

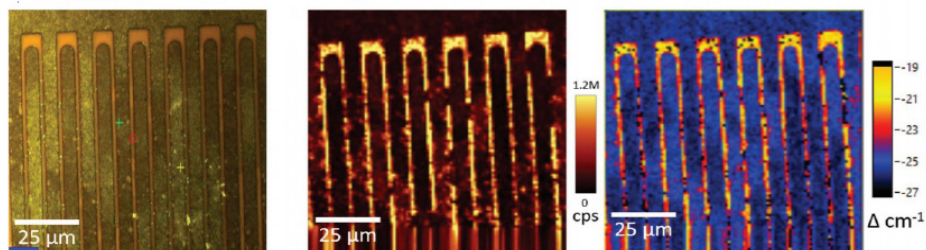
Growing 2D Devices: A Potentially Patentable Method

Imagine growing the materials you need for a device right onto the metal contacts in a circuit. Ohio University Physics and Astronomy professor and NQPI director Eric Stinaff has already filed for a provisional patent that exploits this procedure.

Stinaff and fellow Physics and Astronomy professor and NQPI member Martin Kordesch successfully demonstrated how a chemical vapor deposition (CVD) technique can be used to grow monolayer transition metal dichalcogenides (TMDs) on a molybdenum pattern.

“The metal (molybdenum) acts ... as a seed and a catalyst,” Stinaff said.

The application of Stinaff’s technique can potentially simplify manufacturing of optoelectronic devices such as LEDs and solar cells. Instead of performing extensive lithog-



Optical image, photoluminescence map, and Raman analysis map (left to right) of MoS₂ film formation between molybdenum features.

raphy to fit a metallic pattern to pre-grown TMDs, Stinaff begins by producing the molybdenum patterns to catalyze TMD growth.

TMDs are compounds typically referred to as MX₂, where M symbolizes a transition metal and X represents the surrounding chalcogen atoms. The compound of choice for Stinaff was molybdenum disulfide (MoS₂), a

monolayer semiconductor. Since this TMD only consists of a single layer, MoS₂ has a negligible volume and many other properties that are useful for optoelectronic devices.

CVD involves treating a metallic oxide powder with sulfur residue through intensive heating in a furnace. Stinaff’s CVD procedure includes molybdenum trioxide

(See Growing 2D Devices, page 4)

NIH Supports Goetz Team to Study Novel Therapeutic

Ohio University Chemical and Biomolecular Engineering professor and NQPI member Douglas Goetz and colleagues were recently awarded a grant from the National Institutes of Health (NIH) to characterize an inhibitor of glycogen synthase kinase 3 (GSK3), an enzyme implicated in many disorders including diabetes, Alzheimer’s disease and cancer.

The work is a collaboration with OHIO Heritage College of Osteopathic Medicine (HCOM) professor Kelly McCall and OHIO Chemistry and Biochemistry professors Stephen Bergmeier and Jennifer Hines. An unexpected finding during a screening study involving this group and the late Leonard Kohn, a former HCOM member, turned attention toward further investigation of inhibitors, Goetz said.

“We were working on developing a nov-

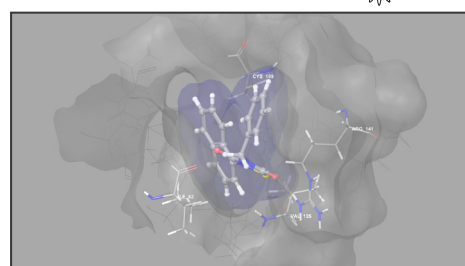
el therapeutic starting from the drug me-thimazole commonly used to treat thyroid disease,” Goetz said. “We screened a series of compounds made in (Bergmeier’s) lab, and ... one only hit GSK3 alpha and beta.”

A GSK3 inhibitor called Tideglusib was previously designed by another group and tested in clinical trials as a therapeutic for Alzheimer’s disease. However, Tideglusib did not produce a clinical benefit. Goetz said that their inhibitor is both more specific and more potent than Tideglusib.

