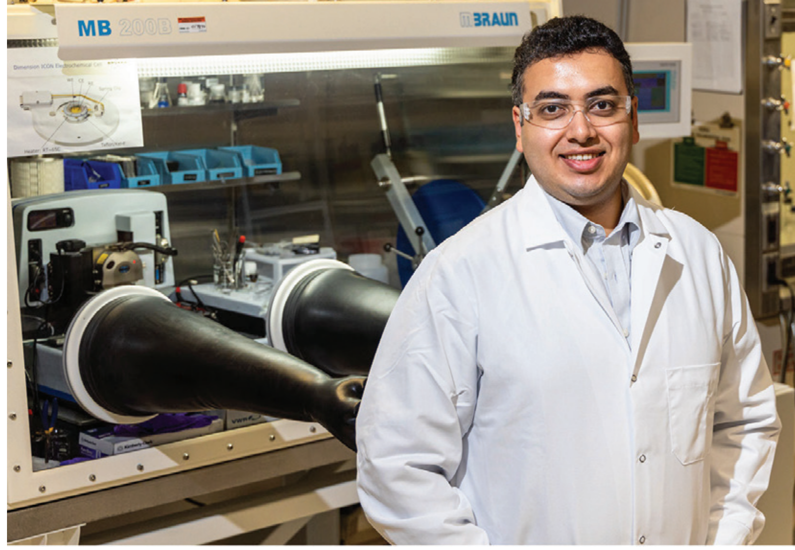
## Developing the Next Generation of Scientific Talent:

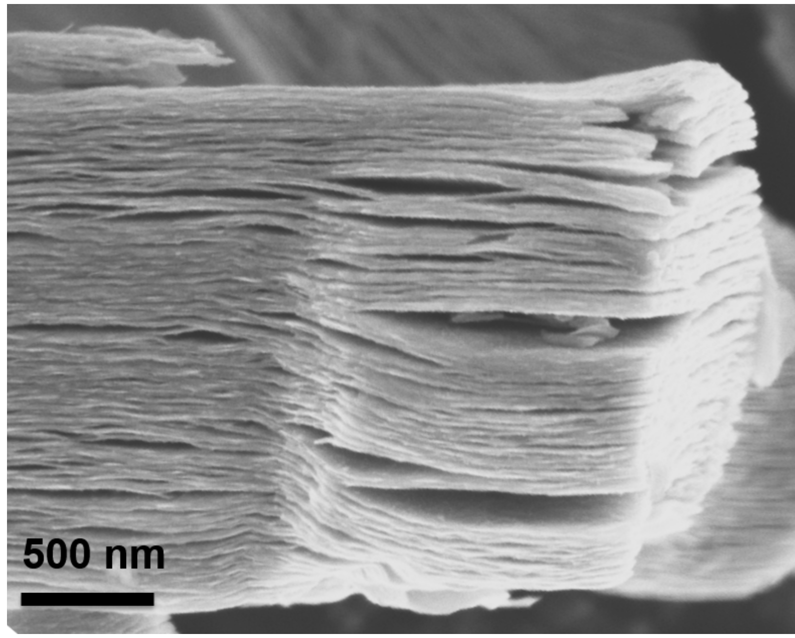
# MICHAEL NAGUIB

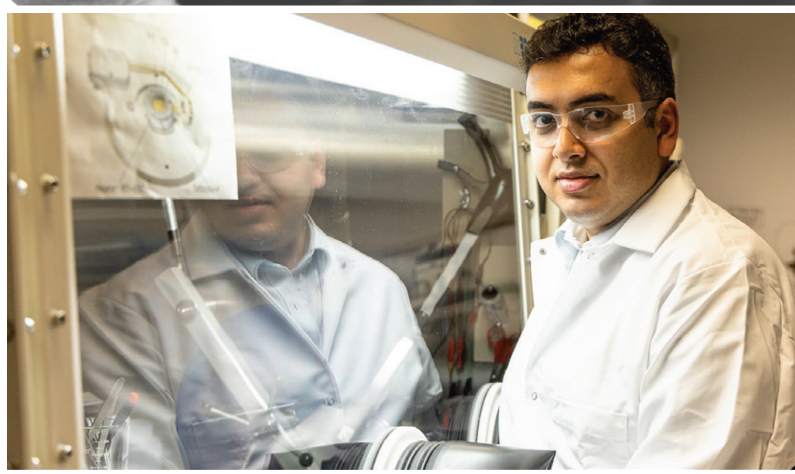
Michael Naguib was born in Egypt and completed his undergraduate and master's degrees at Cairo University. He wanted to study advanced materials, but there was no place to do so in Egypt. Instead he enrolled in a PhD program at Drexel University in Philadelphia. There he was assigned to explore whether certain materials that have a layered structure (with three layers, each having a different chemical composition) could be used to make better electrodes for lithium ion batteries. Michael found that the materials were not useful as electrodes because lithium ions (the charge carriers in modern batteries) could not penetrate the material. To address this, he tried to modify the material by removing the middle layer with acid. The unexpected result was the discovery of a completely new nano-material: a titanium-carbon compound in the form of a two-dimensional sheet less than a nanometer thick. He and his advisors at Drexel immediately recognized the new material's potential for energy storage.

