Researchers at McCormick have developed a method for chemically altering graphene that could pave the way for faster, thinner, and more flexible electronics.

Graphene is a one-atom-thick, honeycomb-shaped lattice of carbon atoms with exceptional strength and conductivity. Many experts believe it could transform integrated circuits and lead to ultrafast computers, cellphones, and related portable electronic devices. But first researchers must learn how to tune the electronic properties of graphene.

That’s not an easy feat: unlike semiconductors made of silicon, pure graphene is a zero-band-gap material, making it difficult to turn off the electric current that flows through it. Therefore, pure graphene is not appropriate for the digital circuitry in the vast majority of integrated circuits. To overcome this problem, researchers around the world are investigating methods for chemically altering the material. The most prevalent strategy is the Hummers method—a process that oxidizes graphene through the use of harsh acids that irreversibly damage the fabric of the graphene lattice—but the resulting material is difficult to control.

Researchers at McCormick, led by Mark C. Hersam, professor of materials science and engineering, chemistry, and medicine, have developed a method to oxidize graphene without the collateral damage produced in the Hummers method. “Our method produces graphene oxide that is chemically homogeneous and reversible, leading to well-controlled properties that likely can be exploited in high-performance applications,” Hersam says. “It’s unclear whether this work will impact real-world applications overnight, but it appears to be a step in the right direction.”

The research was published in the journal *Nature Chemistry.*

Next, researchers will explore other means of chemically modifying graphene to develop a wider variety of materials, much as scientists did for plastics in the last century. “Through chemical modification,” Hersam says, “the scientific community has developed a wide range of polymers, from hard plastics to nylon. We hope to realize the same degree of tunability for graphene.”

The National Science Foundation, the Office of Naval Research, and the US Department of Energy supported this research.

**A STEP TOWARD BETTER ELECTRONICS**

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**RESEARCH MAY LEAD TO LONGER-LASTING HIP JOINTS**

Earlier studies showed that friction between metallic joints causes the formation of a lubricating layer that lessens friction between implants and reduces wear and corrosion. No one knew what this tribological layer was made of until researchers from McCormick and the other institutions studied implants retrieved from patients. They found a well-known atomic fingerprint of graphitic carbon in the tribological layer that formed on the metal parts. Along with other evidence, this discovery led them to conclude that the layer consists primarily of graphitic carbon, a well-known solid lubricant.

“Knowing that the structure is graphitic carbon really opens up the possibility that we may be able to manipulate the system to produce graphitic surfaces,” says Alfons Fischer of the University of Duisburg–Essen. “We now have a target for how we can improve the performance of these devices.”

“Hip-replacement surgery is the greatest advance in the treatment of end-stage arthritis in the last century,” says Joshua J. Jacobs of Rush University Medical Center, the study’s principal investigator and a 1977 McCormick alumnus. “Our findings will help push the field forward by providing a target to improve the performance of hip replacements.”

The next phase, Jacobs says, is to examine the surfaces of retrieved devices and correlate the researchers’ observations of the graphitic layer with the reason for removal and the overall performance of the metal surfaces. Marks also hopes to learn how graphitic debris from the implant might affect surrounding cells.
McCORMICK TEAM ROMPS IN SYNTHETIC BIOLOGY CONTEST

Last fall a team of Northwestern students took top honors at a regional synthetic biology competition of the International Genetically Engineered Machine (iGEM) Foundation. The team—Valerie Chen (biomedical engineering ’13), Nirmit Desai (biological sciences ’13), Rafay Faruqi (biomedical engineering ’12), Kristin Palarz (biological and integrated sciences ’14), Helen Shen (biomedical engineering ’12), and Michael Sherer (biomedical engineering ’13)—used E. coli to design a biosensor that can detect Pseudomonas aeruginosa, a common bacterium that thrives in hospitals and can cause pneumonia, gastrointestinal infections, and skin lesions. Seeking a faster, cheaper alternative to current Pseudomonas-detecting technology, the students took genes used in the quorum-sensing system of Pseudomonas and transferred them into E. coli so that the E. coli would fluoresce upon contact with auto-inducer molecules unique to Pseudomonas.