The group does not yet fully understand the mechanism that accounts for this specificity. They have synthesized structurally similar molecules that also function as GSK3 inhibitors. The team will work to determine the basis of their unique inhibitory function. Hines is exploring their interactions with GSK3 using molecular modeling (see

figure). Additionally, the team will introduce their molecules into human macrophage cells to study inhibition in a cellular system.

Broadly, the team is working to determine what makes these small, relatively simple compounds such effective inhibitors. These studies will potentially yield critical data for designing novel therapeutics for GSK3-mediated diseases. ✨



Molecular modeling image of Tideglusib bound to GSK3, a kinase that is involved in numerous medical disorders (courtesy of J.V. Hines).

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Director's Corner



Dear Colleagues,

Warmest greetings from the campus of Ohio University in Athens, Ohio. We hope you enjoy reading the 17th edition of the NQPI newsletter

and hearing about the latest activities and research being conducted by our members.

One such exciting example is work being done by Chemical and Biomolecular Engineering professor Dr. Doug Goetz, who is studying an enzyme implicated in many disorders including cancer, diabetes, and Alzheimer's disease. We also talk with Mathematics professor and NQPI member Dr. Tatiana Savin, who has developed a theoretical method to solve Hele-Shaw problems. I recommend you check out the article about Dr. Wojciech Jadwisnienczak on fostering Arab and American relations with regard to scientific programs.

I invite you to learn about NQPI's newest member, Dr. Amir Farnoud, a

Chemical and Biomedical Engineering professor who is investigating pulmonary fungal infections at the nanoscale. We are excited to welcome Dr. Farnoud to NQPI.

We take serious pride in our students' work. We hope you enjoy the article on former graduate student Andrada-Oana Mandru, and her work building atomic layers of various magnetic materials. Andrada was a physics graduate student who graduated in 2016 and recently was awarded the 2016 NQPI Outstanding Dissertation Award.

In addition to these exciting developments, our professors are looking forward to working with newly appointed president of Ohio University Duane Nellis, who is a geographer by training and comes to us from Texas Tech. Welcome, President Nellis!

Finally, please visit our regularly updated website, www.ounqpi.org, to learn about the latest NQPI research publications, grants, event photos and more.

I wish you all a productive spring and a relaxing summer.

Sincerely,

Eric Stinaff, NQPI Director

NanoBytes

■ Eight NQPI members authored a total of 37 abstracts presented at the 2017 American Physical Society March Meeting.

■ Physics and Astronomy professor Alexander Govorov published a paper titled, "Cooperative Expression of Atomic Chirality in Inorganic Nanostructures" in *Nature Communications* in February.

■ NQPI student Sara Sand was recently accepted to MIT's Materials Science and Engineering Ph.D. program. For more information on Sand's acceptance, read the article at www.ounqpi.org.

■ Raymond Humienny, an M.S. student in the Scripps School of Journalism, joined the NQPI newsletter staff in January. Raymond earned his B.S. in physics from Xavier University in 2016.

NQPI Welcomes New Member Amir Farnoud

Ohio University Chemical and Biomolecular Engineering professor and NQPI's newest member Amir Farnoud has spent the past thirteen years molding his ideal research career in bioscience.

"I thought, you know, if I do something that will someday lead to a drug that will save someone's life – if I have one of these in a 30- or 40-year career of research – then that's all I really want to do," Farnoud said.

Nominated by OHIO Physics and Astronomy professor and NQPI director Eric Stinaff on September 27, 2016, Farnoud was approved as a member of NQPI on October 13, 2016.

Farnoud studied nanoscale pulmonary research during post-doctoral work from 2013 to 2015 at Stony Brook University in New York. He investigated cell membrane properties of *Cryptococcus neoformans*, a pulmonary fungal pathogen that hides in macrophages of immunocompromised individuals and causes meningitis. Farnoud worked on changing the chemical struc-

ture of glucosylceramide, a lipid produced by the pathogen.

