From Cameras to Computers, New Material Could Change How We Work and Play

Serendipity has as much a place in science as in love.

That’s what Northeastern physicists Swastik Kar and Srinivas Sridhar found during their four-year project to modify graphene, a stronger-than-steel infinitesimally thin lattice of tightly packed carbon atoms. Primarily funded by the Army Research Laboratory and Defense Advanced Research Projects Agency, or DARPA, the researchers were charged with imbuing the decade-old material with thermal sensitivity for use in infrared imaging devices such as night vision goggles for the military.

What they unearthed, published Friday, July 31, 2015, in the journal Science Advances, was so much more: an entirely new material spun out of boron, nitrogen, carbon, and oxygen that shows evidence of magnetic, optical, and electrical properties as well as DARPA’s sought after thermal sensitivity for use in infrared imaging devices such as night vision goggles for the military.

The pair was familiar with “alloys,” controlled combinations of elements that resulted in materials with properties that surpassed graphene’s—for example, the addition of boron and nitrogen to graphene’s carbon to connote the conductivity necessary to produce an electrical insulator. But no one had ever thought of choosing oxygen to add to the mix.

What led the Northeastern researchers to do so?

“We had to start from scratch and build everything,” says Kar, an assistant professor of physics in the College of Science. “We were on a journey, creating a new path, a new direction of research.”

Oxygen, of course, is everywhere. Indeed, Kar and Sridhar spent a lot of time trying to get rid of the oxygen seeping into their brew, worried that it would contaminate the “pure” material they were seeking to develop.

“Well, we didn’t choose oxygen,” says Kar, smiling broadly. “Oxygen chose us.”

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continued on page 3

Notes from the Chair

The past academic year involved many new developments, both in our Department and in the College of Science. Earlier in the year Professor George Alverson was named the Associate Dean for Academic Affairs and his role as Executive Officer in the Physics Department was taken by Professor Armen Stepanyants. We are very grateful to both of our colleagues for their willingness to take on these important administrative service roles. This summer, Dean Murray Gibson decided to step down and take a sabbatical following his five year term as the founding Dean of the College of Science. We look forward to having Murray rejoin our faculty in the upcoming year.

Our search last year for a new faculty member specializing in theoretical particle physics was successful and we welcome Jim Halverson in his new role as an assistant professor. Jim comes to us from the Kavli Institute for Theoretical Physics (UC Santa Barbara) and has interests in string theory, phenomenology, and mathematical physics. He will be replacing one of our distinguished faculty members, Haim Goldberg, who has now retired. Also joining us this fall as a new assistant professor is Bryan Spring, who specializes in experimental biological physics and nanomedicine. Bryan comes to us, already with NIH funding, from Harvard Medical School and the Wellman Center for Photomedicine. In the context of funding, the department also congratulates Professors Mark Williams and Armen Stepanyants for their new NIH sponsored research grants, each totaling well over $1M.

This past year also saw the launch of the new Network Science Institute, which was spearheaded by Physics Professor Alex Vespignani. The Institute offers the nation’s first PhD in Network Science and occupies wonderful new interdisciplinary space at 177 Huntington Avenue. Those who would like to learn more about this rapidly developing field of research, which has origins in statistical physics, may want to visit the Institute website at http://www.networkscienceinstitute.org/.

Finally, this year the Department welcomed a new class of 45 undergraduate and 19 graduate students. Our new departmental website is now operational and Alumni and friends who are interested in donating to undergraduate co-op research or graduate fellowships can find the “giving” link at the bottom of the homepage http://www.northeastern.edu/cos/physics/.

The undergraduate fellowships mesh well with our recently approved BS/PhD degree program and offer research co-op opportunities with department faculty. Both the students and faculty want to thank our Alumni for their continued support.

