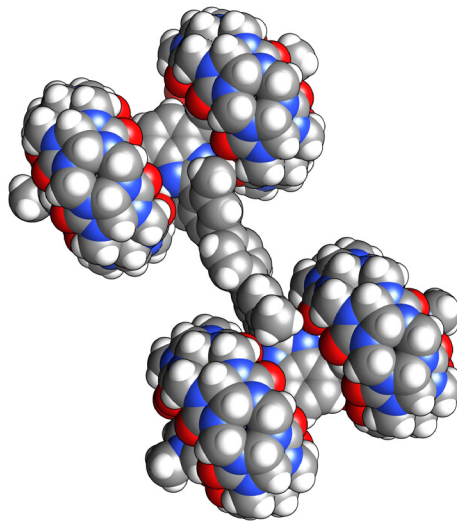


Nanoscale NASCAR

Imagine a phone that turns into a football and then back into a phone. It seems impossible. If scientists can figure out how to manipulate the atomic structure, a lot of unthinkable inventions could become reality, said Saw-Wai Hla, an Ohio University physics and astronomy professor and NQPI member. He explained that imagining the impossible is what motivated his decision to participate in the international NanoCar Race, where teams will race molecular cars.

“The whole competition is not just about building the car...We are trying to develop a technology to transport at the molecular scale,” Hla said.

The international race will be held in Toulouse, France, this fall. Teams have been synthesizing molecules to function



Ohio University team's molecular car design concept, the "OHIO Bobcat Nano-Wagon."

like cars for the competition. Ohio University will compete against other teams from the United States, France, Germany, Japan, and Austria. At the race, the molecular cars are driven through a track made of crystalline gold. Each car in the race measures a few nanometers in length, so small it can only be seen using a Scanning Tunneling Microscope (STM).

Hla and Eric Masson, an Ohio University chemistry and biochemistry professor and NQPI member, have been building their car since last year. Masson's team of graduate students is constructing the race car while Hla's team will drive the car. Masson explained that the nanocar is made of two types of organic molecules: an "H"-shaped frame and four Cucurbituril

See **Molecular Cars** page 4

Sculpting the Band Gap

Ohio University physics and astronomy professor and NQPI member, David Drabold, has collaborated with professors Parthapratim Biswas and Raymond Atta-Fynn, from the University of Southern Mississippi and University of Texas, Arlington, respectively, through an NSF-funded grant to develop a new approach to modeling materials.

Drabold stated, "The three of us put this proposal together and submitted it. It's for \$520,000 and it was funded a few months ago." The proposal was titled "Joint Utilization of Experimental and Theoretical Information: A New Paradigm for Modeling Complex Materials." The challenge of the proposal was to formulate effective ways to design computer models of materials with preferred characteristics (to enable computer design and engineering of

materials), and it outlined one of the first successful attempts to meet this challenge.

Drabold's student, Kiran Prasai, along with Biswas and Drabold, recently published an article, "Sculpting the Band Gap: a Computational Approach," in which they introduced a way to design materials with a desired electronic structure. This work was a helpful illustration of the approach that was useful in convincing the NSF of the significance of the proposed work.

Outreach is an important part of the award. "We intend to do some outreach, especially in the University of Southern Mississippi. There is significant poverty there, and an underserved and underrepresented population. Previous experience has shown that a program to involve local people in the university and physics in particular can open doors for underserved populations

and obtain some promising new students. We're also going to look into starting a program similar to our HTC¹ program at the University of Southern Mississippi, probably in their physics department."

Drabold is optimistic about his plans for developing the research while he and his colleagues plan to work on the outreach. He states, "All of this work is exciting, and it is the kind of stuff that makes the job worthwhile."✱

¹The Honors Tutorial College (HTC) at Ohio University incorporates all the essential features of the traditional British college tutorial system of undergraduate education developed at Oxford and Cambridge Universities. Students in HTC interact very closely with faculty; a large fraction of their class time is spent in individual meetings with faculty members.

Redefining
Microelectronics
Page 2

Measuring
Nanotemperature
Page 3

A New Perspective on
Down Syndrome
Page 4



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Director's Corner



Dear Colleagues:

Warmest greetings from Athens, Ohio! Welcome to the 15th edition of the NQPI Newsletter; I hope you enjoy reading about the latest activities and research being conducted by NQPI members.

One exciting example is Eric Masson and Saw Hla's involvement in the first-ever "NanoCar Race," to be held this fall in Toulouse, France. Hla and Masson will be competing with other prominent groups from around the world in an attempt to "drive" a nanometer sized molecule around single atom obstacles. We wish them luck!