Last October the team competed against 70 other teams at iGEM’s regional competition for North and South America. In addition to their E. coli project, the McCormick team presented a generalized math model for quorum sensing that would allow its work to be applied not just to Pseudomonas but to other pathogens as well. “Eventually you could have a one-size-fits-all detector for multiple pathogens,” Faruqi says.

The judges were impressed by the math model, and Northwestern’s team won a gold medal. The team also received the honor of Best Model in the Americas.

The iGEM project is advised by Joshua Leonard, Michael Jewett, and Keith Tyo, assistant professors of chemical and biological engineering; Nichole Daringor, a graduate student in chemical and biological engineering; and John Mordacq, distinguished senior lecturer in biological sciences.

ANALYTICS MASTER’S PROGRAM DEBUTS NEXT FALL

The demand for workers skilled in data analytics is skyrocketing in today’s marketplace. To prepare students for this growing field, McCormick will introduce a master’s degree program in analytics in the fall.

Housed in McCormick’s Department of Industrial Engineering and Management Sciences, the 15-month MSiA program will combine math and statistics with instruction in advanced computational and data analysis. It is designed to allow recent graduates in engineering, science, or business to start their careers from a position of strength. The program will give students unprecedented access to faculty and resources and a place in a professional network when they graduate.

Under the guidance of faculty and prominent industry leaders, MSiA students will learn to identify patterns and trends; interpret vast quantities of structured and unstructured data; and communicate their findings in practical terms. Each student will complete an internship and a capstone project with an industry partner. Graduates of the program may go on to become analysts for Fortune 500 firms, statistical modeling or communications and media analysts, consultants, or systems engineers.

“We conceived this program because we recognized that there aren’t enough trained individuals in this rapidly growing field,” says Diego Klabjan, associate professor of industrial engineering and management sciences and director of the MSiA program. “McCormick is at the cutting edge of analytics, and we are looking forward to starting the program next fall.”

NEW LEADERSHIP AT SEGAL DESIGN INSTITUTE

McCormick Dean Julio M. Ottino has announced new leadership and a revised administrative structure for the school’s Segal Design Institute. Greg Holderfield (top), currently codirector of the MMM Program and clinical associate professor of mechanical engineering, has been named director of the institute, with Bruce Ankenman (bottom), professor of industrial engineering and management sciences, serving as codirector.

In a further change, the institute will now be advised by two faculty councils. An education council will oversee existing curricular activities and develop new initiatives. A research council will advise on the development and allocation of PhD fellowships and start-up grants for design research and create new initiatives to expand the academic field of design. These councils will consist of people throughout the University engaged in creative and scholarly activities associated with the institute’s mission and may evolve into think tanks for creative idea generation within Northwestern.

“Northwestern’s strategic plan articulates a clear emphasis on design and innovation among University priorities,” says Holderfield. “The Segal Design Institute will be the hub for activities in this area and will continue to produce students who can connect disciplines to create impact.”

The Segal Design Institute was founded in 2007 following a gift from Crate & Barrel cofounders Gordon and Carole Segal.

JANSE TO DIRECT NEW BUSINESS VENTURES

The McCormick School and Northwestern’s Innovation and New Ventures Office (INVO) have named Michael Janse director of new business ventures. In this newly created position shared by McCormick and INVO, Janse will lead efforts to identify promising technologies and educate and assist faculty and students in the commercialization process.

“Michael will help increase the value of Northwestern inventions by advancing them to the proof-of-concept stage and then to potential business ventures,” says Alicia Löffler, executive director of INVO and associate vice president of research.

