Materials Science & Engineering Seminar Series

# Carnegie Mellon University
## Materials Science & Engineering

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# The Rise of MXenes

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**ABSTRACT**: Numerous compounds, ranging from clays to boron nitride (BN) and transition metal dichalcogenides, have been produced as 2D sheets. Although many of these materials remain subjects of purely academic interest, others have jumped into the limelight due to their attractive properties, which have led to practical applications. Among the latter are carbides and nitrides of transition metals known as MXenes (pronounced “maxenes”), a fast-growing family of 2D materials. The family of 2D transition metal carbides and nitrides (MXenes) has been expanding rapidly since the discovery of $Ti_3C_2$ at Drexel University in 2011 [1]. More than 30 different MXenes have been reported, and the structure and properties of numerous other MXenes have been predicted using density functional theory (DFT) calculations [2,3]. Moreover, the availability of solid solutions on M and X sites, control of surface terminations, and the discovery of ordered double-M MXenes (e.g., $Mo_2TiC_2$), i-MAX phases and their MXenes offer the potential for producing dozens of new distinct structures.

This presentation will describe the state of the art in the field. The manufacturing of MXenes, their delamination into single-layer 2D flakes and assembly into films, fibers and 3D structures will be briefly covered. Synthesis-structure-properties relations of MXenes will be addressed on the example of $Ti_3C_2$. The use of MXenes in ceramic- metal- and polymer-matrix composites, smart fibers and textiles will also be discussed. The versatile chemistry of the MXene family renders their properties tunable for a large variety of applications [3-5]. Oxygen or hydroxyl-terminated MXenes, such as $Ti_3C_2O_2$, have been shown to have redox capable transition metals layers on the surface and offer a combination of high electronic conductivity with hydrophilicity, as well as fast ionic transport [4]. This, among many other advantageous properties, makes the material family promising candidates for energy storage and related electrochemical applications [4], but applications in plasmonics, electrocatalysis, biosensors, water purification/ desalination and other fields are equally exciting.

1. M. Naguib, M. Kurtoglu, V. Presser, J. Lu, J.-J. Niu, M. Heon, L. Hultman, Y. Gogotsi, M. W. Barsoum, Two-Dimensional Nanocrystals Produced by Exfoliation of $Ti_3AlC_2$, *Advanced Materials*, **23** (37), 4248-4253 (2011)

2. M. Naguib, O. Mashtalir, J. Carle, V. Presser, J. Lu, L. Hultman, Y. Gogotsi, M.W. Barsoum, Two-Dimensional Transition Metal Carbides, *ACS Nano* **6** (2) 1322–1331 (2012)

3. B. Anasori, Y. Gogotsi (Ed.) *2D Metal Carbides and Nitrides (MXenes): Structure, Properties and Applications* (Springer), 2019

4. B. Anasori, M. Lukatskaya, Y. Gogotsi, 2D Metal Carbides and Nitrides (MXenes) for Energy Storage, *Nature Reviews Materials*, **2**, 16098 (2017)

5. K. Hantanasirisakul, Y. Gogotsi, Electronic and Optical Properties of 2D Transition Metal Carbides and Nitrides (MXenes), *Advanced Materials*, **30** (52) 1804779 (2018)

**BIOGRAPHY:** Dr. Yury Gogotsi is Charles T. and Ruth M. Bach Chair Professor and Distinguished University Professor of Materials Science and Engineering, Mechanical Engineering and Mechanics, and Chemistry at Drexel University in Philadelphia. He also serves as Director of the A.J. Drexel Nanomaterials Institute. He received his MS (1984) and PhD (1986) from Kiev Polytechnic and a DSc degree from the Ukrainian Academy of Sciences in 1995. His research group works on 2D carbides and nitrides, nanostructured carbons, as well as other nanomaterials for energy, water and biomedical applications. He has co-authored 2 books, more than 600 journal papers, edited 14 books, and obtained more than 50 patents. He was recognized as Highly Cited Researcher in Materials Science and Chemistry (Web of Science) in 2014-2019.

He has received numerous awards for his research including several honorary doctorates, the European Carbon Association Award, S. Somiya Award from the International Union of Materials Research Societies, Nano Energy award from Elsevier, International Nanotechnology Prize (RUSNANOPrize), R&D 100 Award from R&D Magazine (twice) and two Nano 50 Awards from NASA Nanotech Briefs. He has been elected a Fellow of the American Association for Advancement of Science (AAAS), Materials Research Society, American Ceramic Society, the Electrochemical Society, Royal Society of Chemistry, NanoSMAT Society, as well as Academician of the World Academy of Ceramics and Fellow of the European Academy of Science. He also served on the MRS Board of Directors and currently acts as Associate Editor of ACS Nano.

**Doherty Hall 2210, 11:30AM**
**Friday, November 1, 2019**