-Paul Champion, Chair
A recent paper by Pran Nath, Distinguished Professor of Physics, was chosen as Paper of the Week on *Physica Scripta*, Journal of the Royal Swedish Academy of Sciences. It documents the great physics breakthroughs he and the physicists he worked with have made over the past 50 years while at Northeastern University. Nath has been a prolific researcher with over 400 papers in this period. However, his paper in *Physica Scripta* in particular captures the mind and the imagination of the reader in a way that shows how the field of particle physics has evolved over the past decades and how his own work was transformational in the evolution of the field.

In fact, looking back at his long and prolific career, Nath can easily reference the top moments that were transformational. “I would say there are three pivotal points in my career,” Nath explained, “I arrived [at Northeastern] in 1966 as an assistant professor, and very shortly after that, I started working on a project with colleagues that lead to a breakthrough. We developed a new Lagrangian approach to the study of physics of mesons and this approach continues to be valid several decades later.”

A lot of Nath’s stories could be told that way. The second breakthrough of his work came when he and his colleague, the late Richard Arnowitt, extended the theory of supersymmetry by bringing in gravity, which other scientists eventually developed into string theory.

The third breakthrough, arguably his magnum opus, was in helping create the Minimal Supergravity model known as mSUGRA, which joins the fields of supersymmetry, gravity and particle physics. The mSUGRA model predicts a host of new particles popularly known as superparticles. It is one of the most widely investigated models of particle physics and is currently continuing to be explored at the Large Hadron Collider—the world’s largest and most powerful particle accelerator, located in Geneva, Switzerland.

Superparticles have not been seen so far, but this is due to the high scale of energy required to see them, according to Nath. “It’s quite simple—we just haven’t reached the level of energy to see them.” According to the work Nath and his group have done, the discovery of the Higgs boson in 2012 at a mass higher than expected requires the superparticle mass to be high, which in turn requires the energy of the particle physics accelerators to be rather large to see them.

Nath explains that the biggest barrier to the exploration of new particle physics is ultimately the highest energy scale physicists can achieve in the laboratory. There could be a whole slew of new physics out there that we currently cannot reach because the energy scale is not high enough. But our ability to increase reachable energy scales has increased exponentially since the 1950s, and Nath, along with other scientists working in this field, have been there to shepherd much of the new science through this period.

Nath’s work has contributed significantly to a revolution in the way that particle physics was seen by the world. By the mid-60s, scientists were beginning to realize that particle physics known up to that point just was not enough to explain all the various and new phenomena around them. The development of new particle accelerators and advanced mechanisms for particle detection allowed for new physics to be explored at higher and higher energies, and the push to advance to ever higher energies isn’t slowing down anytime soon. This gives hope to Nath that his work will continue to be utilized in the exploration of new physics at larger particle accelerators in the future.

Nath started his research at Northeastern in the mid-60s. In the 50 years since, both Nath and the scientific community have seen the limits of what is possible tested by leaps and bounds. While, as Nath explains, our current knowledge of the Universe is incomplete, there is no denying the impact of the work he has done to try and rectify this problem.

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Emily Ashbolt, Biomedical Physics, 2017

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**Newly Created Graduate Physics Journal Club Activity Provides Platform to Discuss Research and Ideas**

The Physics Graduate Students’ Journal Club is a weekly activity organized by the physics graduate students for the graduate students. After working long hours doing research and teaching or taking classes, this is a time for us to meet, to have informal talks and to catch up with other graduate students, find out what they are doing and what excitement and joy they might have encountered or found within or outside their field.

The Journal Club provides a platform for us graduate students to share information. We have the opportunity to share excitement and joy in the form of short talks consisting of discussing a paper. During each discussion, we think critically of the paper. We ask questions as if nobody is listening to us or evaluating us; it is a brainstorming time, a freedom we enjoy and which enables us to learn from one another. The social interaction by students coming from across the globe is vibrant and dynamic and gives a collaborative international dimension to science, a community of young people who are transcending national barriers and who are able to think critically, thereby creating a rich discussion which broadens our knowledge of physics.

The success of this club is due to the strong and enthusiastic participation of the graduate student body from all physics disciplines confounded. We would like thank the Department of Physics for offering us such a platform and especially Professor Williams, Professor Champion, Professor Whiford and the staff members for their unconditional encouragement and support.