Publication of that discovery—of what soon became clear was a whole family of two-dimensional materials now called MXenes—triggered a world-wide surge of research. To explore MXenes and related phenomena in more detail, the U.S. Department of Energy's Office of Science funded an Energy Frontier Research Center (EFRC) on Fluid Interface Reactions, Structures and Transport. The research team included computational modelers, university experts in materials synthesis and thermodynamic analysis, and scientists at DOE's Oak Ridge National Laboratory (ORNL) who could probe the material's structure with neutrons and powerful microscopes.

After completing his PhD, Michael moved to ORNL with a prestigious fellowship. There he played a major role in the research on MXenes as one of the team's principal investigators—unusual for a young scientist. What has already emerged from the research is a much clearer understanding of the structure, chemistry, and the electronic behavior of these new materials—including how they behave in the presence of battery electrolytes, water, or other fluids.





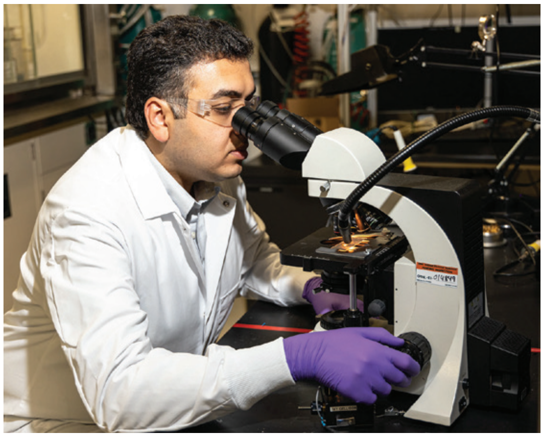



**Top:** Michael Naguib in a laboratory at DOE's Oak Ridge National Laboratory, where he participated in the research that led to improved understanding of the new class of MXene materials—materials he had previously discovered as a graduate student.

**Middle:** Multiple layers of the remarkable two  dimensional material known as a MXene, shown here under powerful magnification (each layer is less than 1 nanometer in thickness).

**Bottom:** Naguib is now a faculty member at Tulane University in New Orleans, where he is continuing his research on novel energy materials and helping to build that university s first doctoral program in materials physics and engineering.

*(All photos from Carlos Jones at Oak Ridge National Laboratory)*



*"Michael's achievements—some 60 publications and more than 12,000 citations in the scientific literature—in such a short time are simply unique."*

*—David Wesolowski, Oak Ridge National Laboratory*

## Professional Affiliations

- Cairo University
- Drexel University
- Oak Ridge National Laboratory
- Tulane University

Because their properties can be fine-tuned by adjusting their composition, MXenes may find a wide range of industrial uses:

> They can be used to shield mobile phones and other devices from electromagnetic interference.

> They have major potential in energy storage devices. Lithium ions can diffuse very readily into MXene and thus may enable batteries with increased energy storage and more rapid re-charging.

> They can store large amounts of electric energy on their surface, acting as a supercapacitor (which stores energy as electric charges as opposed to storing energy in a chemical reaction as in a battery). Small supercapacitors already play an important role in micro-electronic circuits, and those made from MXenes could store even more energy. Larger-scale supercapacitors, because of their rapid reaction time, could help stabilize the electrical grid by smoothing out surges.

There are now some 20 different MXenes known. They can be easily synthesized and are stable in water and in a variety of organic solvents, making them relatively easy to process—even in large-scale production. A big Japanese company has licensed the MXene technology for a wide range of applications and is said to be nearing commercial production.

For Michael, the EFRC experience proved invaluable. He developed leadership skills and learned how to work as part of an interdisciplinary team. Perhaps most important, he became literate in the many areas of science required to undertake the investigation—"learning to speak the language" of computational modeling; of neutron, x-ray, and scanning probes; and of potential energy storage materials. He also established himself as far more than a junior scientist, with some 60 publications and more than 12,000 citations in the scientific literature—more than most scientists achieve in a lifetime.

David Wesolowski of Oak Ridge National Laboratory and former director of the EFRC Center says, "Michael's achievements in such a short time are simply unique." At the end of his stay at Oak Ridge, Michael accepted an assistant professorship at Tulane University in New Orleans, where he is helping to build that institution's (and Louisiana's) first doctoral program in materials physics and engineering. As an immigrant on his way to becoming a U.S. citizen, Michael is a significant addition to the scientific talent pool in this country.

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