Janse has focused on investing in early-stage technology throughout his career. He founded a semiconductor technology start-up with a university researcher and held positions with the Harris & Harris Group, an advanced materials-focused venture capital firm in Palo Alto, California; ARCH Venture Partners in Chicago; and Motorola’s Semiconductor Products Sector. He holds an MBA from the University of Chicago and a BS in chemical engineering from Brigham Young University.

“Innovations that never leave the lab cannot help solve global challenges,” says Julio M. Ottino, dean of McCormick. “We are excited to have Michael augment the activities encompassed by INVO and the Farley Center for Entrepreneurship and Innovation.”
NEW SCAFFOLDS FOR TISSUE ENGINEERING

Northwestern researchers have developed an improved method for creating the scaffolds that are key to tissue engineering. These artificial lattice-like structures provide a template to support growing cells and over time are absorbed into the body, leaving behind only living tissue. Scaffolds are typically engineered with pores that allow cells to migrate throughout the material. But current methods have various drawbacks, such as creating imperfect pore structures and requiring lengthy processing, says Guillermo Ameer, professor of biomedical engineering and surgery.

The improved scaffolds developed by Ameer and his colleagues are created from a combination of ceramic nanoparticles and elastic polymers. These new scaffolds are highly flexible and can be tailored to degrade at varying speeds, depending on the expected recovery time of patients. The scaffolds (shown above) can also incorporate nano-sized fibers, providing a new range of mechanical and biological properties. “The technology could prove very useful in repairing anterior cruciate ligament tears and in bone-void fillers,” Ameer says.

A paper describing the research was featured in the journal *Tissue Engineering.*

METAMATERIAL BOOSTS POTENTIAL OF SOLAR CELLS

Solar power may be on the rise, but solar cells are only as efficient as the amount of sunlight they collect. Under the direction of a new McCormick professor, researchers have developed a material that absorbs a wider range of wavelengths and could lead to more efficient and less expensive solar technology.

“To capture light most efficiently, a solar cell needs to have a broadband response,” says Koray Aydin, assistant professor of electrical engineering and computer science and lead author of a paper that appeared in the journal *Nature Communications.* “This design allows us to achieve that.”

The researchers used metal and silicon oxide to create thin but complex trapezoidal metal gratings on the nanoscale (shown below) that can trap a wider range of visible light. These materials achieve very high absorption rates, Aydin says, due to local optical resonances that cause light to spend more time inside the material until it gets absorbed. They also collect light from many different angles—a useful quality when dealing with sunlight, which hits solar cells at different angles as it moves throughout the day. If applied to semiconducting materials, the technology could lead to thinner, less expensive, and more efficient solar cells.

Aydin came to McCormick from the California Institute of Technology, where he was a research scientist in applied physics and materials science. His research was supported by the Department of Energy’s Light-Material Interactions Energy Frontier Research Center, where Aydin was assistant director. Aydin received his BS and PhD in physics from Bilkent University in Ankara, Turkey.

Aydin was drawn to Northwestern because of its collaborative work environment and proximity to unmatched facilities, such as Argonne National Laboratory. “When I interviewed at McCormick, I met with not only the electrical engineering faculty but also members of the materials science faculty,” Aydin says. “That showed me how much the school values collaboration and interdisciplinary interactions.”
the world’s largest general scientific society. He was cited for his development of pioneering optical and X-ray scattering methods used to study the structural dynamics of polymers during flow and processing. His research emphasizes in situ investigation of flow-induced structural changes to elucidate the origins and mechanisms of complex rheology in polymers.

Ken Forbus, Walter P. Murphy Professor of Electrical Engineering and Computer Science, has received a Humboldt Research Award from the Alexander von Humboldt Foundation in Germany. The award is given to academics whose fundamental discoveries, new theories, or insights have had a significant impact on their disciplines and who are expected to continue their cutting-edge achievements. Forbus’s areas of expertise include qualitative reasoning, spatial reasoning, analogical reasoning and learning, learning from natural language, and inference engine design.