These are unforgettable memories of our graduate life, we have created a strong friendship which will last for a long time to come. In brief, the Physics Graduate Students’ Journal Club is awesome!

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Divakaran Munugesapillai, Graduate Student
“That’s where the Aha! moment happened for us,” says Kar. “We realized we could not ignore the role that oxygen plays in the way these elements mix together.”

“So instead of trying to remove oxygen, we thought: Let’s control its introduction,” adds Sridhar, the Arts and Sciences Distinguished Professor of Physics and director of Northeastern’s Electronic Materials Research Institute.

Oxygen, it turned out, was behaving in the reaction chamber in a way the scientists had never anticipated: It was determining how the other elements—the boron, carbon, and nitrogen—combined in a solid, crystal form, while also inserting itself into the lattice. The trace amounts of oxygen were, metaphorically, “etching away” some of the patches of carbon, explains Kar, making room for the boron and nitrogen to fill the gaps.

“It was as if the oxygen was controlling the geometric structure,” says Sridhar.

They named the new material, sensibly, 2D-BNCO, representing the four elements in the mix and the two-dimensionality of the super-thin lightweight material, and set about characterizing and manufacturing it, to ensure it was both reproducible and scalable. That meant investigating the myriad permutations of the four ingredients, holding three constant while varying the measurement of the remaining one, and vice versa, multiple times over.

After each trial, they analyzed the structure and the functional properties of the product—electrical, optical—using electron microscopes and spectroscopic tools, and collaborated with computational physicists, who created models of the structures to see if the configurations would be feasible in the real world.

Next they will examine the new material’s mechanical properties and begin to experimentally validate the magnetic ones conferred, surprisingly, by the intermingling of these four nonmagnetic elements. “You begin to see very quickly how complicated that process is,” says Kar.

Helping with that complexity were collaborators from around the globe. In addition to Northeastern associate research scientists, postdoctoral fellows, and graduate students, contributors included researchers in government, industry, and academia from the United States, Mexico, and India.

“There is still a long way to go but there are clear indications that we can tune the electrical properties of these materials,” says Sridhar. “And if we find the right combination, we will very likely get to that point where we reach the thermal sensitivity that DARPA was initially looking for as well as many as yet unforeseen applications.”

--news@Northeastern

From Cameras to Computers cont. from page 1

Department Nota Bene

New Faculty

James Halverson joins the University this fall as an assistant professor in the Theoretical Particle Physics Group. Dr. Halverson received his PhD from the University of Pennsylvania and was most recently at the Kavli Institute for Theoretical Physics in California.

Bryan Spring also joins the University this fall as an assistant professor. Prior to his appointment at Northeastern, Dr. Spring was at the Wellman Center for Photomedicine, Harvard Medical School and Mass General. He received this PhD from the University of Illinois at Urbana-Champaign. He joins the Experimental Biomedical Physics Group.

Retirement

Best wishes to Professor Haim Goldberg who retired from Northeastern after 48 years with the Department.

In Memoriam

Emeritus Professor David Garelick passed away on December 15, 2014. Dave was a member of the Experimental High Energy Physics group. He was a devoted member of the department and co-director of the Introductory Physics Laboratory for many years. Dave always put students first, and personally helped many new graduate students adjust to life in Boston.

Emeritus Professor Mike Glaubman passed away August 15, 2015. Mike was a member of the Experimental High Energy Physics group and worked on L3 at CERN for many years. He served as Chair of the Department and was involved in helping to develop the Introductory Physics Labs and was very enthusiastic about almost anything involving physics. He was a valued colleague and a good citizen who did many things to make our department a better place.

Highlights

The first annual Nanomedicine Day was held June 15, 2015 at Northeastern. The event featured talks and posters by CanCURE co-op students, IGERT doctoral students, and other graduate students performing nanomedicine research at Northeastern.