You will also learn from Hugh Richardson's group about issues, challenges, and advancements associated with measuring temperature at the nanoscale. Another NQPI member, Allan Showalter, discusses his genetic work on plants to develop improved salt tolerance which may be useful in certain parts of the world where abundant fresh water is at a premium. We would also like to congratulate Tadeusz Malinski on his grant to study the molecu-

lar physiology of Down Syndrome, an area with the potential to improve many lives around the world. Savas Kaya is working to change the way we use electronics. These important broad topics, and the researchers investigating them, are a testament to the interdisciplinary strengths of NQPI.

We also take great pride in our students' achievements. Mahmoud M. Asmar was recently awarded the NQPI Outstanding Dissertation Award. Doctoral student Kiran Prasai was recently awarded the \$15,000 "Donald Clippinger Graduate Fellowship." Prasai, a student of NQPI member David Drabold, is developing new methods of constructing computer models of materials useful in a variety of electronic applications, particularly for photovoltaic and memory materials. We would also like to congratulate all the student participants of our joint CMSS/NQPI poster session last fall.

Lastly, NQPI has a new website that is being updated regularly. Please visit www.oungpi.org to learn about the latest NQPI research, grants, publications, event photos and more.

I wish you a relaxing summer,
Eric Stinaff, NQPI Director

NanoUpdates

Doctoral student Kiran Prasai was awarded the "Donald Clippinger Graduate Fellowship" for computer design of materials research.

NQPI member Alexander Govorov was recently named Ohio University's Distinguished Professor for 2016. The Distinguished Professor Award is the university's highest academic honor; Govorov is the fourth NQPI member to achieve this honor.

Additionally, Govorov received two \$70,000 grants from Rice University for his project titled "Coherent Effects in Hybrid Nanostructures for Lineshape Engineering of Electromagnetic Media."

NQPI member Tadeusz Malinski published a paper titled "Development of Novel FP-based Probes for Live-Cell Imaging of Nitric Oxide Dynamics" in *Nature Communications*.

Poster Session



Students showcase their research in Clippinger.

NQPI, along with the Condensed Matter and Surface Science (CMSS) Program sponsored their bi-annual poster session on November 19, 2015.

Thirty-six graduate students presented posters, which were judged by NQPI and CMSS faculty. Cash prizes were awarded for first and second place. Students presented their research in an informal setting, Clippinger Hall, and received coaching and feedback from the faculty.

The poster session showcased the outstanding, high-impact research being done by our faculty and their students.✱

Redefining Microelectronics

A jacket that functions as a digital wallet or a blood glucose monitor may seem futuristic, but Ohio University electrical engineering and computer science professor and NQPI member, Savas Kaya, is developing a technology to make these devices possible within three to five years.

Kaya's lab is creating "printed electronics" to incorporate wireless communication devices into ordinary items, using a low-cost, high efficiency system. With this technology, almost any surface - plastic, paper, textile or pavement - could have embedded sensors or its own microchip computer. Kaya's lab is aiming to use printed electronics in microfluidic systems to control the flow of solutions within these devices. A set of tiny capillary channels designed to function in tandem located in close proximity to the printed sensors and electronics can enhance microfluidics devices and transfer data wirelessly.

Printed electronics in Kaya's lab are created by using an inkjet printer and a mi-

croplotter. The inkjet expels a solution in a specific configuration, layer by layer. The microplotter, which functions similarly to a fountain pen, contains a glass capillary tube that is used to create fine patterns at a resolution of just a few microns.

The devices that are being used for the project were funded through an OU 1804 Award Kaya received last summer. The project was also supported by NQPI and the Condensed Matter & Surface Science program. Previously, Kaya's lab began developing these techniques using a standard inkjet computer printer that lacked sophistication and resolution needed for complex structures.

Kaya said he envisions the development of numerous novel devices, including patient health and environmental monitors as well as home gas sensors. He said the technology might even eliminate the need for firemen, policemen and servicemen to carry unwieldy equipment for sensing and communication.✱

Plants' Salt Response Suggests Biochemical Connection

Ohio University environmental and plant biology professor and NQPI member, Allan Showalter, is investigating the interplay between five plant genes in *Arabidopsis thaliana* that may contribute to saline tolerance. The genes (*GALT2*, *GALT5*, *SOS5*, *FEI1* and *FEI2*) encode proteins that perform distinct biochemical functions.