"The thing is if the fungus can't produce this one lipid, it can't kill mice," Farnoud said "We're still trying to figure out what's so important about this one lipid."

Farnoud began teaching at OHIO in 2015, continuing research on nanoparticle-biomembrane interactions, drug delivery for fungal infections and nanoparticle-protein interactions. Currently, Farnoud said he is focusing on the effects of hookah and e-cigarette smoke on lung surfactant function.

"If you add a lot of nicotine to your lung surfactant, nothing happens," Farnoud said. "But if you add e-cigarette smoke, surfactant function changes, so there is something in there that is not nicotine that is doing something."

In the meantime, Farnoud said he has enjoyed teaching and being able to be a part of helping students grow as scientists.

"Research is kind of the long-term satisfaction, whereas teaching is kind of the

short-term satisfaction," Farnoud said. "You see people coming in as kids and going out as engineers, so that is very rewarding."

For more information about Farnoud, please see the extended version of this text at www.ounqpi.org. ✨



Amir Farnoud in his laboratory in Stocker Center.

Fostering Arab-U.S. Science Relations

Science not only breaks boundaries but it builds communities across international barriers. On November 5, 2016, Ohio University's Wojciech Jadowski, professor of Electrical Engineering and Computer Science and NQPI member, helped expand scientific horizons at the fourth Arab-American Frontiers of Science symposium in Abu Dhabi, United Arab Emirates.

Inspired by former President Barack Obama's "A New Beginning" speech in Cairo, the National Academy of Sciences (NAS) launched the first Frontiers symposium in 2011, an interdisciplinary and international effort to bring together U.S. and Arab researchers with similar interests. Frontiers serves as not only a collaboration of ideas but as an application of research pertaining to Arab regions from scientists of the United States and the Arab League.

"The Frontiers symposium is an unprecedented opportunity for U.S. and Arab scientists to share state of the art knowledge on a wide array of topics and explore how these findings apply to the regional context," said Dalal Najib, senior program officer at the NAS.

Jadowski showcased ongoing re-

search in Frontier's session on Solar Energy and Water for Sustainable Living. His collaborations with Arab partners in Tunisia, Saudi Arabia and Pakistan explore the development of novel materials for solar energy conversion, as well as mercury-free deep ultraviolet devices for germicidal applications (in general) and chemical additive-free water treatment (in particular).

"I found that U.S. researchers, who are working specifically on solar energy and water problems, can find opportunities to bolster their efforts when interacting with people from Arab countries who consider these technological challenges as critical for their nations," Jadowski said. "Thus, there is a lot of potential in Frontiers. People who work with that shall definitely consider it as a step forward toward fostering their collaboration."

Back in Athens, NQPI has served as a catalyst for former Arab students to develop research relationships between their home countries and the U.S. For example, Jadowski collaborates with former OHIO and NQPI students Mohammad Ebdah, Hamad Albrithen and Aurangzeb Khan. Ebdah and Albrithen work as professors at

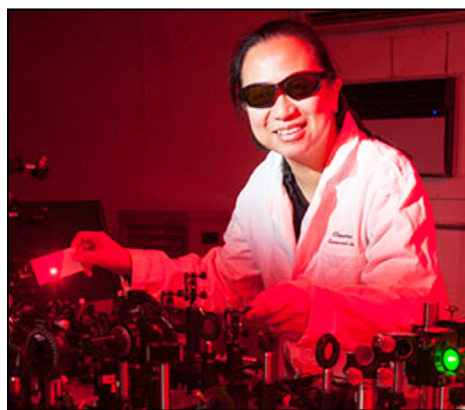
King Saud University in Riyadh, Saudi Arabia; and Khan works as a professor at Abdul Wali Khan University in Mardan, Pakistan. Albrithen said these collaborations facilitate a healthy international rapport between scientists.

"I would suggest the highest level of engagement with (international collaboration) since going international requires breaking barriers and building bridges," Albrithen said. ✨



Jadowski poses a question during Frontiers.