Nicole Immorlica, assistant professor of electrical engineering and computer science, received a Sloan Research Fellowship. She is one of 126 outstanding early-career scientists and scholars recognized by the Alfred P. Sloan Foundation this year. Immorlica’s research interests lie in the structure, formation, and design of social networks and problems at the intersection of game theory and algorithms. Understanding the theoretical properties underlying networks and the incentives they introduce is fundamental to creating well-designed and functioning systems.

Michael C. Jewett, assistant professor of chemical and biological engineering and a member of the Chemistry of Life Processes Institute and the Robert H. Lurie Comprehensive Cancer Center of Northwestern University, has been awarded a Packard Fellowship for Science and Engineering by the David and Lucile Packard Foundation. Jewett, a synthetic biology expert, is among the 16 promising science and engineering researchers nationwide to receive an unrestricted research grant of $875,000 over five years. With his Packard Foundation funding, Jewett will advance his research on developing cell-free synthetic biology for speedy, on-demand biomanufacturing of new classes of lifesaving drugs, sustainable fuels, and novel materials from renewable resources.

John Rudnicki, professor of civil and environmental engineering and mechanical engineering, received the 2011 Daniel C. Drucker Medal from the American Society of Mechanical Engineers. The society honored Rudnicki for providing a new understanding of deformation instabilities in brittle rocks and granular media, including their interactions with pore fluids, with applications to fault instability, quantification of energy radiation from earthquakes, and environment- and resource-related geomechanics.

Joseph L. Schofer was named a national associate by the National Research Council of the National Academies. Schofer, an expert in the planning and management of transportation systems, is professor of civil and environmental engineering, associate dean for faculty affairs, and director of the Infrastructure Technology Institute. The honorary title is bestowed on people with an “extraordinary dedication” to the National Academies. Schofer, who has taught at McCormick since 1970, is active on the Transportation Research Board of the National Research Council, where he has chaired policy studies, taken part in committees and task forces, and served in numerous leadership roles since 1968.

Randall Q. Snurr, professor of chemical and biological engineering, was elected a fellow of the American Association for the Advancement of Science, the world’s largest general scientific society. He was honored for advancing the application of nanoporous metal-organic frameworks in energy storage and separations as well as for showing the power of molecular simulation to design new materials. Snurr is particularly interested in the development of nanoporous materials to solve environmental and energy problems.

STUDENT TEAM WINS BIG IN BUSINESS COMPETITIONS

NuMat Technologies, a start-up comprising three Northwestern graduate students and a research professor, has won nearly $1 million this year in two prestigious competitions. In March it won $100,000 in the Clean Energy Challenge, an annual competition that awards prizes to top Midwest clean-technology entrepreneurs. In April it won four awards—including the grand prize—worth $874,000 in the Rice Business Plan Competition, the world’s richest and largest graduate-level business plan contest.

NuMat Technologies developed a computational screening tool to rapidly identify and test metal-organic frameworks (MOFs), crystals with nanoscopic pores and incredibly high surface area that can be used for the storage of gases. It created algorithms able to generate large databases of hypothetical MOFs tailored to address specific problems, and it designed technologies to streamline the development of these materials. The process was developed in the lab of Randall Q. Snurr, professor of chemical and biological engineering. (See related story on page 10.)

“A major challenge today is figuring out a way to store fuels that are clean and eco-friendly,” says Chris Wilmer, a graduate student in chemical and biological engineering. “We’ve developed a plan to identify the right materials to store clean fuels, synthesize them, test them, and produce them on a large scale for industry.”

In addition to Wilmer (far right), members of NuMat Technologies include (from left) research associate professor Omar Farha, graduate student Tabrez Ebrahim, and graduate student Ben Hernandez.
TWO ELECTED TO THE NATIONAL ACADEMY OF ENGINEERING

Tobin J. Marks and Samuel I. Stupp have been elected to the National Academy of Engineering, among the highest professional distinctions accorded to an engineer. The NAE cited Marks (top) for his innovations in electronic, photonic, and photovoltaic materials and catalytic polymerization, while Stupp (bottom) was lauded for advances in processes of self-assembled polymers for biomedical applications.

