UV sensors to expand the device's applicability. Carbon quantum dots are carbon plates or disks (tiny flakes of graphene) between two and ten nanometers in diameter that possess fluorescent properties. Their unique optical properties are due to quantum confinement effects arising from their sizes. Researchers have been scrambling to make sense of this phenomenon and put it to useful application. A few current ideas involve UV detection for military-grade equipment (i.e. rapid detection of missiles or enemy personnel) and overexposure to UV rays from the sun, Staser said.

"People have thought about coupling (carbon quantum dots active in the UV range) with normal solar cells to increase the wavelength range over which solar panels operate because solar panels don't typically do very well under the UV range," Staser said.

Staser's current involvement with NQPI complements Physics & Astronomy professor Martin Kordesch's research with molybdenum disulfide. With help from undergraduate student Ari Blumer and the State of Ohio's Coal Development office, Staser and Kordesch are producing carbon quantum dots from coal and coupling them with molybdenum disulfide to make supercapacitors.

"Because of its electrochemical activity, (this combination) stores energy by charge transfer processes," Staser said. "It's like a hybrid capacitor electrode."

Supercapacitors are exciting because they have applications ranging from small-scale energy storage, like cell phones and wearable sensors, all the way up to grid-scale storage for renewable energy. Additionally, energy storage for electrical vehicles, such as plug-in hybrid cars, benefit from supercapacitor efficiency. Staser's research positions OHIO as a leader in this new frontier of energy conservation.

John Staser (Photo: Russ College of Engineering and Technology)

New NQPI Member Keerti Kappangantula

Keerti Kappangantula (Photo: Russ College of Engineering and Technology)

One of NQPI's newer members and Mechanical Engineering professor Keerti Kappagantula is a combustion specialist who has had an explosive career since arriving at Ohio University three years ago, but nowadays she is more about building things up than breaking things down.

"I know 'combustion' sounds really exciting and 'explosions' sound nice, but it's only a very small part of the larger things that we do (in mechanical engineering)," Kappagantula said. "The big picture that I'm very interested in is efficient manufacturing, because that actually works toward energy conservation."

Kappagantula came to OHIO from Texas Tech University, where she began conducting research on nano-energetic materials. These are reactive materials used in redox reactions at the nanoscale level. When the reaction is initiated, the subsequent energy release can be applied to mechanisms such as solders or batteries – or explosives. That is, depending on how fast or slow the energy release is.

"My job was to tailor (the reactions) depending on who was applying it and get the combustion dynamics to work for specific applications," Kappagantula said. "(At OHIO), I still do that, but I do it on the manufacturing side of things."

Indeed, while explosive research is certainly a conversation piece for Kappagantula, so is the $2.18 trillion manufacturing industry. As of 2016, manufacturing in the United States drives roughly 18 percent of the world's products, but the costs of operation and labor associated with U.S. manufacturing have risen in tandem with the standard of living. Kappagantula's position at the Russ College of Engineering and Technology enables her to serve as the facilitator between lab work and industry applications that could possibly make manufacturing more efficient in the U.S.

Equally as important, Kappagantula is passionate about teaching the next generation of engineers. She said her former professors from Texas Tech University have helped inspire the pursuit of her current career.

"Even now I keep in touch with my undergrad teachers, and they've had a huge, huge influence on how I think and how I function as both a researcher and an engineer," Kappagantula said. "I want to be somebody who helps another student on that scale."

Nanoscale Defense: Predicting Intrusions to Membranes

Like the outermost walls surrounding a castle, the plasma membrane is the cell's first defense against invaders. Biological membranes are semipermeable, meaning that they are designed to block unwanted molecules while permitting the passage of compounds necessary for cellular function.

And yet, an occasional intruder will slip through. Cytotoxins can invade living cells, potentially incurring cellular damage. Many researchers are interested in what makes these molecules toxic to organisms.

Chemical & Biomolecular Engineering professor and NQPI member Amir Farnoud is characterizing which types of compounds are likely to bind to the membrane. His recent work, conducted in collaboration with Chemistry & Biochemistry professor and NQPI member Katherine Cimatu, was featured on the front cover of the February issue of *Environmental Science: Nano*.

