

MSE-Colloquium@NTU

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MXenes: Expanding the World of Two-Dimensional Materials

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About the Talk

Two-dimensional (2D) solids – the thinnest materials available to us – offer unique properties and a potential path to device miniaturization. The most famous example is graphene, which is an atomically thin layer of carbon atoms bonded together in-plane with sp² bonds. Recently, an entirely new family of 2D solids – transition metal carbides (Ti₂C, Ti₃C₂, Nb₄C₃, etc.) and carbonitrides – was discovered by Drexel University scientists [1,2]. Selective etching of the A-group element from a MAX phase results in formation of 2D Mn+1X_n solids, labeled “MXene”. Eleven different carbides and carbonitrides have been reported to date [2-5]. Structure and properties of numerous MXenes have been predicted by the density functional theory, showing that MXenes can be metallic or semiconducting (up to 2 eV band gap), depending on their surface termination. Their elastic constants along the basal plane are expected to be higher than that of the binary carbides. Oxygen or OH terminated MXenes, are hydrophilic, but electrically conductive. Hydrazine, urea and other polar organic molecules can intercalate MXenes leading to an increase of the c lattice parameter of MXenes [3]. When dimethyl sulfoxide was intercalated into Ti₃C₂, followed by sonication in water, a stable colloidal solution of single- and few-layer flakes was produced. One of the many potential applications for 2D Ti₃C₂ is in electrical energy storage devices, such as batteries, Li-ion capacitors and supercapacitors [4,6]. Cations ranging from Na⁺ to Mg²⁺ and Al³⁺ intercalate MXenes. Ti₃C₂ paper electrodes, produced by vacuum assisted filtration of an aqueous dispersion of delaminated Ti₃C₂, show a higher capacity than graphite anodes and also can be charged/discharged at significantly higher rates. They also demonstrate very high intercalation capacitance (up to 900 F/cm³) in aqueous electrolytes.

1. M. Naguib, et al, *Advanced Materials*, 23 (37), 4207-4331 (2011)
2. M. Naguib, et al, *ACS Nano* 6 (2), 1322–1331 (2012)
3. O. Mashtalir, et al, *Nature Communication*, 4, 1716 (2013)
4. M. R. Lukatskaya, et al, *Science*, 341, 1502-1505 (2103)
5. M. Naguib, et al, *Advanced Materials*, 26, 992-1005 (2014)
6. M. Ghidui, et al, *Nature*, 516, 78–81 (2014)

About the Speaker

Professor Yury Gogotsi is Distinguished University Professor and Trustee Chair of Materials Science and Engineering at Drexel University. He is also the founding Director of the A.J. Drexel Nanomaterials Institute and Associate editor of *ACS Nano*. His Ph.D. is in Physical Chemistry from Kiev Polytechnic and D.Sc. in Materials Engineering from Ukrainian Academy of Sciences. He works on nanostructured carbons and other nanomaterials for energy related and biomedical applications. He has co-authored 2 books, more than 400 journal papers and obtained more than 50 patents. He has received numerous national and international awards for his research and was elected a Fellow of AAAS, MRS, ECS and ACerS and a member of the World Academy of Ceramics.