The knockout of any one of the genes results in a common phenotype: roots that swell in the presence of salt. The effect is unchanged when the expression of all five genes is hindered. Showalter said he believes the kinases encoded by *FEI1* and *FEI2* may contribute to a signaling pathway that involves *GALT2*, *GALT5* and *SOS5*. *GALT2* and *GALT5* encode enzymes which transfer sugars onto a cell wall protein encoded by *SOS5*.

"If you see the same (phenotype) in a multiple knockout mutant, then that implies those genes are in the same pathway," Showalter said. "If they were in two different pathways, you might expect the



Allan Showalter's lab is studying *Arabidopsis thaliana*, a plant commonly used as a model organism for genetic studies.

root to swell even more. But that wasn't the case."

Molecules in a linear pathway are interdependent, meaning that the knockout of any associated gene would halt the process entirely. If the knockout of any of the genes - or several genes at once - results in a common phenotype, the encoded proteins may function together.

Showalter's group is working to provide evidence for a biochemical connection be-

tween the proteins encoded by these genes by performing an enzyme-linked immunosorbent assay (ELISA). In essence, a kinase (encoded by *FEI1* or *FEI2*) is made to adhere to a plastic well. The sugar-linked adhesion protein (encoded by *SOS5*) is added and washed. The group can then test for a tag sequence on the sugar-linked protein. If the tag is present after washing, Showalter said he will know the molecules share a common pathway and physically interact with one another.

He said a better understanding of physiological responses to salt may allow for the development of genetically engineered crops that can tolerate high-salt environments such as those in certain parts of the Middle East and in other parts of the world.

"People are thinking about...how all these components of a salt-sensing, salt transduction system are working," Showalter said. "But you have to understand how this pathway works in order to manipulate it."✱

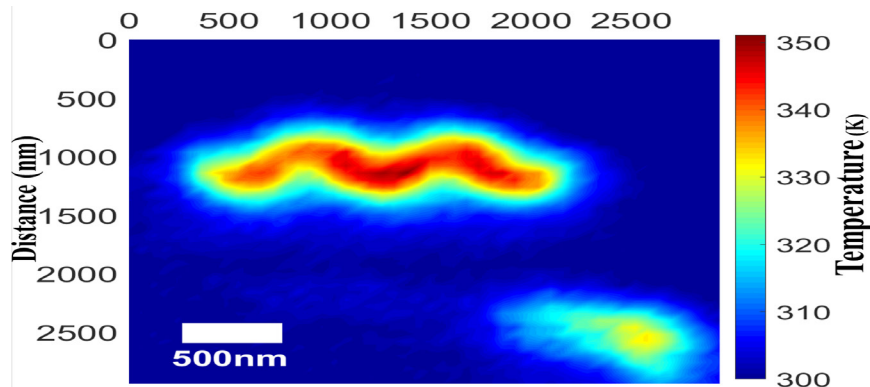
New Technique for Measuring Temperature at the Nanoscale

Picture an object that is approximately one thousand times smaller than a human hair. Now imagine trying to test the temperature of this object you can't even see. Ohio University chemistry and biochemistry professor and NQPI member, Hugh Richardson, and graduate student Susil Baral, have made this their mission.

Richardson and Baral are developing a technique to test temperature at the nanoscale, which may be helpful in various applications: from better electronic devices to improved medical treatments, the pair explained.

"Temperature measurement at nanoscale provides an ideal way to understand interesting properties of the particles at the nanoscale," Baral said.

For example, one common treatment for cancer is hyperthermia. This method involves using high temperatures to kill cancerous cells because cancerous cells are more sensitive to heat. Hyperthermia's major limitation is that the treatment can often destroy healthy, noncancerous cells, as well. If the temperature of the healthy tissue near the cancer cells could be measured, treatments like hyperthermia could be further developed.



Thermal image of a lithographically fabricated gold nanosnake imaged with Er^{3+} based nanothermometry.

However, you can't stick a traditional thermometer into something as small as a cell. Richardson and Baral believe that using optical manipulation and microscopic imaging may be useful to probe temperature at the nanoscale.

To test their new nanotemperature measurement technique, the pair has been working with synthesized objects at the nanoscale. They used light to increase temperatures. Then, images are taken to see how the heat is being distributed inside the nanosized object.

Another limitation is that measuring objects with light blurs the image if the object is

smaller than the diffraction limit (approximately 250 nanometers). This blurring distorts the temperature measurement. This limitation can be overcome by using nanoparticle thermal sensors that are smaller than 250 nanometers.