Toying with Molecular Interfaces



Dr. Katherine Cimatu in her lab in Clippinger Hall.

Ohio University Chemistry and Biochemistry professor and NQPI member Katherine Cimatu recently published a series of papers in the *Journal of Physical Chemistry C* describing the roles of various functional groups in the molecular conformation of monomers and polymers at different interfaces.

Polymer coatings and inhibitors have many commercial applications including prevention of pipeline corrosion and prevention of biofilm formation.

Cimatu's group uses sum-frequency generation (SFG) to characterize methacrylate-

based functional monomers and polymers at the air-liquid (for monomers), solid-liquid, and air-solid (for polymers) interfaces. Chemical structure influences the orientation and conformation of monomeric and polymeric molecules at the bulk and interface.

"SFG is very interface-specific," Cimatu said. "We isolate the consequences of the change in the chemical structure from the bulk to the interface."

First, the group characterized the influence of three substituents on monomer- and polymer-air interfaces: hydroxy-, as a reference; chloro-, for halide/electronic effects; and phenoxy-, for steric (bulk) effects. They found that substitution at the ethyl group affected the functional monomer conformation. In contrast, the alkene-methyl group was not present in the polymer film.

Using polarization combination analysis and mapping, they calculated the degree of ordering in the specific monomer 2-methoxyethyl methacrylate. The monomer was oriented and partially ordered, with varying substituents such as methoxy-, methylene-, methyl- and alkene-methylene groups at the interface. Cimatu said she un-

derstands more fully the interfacial properties of this monomer.

Finally, they addressed the effects of four bulky substituents: methoxy-, phenoxy-, isopropoxy- and tert-butoxy- methacrylate-based functional monomers. These groups affected the number density of less bulky ones, allowing the bulky substituents to orient themselves toward the interface.

Cimatu is collaborating with OHIO Chemical and Biomolecular Engineering professors Srdjan Nescic, Marc Singer, Sumit Sharma and David Young to study corrosion inhibitors on steel surfaces through OHIO's Institute for Corrosion and Multiphase Technology. Additionally, Cimatu collaborates with Chemistry and Biochemistry professor and NQPI member Jixin Chen to study perovskite materials used in solar cells.

"What we're doing right now with these functional monomers is just models to fully understand how these multi-functional and complex small molecules behave at different interfaces," Cimatu said. "But with this new knowledge, hopefully, we can design new monomers and create polymers that will be applicable as coatings and inhibitors." ✨

Math Breaks Through Boundaries

Ohio University Mathematics professor and NQPI member Tatiana Savin is utilizing her unique expertise to address physical problems using mathematical tools.

In a paper accepted for publication in *Contemporary Mathematics* in collaboration with Israel Institute of Technology professor Alexander Nepomnyashchy and Savin's Ph.D. student, Lanre Akinyemi, derived a model to obtain exact solutions for the Muskat problem, which is a two-phase version of a celebrated Hele-Shaw problem.

Savin's group developed a theoretical method to control the evolution of the interface separating two fluids in a Hele-Shaw cell. The cell consists of two parallel plates with two fluids sandwiched in a narrow gap between the plates. There are two classical formulations of the Hele-Shaw problems: the one-phase problem and the two-phase (Muskat) problem. In one-phase problems, one fluid is viscous while the other is inviscid, so the pressure on the free boundary is a known function.

