Doctoral candidate publishes on graphene's potential

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Since graphene was first isolated in 2004 with the help of Scotch tape, researchers have excitedly turned to the material to discover its potential applications. A single layer of carbon atoms whose applications range from ultrafast electronics to biosensors to flexible displays, graphene is strong, light, transparent, and a conductor of heat and electricity. But what can we do with this new material? As researchers across the globe peel away layer after layer of potential application, Milan Begliarbekov, a doctoral candidate at Stevens Institute of Technology, has found some unique applications for this distinctive material.

Graphene is charged with possibilities for Milan. With the help of a world-class Stevens faculty, support from the National Science Foundation (NSF) Graduate Teaching Fellows in K-12 Education (GK-12) program through the New Jersey Alliance for Engineering Education (NJAEE), and an award from the Air Force Office of Scientific Research (AFOSR), Milan is conducting groundbreaking research of the material. He has already published two papers on graphene in Applied Physics Letters in pursuit of his Ph.D. and has a third paper in the pipeline. Both published articles have also been selected for the *Virtual Journal of Nanoscale Science and Technology*.

His first published article, "Determination of edge purity in bilayer graphene using μ-Raman spectroscopy," confirms a technique for differentiating between monolayer and bilayer graphene, and introduces a new method to quantify the composition of graphenes chiral edges through μ-Raman spectroscopy.

Milan's second article, "Aperiodic conductivity oscillations in quasiballistic graphene heterojunctions," establishes a new signature of Klein tunneling in graphene heterojunctions. The research has applications in nanolectronics such as graphene field effect transistors (GFET), which have been shown to be capable of ultra-high frequency (300 GHz) operation.

Milan's next article, yet to be published, is "Quantum Inductance and High Frequency Oscillators in Graphene Nanoribbons." The paper proposes a novel technique for measuring the speed of ultra-high frequency transistors. Currently it is very difficult to measure ultra-high-frequency signals above 40 GHz by purely electronic means. However, Milan's research indicates that graphene nanoribbons can serve as all-electronic ultra-high frequency oscillators and filters, which would extend the possibilities of high-frequency electronics into new realms.

Since graphene planes were first isolated, much research has focused on the material's applications in nanoelectronics, due to its high electrical conductivity. But researchers at Stevens have taken a different approach, pioneering applications of this unique material in optics. Milan's research represents a fine example of this innovative thinking.

As he works with a material whose greatest applications may still be unrealized, Milan says he enjoys the level of creativity he is afforded in exploring graphene's possibilities. "I like working with Professor Strauf, because of the freedom he gives me to choose my own research projects," Milan says. "He allows me to explore things I find interesting, rather than asking me to work on a pre-defined research objective."

"Given that the our team just started two years ago to work with graphene in a collaboration with Professor Yang's group from the Mechanical Engineering Department, Milan's research success is quite remarkable," says Dr. Stefan Strauf, Assistant Professor of Physics and

Engineering Physics (PEP) and Director of the Nanophotonics lab. "Milan is one of these unique graduate students you would like to clone into a dozen in your lab in order to implement all of his ideas."

The exploration of ideas has also led to the creation of a system that utilizes graphene's unique reaction to light. Working with Stevens faculty Dr. Stefan Strauf and Dr. Chris Search, who is also an Assistant Professor of PEP, Milan is determined to convert new ideas into patentable technology. "We are pleased to announce that with the help of the Office of Academic Entrepreneurship, Milan is in the process of applying for a patent with a novel application of graphene that exploits its near-perfect efficiency as a conductor," says Dr. Christos Christodoulatos, Professor and Associate Provost of Academic Entrepreneurship.

In addition to the AFOSR grant, Milan was also supported by the NSF GK-12 program through NJAEE. As an NJAEE fellow from 2008 to 2010, Milan worked alongside teacher mentors in local high school classrooms to expose younger students to cutting edge science and engineering research. The GK-12 program was established to support the NSF's goal of enhancing science, technology, engineering, and mathematics (STEM) curriculums for K-12 teachers and students. "The NJAEE program provides a unique opportunity for graduate students to enhance their teaching and communication skills, instills in them the spirit of innovation and entrepreneurship, and at the same time provides them a forum to share their passion and enthusiasm for science and engineering with younger students," says Dr. Frank Fisher, Associate Professor of Mechanical Engineering and co-Director of the Stevens Nanotechnology Graduate Program who is a co-PI on the NJAEE project. "Milan was just fantastic as a NJAEE Fellow, and has recently been able to apply these skills as an instructor in the Physics department here at Stevens as well as Queensborough Community College of CUNY."

The patent and papers are the most recent examples of Milan's success at Stevens. As an undergraduate at Stevens, Begliarbekov took advantage of both the Charles V. Schaeffer, Jr. School of Engineering and Sciences and what would become the College of Arts and Letters to graduate with two degrees, a B.S. in Physics and a B.A. in Literature. Having taken graduate-level courses in nanotechnology as an undergraduate, "I was already ahead of the curve," he says, when it came to searching for a graduate program.

Provided by Stevens Institute of Technology