Researchers construct synthetic models to study the properties of biological membranes, Farnoud said. But not all synthetic membranes are created equal. Many researchers study simple lipid monolayers (single layer), despite the fact that biological membranes in nature are actually bilayers (double layer).

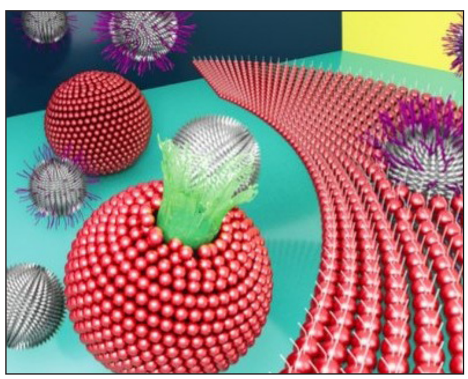


Diagram of monolayer and bilayer membranes, the former is represented as a flat plane and the latter as a spherical structure (Illustration: Environmental Science: Nano*)*

In this paper, Farnoud investigated the applicability of synthetic monolayers to biological systems. His team, which included graduate student Saeed Nazemidashtarjandi and recent graduate Ali Asghari Adib, compared the binding of nanoparticles to both monolayer sheets and bilayer vesicles. They introduced silica nanoparticles with different functional groups (plain, amine, and polyethylene glycol) to both types of membranes.

"People use silica nanoparticles both for drug delivery and for industrial products," Farnoud said. "This is relevant from a drug delivery standpoint (as well as) an environmental health hazard standpoint, because you can get exposed to particles in both ways."

What they found was remarkable; some groups disrupted the monolayer exclusively, while the others disrupted only the bilayer. Farnoud said the difference is likely due to geometry; lipid monolayers are flat sheets, while bilayers (both natural and synthetic) are spherical. Synthetic bilayers better represent the dynamics of living cells and are thus likely a more appropriate model for biological systems.

Farnoud's group is continuing their work with silica nanoparticles. He said he plans to design bilayers that are more complex by incorporating more diverse lipids that are characteristic of biological membranes. Additionally, Farnoud is interested in how rigid "lipid rafts" in the membrane influence these interactions.

"We're making our membrane models much more sophisticated," Farnoud said. "We're trying to mimic the cell with our membrane model."

Uncovering Hidden Electronics

Distinguishing identical twins can be a difficult task at first. Physics & Astronomy professor and NQPI member Nancy Sandler encounters a similar scenario when dealing with seemingly identical carbon atom pairs.

Sandler recently authored two papers in *Nano Letters* that described her group's efforts to characterize the properties of these carbon pairs. The oppositional pairs that comprise the honeycomb sheets of graphene were thought to be indistinguishable at the quantum level, Sandler said. This means the atoms would exhibit identical electron distributions.

"In pristine graphene, one carbon atom is the mirror image of the other," Sandler said. "They are pretty much like your right and left hand."

Sandler was intrigued when Marcus Morgenstern, an experimental physicist from RWTH Aachen University, Germany, reported in 2012 that his group had found a way to distinguish the atoms by looking at pairs that are separated beyond their equilibrium distance.

Two then-visiting graduate students in Sandler's group, Daiara Faria (from Brazil) and Ramon Carrillo-Bastos (from Mexico), generated mathematical models to characterize charge distributions in graphene. Carrillo-Bastos, who specializes in numeric calculations, simulated the effect of deformation on the paired atoms.

They found that when the surface of graphene was disturbed, the sublattice symmetry was altered, resulting in unequal charge distribution in the pair. Yet the net flow of electrons was unaffected, which explained why charge current distributions had appeared indistinguishable under these conditions. These results were confirmed by analytic models solved by Sandler's graduate student Dawei Zhai.

"It clicked," Sandler said. "When the membrane is not strained, there is no way to distinguish one carbon atom from the other. But if you bring it out of the plane, you can see the breaking of this symmetry."