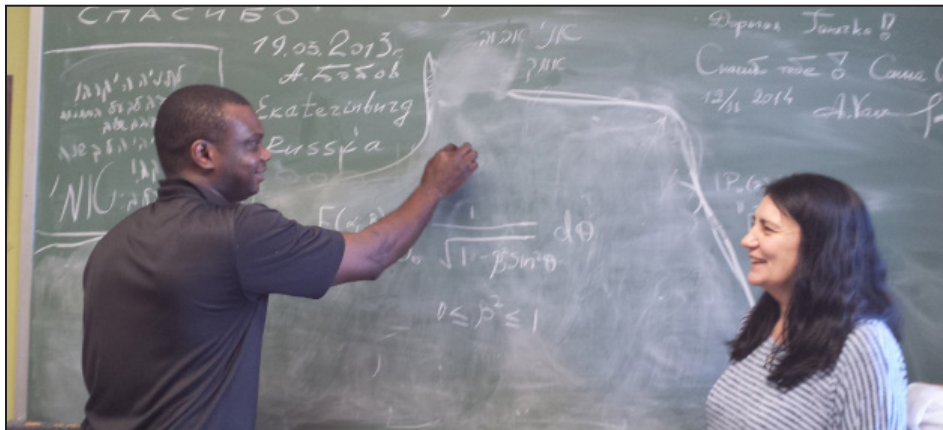
In Muskat problems, the pressure on the boundary is unknown.

Several moving boundary processes can be reduced to Hele-Shaw flows after some idealizations, including solidification, dendritic crystal growth, electrodeposition, viscous fingering and bacterial growth. Savin said her work has implications to crystal growth and to flows in porous media.

"Because I'm a mathematician, I'm more interested in a certain type of differential equation," Savin said. "But sometimes they happen to describe important processes."

One of Savin's current projects involves the interplay between manipulation of the sinks, sources, and variation of gap width between plates in the Hele-Shaw cell for one- and two-phase problems. From a broader perspective, Savin said her work involves systems with moving interfaces.

"It's mainly developing of mathematical tools," Savin said. "But it sometimes can describe processes related to materials science."✱



Savin (right) and Akinyemi (left) use math to describe physical processes such as crystal growth.

Growing 2D Devices (cont.)

(Continued from page 1)

(MoO_3) and sulfur powder to grow MoS_2 on a molybdenum pattern sitting atop a substrate. A flow of argon is used to treat the MoO_3 with the sulfur residue, decomposing the MoO_3 .

"The molybdenum powder will essentially vaporize and ... interact with the sulfur," Stinaff said. "What's happening in that (reaction is) you're forming MoS_2 constituents, or atoms, and they'll meet up with other ones and start to build the material."

Moreover, directed MoS_2 growth provides new research directions. When used in CVD, Stinaff said that metals such as titanium produce little to no MoS_2 growth and

might be useful for designing complex patterns. Additionally, Stinaff has observed how other TMDs interact with MoS_2 growth and conductivity. Tungsten disulfide (WS_2) is another TMD that Stinaff has used on molybdenum to create hetero-structures of WS_2 and MoS_2 layered material.

With future research focused on determining the electrical properties of test devices, Stinaff said the team hopes to eventually turn this project into an industrial method.

"What I think is really important about the work that we're doing is it provides a very simple way to make devices using these materials," Stinaff said. ✱

Dissertation Award



Andrada-Oana Mandru

NQPI is pleased to announce Andrada-Oana Mandru as the recipient of the 2016 NQPI Outstanding Dissertation Award. This honor recognizes her quality research, presentations, multiple publications and numerous awards.

Her dissertation was titled: "Ferromagnetic Thin and Ultra-Thin Film Alloys of Manganese and Iron with Gallium and Their Structural, Electronic, and Magnetic Properties." Mandru's thesis work used Molecular Beam Epitaxy (MBE) to build atomic layers of various magnetic materials. Mandru, a student of Physics and Astronomy professor and NQPI member Arthur Smith, will receive a \$500 prize for the Dissertation Award.

Mandru is the fifth winner of this annual award. Previous winners were Ginetom Diniz, Andrew DiLullo, Zhiyuan Fan, and last year's winner Mahmoud Asmar.

In 2015, Mandru was awarded the American Vacuum Society's Russell and Sigurd Varian Award and Leo M. Falicov Award.

David Ingram, Physics and Astronomy department chair and NQPI member said, "Andrada was a model student in all departmental activities." He said he found her thesis to be "of the highest level, both in terms of clarity and content."

When asked about receiving the award, Mandru said, "I was really happy to hear that I received the award! I am also happy to see that hard work pays off in the end." ✱

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