Marks, the Vladimir N. Ipatieff Professor of Catalytic Chemistry and professor of materials science and engineering, is a world leader in the understanding and development of new catalysts that enable the production of recyclable, environmentally friendly, and sustainably produced plastics and elastomeric materials. His research has resulted in a far deeper understanding of chemical bonds and has directly led to multibillion-dollar industrial processes. Among his many honors are the US National Medal of Science and membership in the American Academy of Arts and Sciences and the National Academy of Sciences. Marks also received the 2012 National Academy of Sciences Award in Chemical Sciences, the academy’s highest honor for chemical research.

Stupp, the Board of Trustees Professor of Materials Science and Engineering, Chemistry, and Medicine and director of Northwestern’s Institute for Bionanotechnology in Medicine, conducts research focused on molecular self-assembly strategies to create highly functional materials of interest in widely varying fields ranging from regenerative medicine to electronics. He has developed novel materials to promote regeneration in the central nervous system, bone, cartilage, and blood vessels and has used self-assembly to create electronically active materials with a focus on energy technologies. A member of the American Academy of Arts and Sciences, Stupp has received a Department of Energy Prize for Outstanding Achievement in Materials Chemistry and the Materials Research Society Medal. In 2005 Scientific American named him one of 50 “Leaders Shaping the Future of Technology.”

The NAE elected 66 new members and 10 foreign associates. It acts as the federal government’s chief advisory agency on engineering and technology issues. Its more than 2,000 peer-elected members and foreign associates are senior professionals in business, academia, and government.

STUDENTS IMPROVE TREADMILL FOR WHEELCHAIR ATHLETES

It had been a long week for students in Engineering Design and Communication. As their first quarter at Northwestern came to an end, students in the freshman design course had completed what may have been their grandest collegiate accomplishment to date: a prototype for a piece of computerized workout equipment for wheelchair athletes.

Engineering Design and Communication is a two-quarter course required of new McCormick undergraduates. In the first quarter, EDC students create projects to help physically disabled people at client organizations such as the Rehabilitation Institute of Chicago and Children’s Memorial Hospital. Last fall, one section of the class focused on an exercise device called a trainer that accommodates various shapes of racing and sporting wheelchairs and simulates wind resistance for athletes at the Rehabilitation Institute of Chicago’s Fitness Center and Sports Program.

The students started by interviewing athletes and staff at the Rehabilitation Institute to learn about the shortcomings of its current equipment. They learned athletes were not able to get onto the trainer by themselves; two staff members were required to lift them. Furthermore, the trainer provided only one level of resistance and accommodated only one type of athletic wheelchair, preventing many athletes from using the machine. “We asked the EDC class to tackle all these shortcomings and create a piece of exercise equipment that could be utilized much like a treadmill, only for wheelchair users,” said Eric Johnson, program specialist at the institute.

The result was the “Lone Roller.” The prototype addressed these concerns and added a system to lock wheelchairs, as well as a computerized control system that allows athletes to vary the level of their workouts and to get data readouts of their performance. The device will help the institute address basic exercise needs and aid in athlete training and performance testing, and it may be used in research projects, as well. Johnson said, “We couldn’t be more thrilled to have this piece of equipment as a staple for our sports and fitness programs.”

Completing the project in such a short time is an achievement, said Aaron Stebner, an EDC course instructor and PhD student with years of industry experience. (See page 34 for a profile of Stebner.) In a commercial market, he explained, the trainer prototype would be assigned to a large team of experienced engineers, professional assemblers, and wirers, and it would still take 20 to 25 weeks to complete the job. “It is absolutely remarkable that a class of 15 first-quarter engineering students researched, designed, manufactured, programmed, and built a fully functioning product for their client in 10 weeks,” he said.