Richardson's team is working to move beyond technical limitations to improve the optical temperature measurement technique. Although Richardson could not release any more specific details about the technique just yet, he is confident that the optical method will push the frontier, and said to expect a publication detailing their findings in the near future. ✱

A New Perspective on Down Syndrome

Ohio University chemistry and biochemistry professor and NQPI member, Tadeusz Malinski's, work on cardiovascular and neuronal function attracted the attention of Ita Pluta-Plutowska, who recently gifted him \$400,000 to study the molecular physiology of Down Syndrome.

Down Syndrome affects approximately 400,000 people in the United States, according to the National Down Syndrome Society. However, Malinski said the disorder is understudied and poorly funded. Patients exhibit accelerated aging, and experience cognitive decline similar to that of Alzheimer's Disease. Malinski said although the two conditions have different causes, the physiological symptoms are similar to those of normal aging.

Malinski has gained worldwide recognition for his work on the dysfunctions of the nervous and cardiovascular systems. Malinski's approach for studying Down Syndrome encompasses both systems, which will allow his team to characterize the disorder comprehensively. Previous studies have focused primarily on the brain, even though most patients tend to develop heart complications.

Malinski's group is using a nanosensing device to track changes in molecules within a single cell. He is measuring the concentrations of three critical molecules in the brain and heart that are linked to aging: nitric oxide, superoxide and peroxyntirite. Nitric oxide is a vasodilator and an impor-

tant signaling molecule. Superoxide and peroxyntirite are oxidative species that react rapidly with nitric oxide, diminishing the molecule's concentration within the cell.

Imbalances of these molecules can trigger cell death and system deterioration. In the brain, the resulting "gaps in communication" due to neuron loss can cause cognitive decline. Malinski said this nanosensing device will allow him to visualize the mechanism in real time.

"This is the beauty of nanotechnology and nanomedicine," Malinski said. "We can now perform (these measurements) in a very small volume, and we can look for the processes and visualize how they occur in time and space."

Malinski's group is currently characterizing the concentration of each molecule using a mouse model. Ultimately, he intends to develop treatments to restore system balance by maximizing the concentration of nitric oxide and minimizing the concentration of the reactive species. Malinski believes his methods will yield insight on therapeutic treatments that may improve the lives of people affected by Down Syndrome. He said early interventions are critical for the prevention of neuronal and cardiovascular decline.

"The human factor here is tremendous," Malinski said. "These people are suffering, but so are the people who are taking care of them. You not only extend the life, but the quality of life."✱

Molecular Cars...

Continued from page 1

"wheels." The name comes from the resemblance of these molecules to pumpkins, which are members of the Cucurbitaceae family of plants.

"There's no chemical bond between the frame and the wheels, so the frame is really floating into the wheels," Masson said.

Given their design, the biggest challenge will be ensuring that the frame stays in place, Masson said. He said that a wheel may potentially fall off during the race and the team would have to rebuild the car on the gold surface to continue. "In fact, we would be absolutely delighted if that incident were to happen during the race!" he said, noting that that reconstruction process has never been published.

While Masson's team is working on the chemical synthesis of the car (i.e. its

engineering), Hla's team is strategizing how to drive a car that does not have a steering wheel. Hla explained that the car will be pushed using an STM's tip. The tip is a nanosized metal needle that will propel the car. Several test drives are necessary to ensure the car will move according to plan.

Maintaining the temperature of the molecules is also essential. If the molecules get too hot, they will not stop moving. So, the car has to be cooled using helium to -400 degrees Fahrenheit prior to the race.

The event will be filmed live, showing photo images captured at various points in the race via the STM. If Ohio University wins, they will receive worldwide recognition. But for the NQPI members the real prize is proving that science can make almost anything seem possible.✱

Mahmoud M. Asmar Wins 4th Annual NQPI Outstanding Dissertation Award



Mahmoud M. Asmar

NQPI is proud to announce Mahmoud M. Asmar as the recipient of the NQPI Outstanding Dissertation Award. He will receive a \$500 prize for his dissertation titled, "Electronic and Spin Transport in Dirac-Like Systems." In his dissertation, he focused on the study of the relation between symmetric and transport phenomena.

Asmar was born and raised in Bogota, Columbia and moved to Palestine as a teenager. Asmar received his Ph.D. in physics and astronomy from Ohio University in 2015, where he worked with physics and astronomy professor and NQPI member, Sergio E. Ulloa, who served as his dissertation advisor. He is currently a post-doctoral researcher at Louisiana State University in Baton Rouge, where he is investigating topological insulator interfaces and cold atomic systems.

Offering career advice, Asmar said, "My advice to the future physics majors is to love what they do, because few people can do it."

When not busy in a physics lab, Asmar's hobbies include reading philosophy books and keeping up with politics. His future plans are to continue with his physics research.✱

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