Sandler collaborated with Morgenstern's group and used models to characterize the deformations in agreement with experimental data. The second article focused on fold deformations and was written in collaboration with professor Marc Bockrath from Ohio State University. Sandler's graduate student, Tareq Mahmud, is currently incorporating the effect of electronic interactions.

The group's work can be used to help researchers better understand the properties of other materials with similar geometries. One idea, Sandler said, would be to predict and describe similar phenomena in molybdenum disulfide that is grown by NQPI colleagues Eric Stinaff and Martin Kordesch using chemical vapor deposition.

"What would the effect of strain be? Can you manipulate mechanically the electrical properties of the material?" Sandler asked. "Because that's the beauty of it: to control currents using simple mechanical forces."

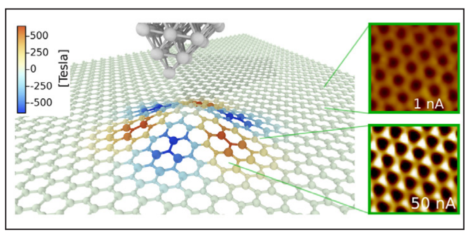


Diagram of symmetrical carbon molecules (Illustration: Peter Nemes-Incze)

J. Chen Fine-tunes ...

Continued from page 1

result, the summation of points creates a resolved image of the DNA structure.

Following this procedure, he would determine the binding rate of each particle and its position along the DNA. As a result, Chen proposed a formula to optimize PAINT imaging.

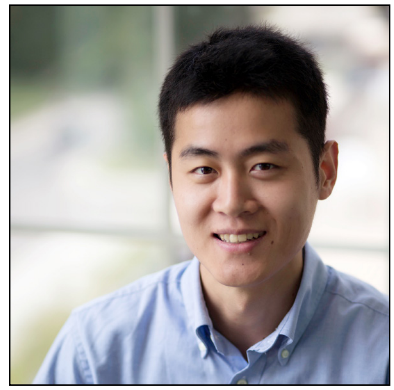
For this study, Chen excited individual YOYO-1 dyes in DNA solution using a 473 nm laser. With each new dye added, Chen needed to photobleach the previously excited YOYO-1 molecule.

"If a second dye (is) bound to the DNA with the first one present, we cannot resolve (the image)," Chen said. "There is a huge background noise next to the first dye, so you have to bleach it fast enough at the same time the new molecule is coming."

Although Chen said the research is fundamental for fluorescence techniques, it provides a starting point for later research on topics such as DNA origami, virus imaging and gene regulation.

"The final conclusion of this is that we can measure the bleaching rate separately, and we can calculate the diffusion rate," Chen said. "Then we can find statistical balance between the power density (of the laser) and the amount of solution we need for imaging."

Dissertation Award



Jingzhou Wang (Photo: Jingzhou Wang)

NQPI is proud to announce Jingzhou Wang as the recipient of the 2017 NQPI Outstanding Dissertation Award. Wang earned his Ph.D. in Electrical Engineering under the supervision of Ohio University professor of Electrical Engineering and Computer Science and NQPI member Wojciech Jadwisienczak in October 2016. His dissertation was titled, "Optical and Electrical Study of the Rare Earth Doped III-nitride Semiconductor Materials."

Wang was recognized for his impressive publication record, prior research awards, and academic achievements. In his dissertation research, Wang applied deep-level transient spectroscopy (DLTS) to rare earth doping in III-nitrides. Jadwisienczak described his former student as "talented, technically skilled, highly motivated and determined." Jadwisienczak noted that Wang's work has garnered interest from other researchers, who have applied his findings to numerical simulations describing quantum well structure of rare-earth elements.

Wang is now a technical patent claims evaluator for Global Prior Art, a Boston-based company that specializes in intellectual property management. "I'm glad to receive the NQPI Outstanding Dissertation award after years of hard work as a Ph.D. student," Wang said. "Study(ing) at (OHIO) was a great experience. I appreciate the help from all my friends and colleagues. Go Bobcats!"

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