CanCURE leaders Srinivas Sridhar and Anne Van De Ven-Moloney have received a $500K grant from the National Science Foundation to establish a Nanomedicine Academy that spans 5 institutions including Northeastern University, Morgan State University, Tuskegee University, Florida International University, and University of Puerto Rico Mayaguez. This newest program leverages Northeastern’s expertise in nanomedicine education and long-distance learning to create an interactive knowledge-sharing framework that empowers low-resource institutions to offer cutting-edge courses in Nanomedicine. The first of 5 new nanomedicine courses kicked-off this September with students enrolled at all 5 partnering institutions.

Lawrence Awards

The 2015 Lawrence Awards were held on April 22 at Northeastern’s Raytheon Amphitheater. Congratulations to our winners.

Excellence in Teaching

First Year: Jonathan Carifio
Second Year: Andrew Spisak
Advanced: Peter Mistark
Undergraduate: Elise Jortberg

Graduate Academic Excellence

Jonathan Carifio
Wei Fan
Jiahua Tian

Journal Club Speaker Award

Rohan Gala
Andrew Taylor

Undergraduate Scholastic Excellence

Eleanor Blair
Mollie Rosen
Preston Epps
Adam Sanford
Eric Holtzman
Oasmaa Shahid
Marko Lazarevic
Jeffrey Wallace
Matthew Maroun
Jacob Wolfsberg
Anton Ogandzhanyan
Kelsey Yee
Alexander Piers

Undergraduate Research

Andrew Clark
Matthew DeCapua

Undergraduate Scholastic Excellence

Rohan Gala
Andrew Taylor
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web: www.northeastern.edu/cos/physics
email: physics@neu.edu
phone: (617)373-2902

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h.silverman@neu.edu or (617)373-8654

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Doctor of Philosophy
Darin Baumgartel
Advisor: Professor Emanuela Barberis
The Search for the Pair Production of Second-Generation Scalar Leptoquarks and Measurements of the Differential Cross Sections of the W Boson Produced in Association with Jets with the CMS Detector at LHC

Julio Chapeton
Advisor: Professor Armen Stepanyants
Steady-State Learning and Synaptic Connectivity in Local Cortical Networks of Excitatory and Inhibitory Neurons

Matthew Chasco
Advisor: Professor Darien Wood
Fishing for New Physics with Massive Neutral Dibosons: Measurements of ZZ Production Cross Section and the Search for Invisible Higgs Boson Decays Beyond the Standard Model with the CMS Detector at the LHC

Fabio Ciulla
Advisor: Professor Alessandro Vespignani
Diffusion Processes in Geographical Networks

Susan Ghassian
Advisor: Professor Albert-László Barabási
Network Medicine: A Network-Based Approach to Human Diseases

Michelle Jamer
Advisor: Professor Don Heiman

Synthesis and Characterization of Novel Magnetic Heusler Semiconductors for Device and Materials Applications
Jialin Li
Advisor: Professor Mark Williams
Complex DNA Binding Kinetics of HIV-1 Nucleocapsid Proteins
Deilia Mocanu
Advisor: Professor Alessandro Vespignani
Data Science and Spatio-Temporal Resolved Social Networks
Mohammad Soltanieh-ha
Advisor: Professor Adrian Feiguin
Interplay Between Charge, Spin, and Phonons in Low Dimensional Strongly Interacting Systems
Lili Wang
Advisor: Professor Latika Menon
Titania Nanostructures for Optoelectronics Applications
Jinzhong Zhang
Advisor: Professor George Alverson
Search for the Stueckelberg Z’ Decaying into Dimuon Pairs at CMS/LHC

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Alexander Meilus
Kaiyu Sun
Lili Wang
Huan Yang
Yongbo Zhang

Bachelor of Science
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Curtis Bare
Mackenzie Bennett
Colton Caramihalis
Juan Del Hoyo Gonzalez
Trithap Devakul
James Grammatikos
Richard Kamienski
Daniel Miller
Patrick Morton
Marco Muzio
Ian Powell
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