



MXenes - A Boon to Lithium Ion Batteries

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Abstract: In the battery family, Lithium Ion Batteries remain top dog. One of the new tricks for the old dog to learn is MXene. MXene is an entirely new family of two dimensional super capacitors that triples the amount of electric energy it can store. They tuned to specific functions as anode and cathode could serve to development of a flexible Lithium Ion Battery. This paper reviews MXene, its characteristics and applications.

Keywords: MXene, Battery, Capacitors, Electrodes.

I. INTRODUCTION

Graphene, a single-layer hexagonal arrangement of carbon atoms is touted as a game-changing material that could boost the power and energy capacity of a lithium-ion battery. It is an excellent conductor of electricity. In a battery, the massive surface area of such carbon sheets could be a boon to increasing the power capacity of a lithium-ion battery. The only problem is lithium ions won't bond with graphene, which makes it practically useless in a battery. Scientists are still discovering all the wonderful things that graphene might be able to do, but still waiting for a lithium-ion battery with 2,000kWh/kg and a Tesla Model S with 5,000mi range on a single charge. With battery technology constantly advancing, it wouldn't surprise something like this is made in the next decade. Researchers at Drexel University have discovered new electrochemical properties of a new nanomaterial MXenes, which could give graphene a run for its money.

About three years ago, Dr. Michel W. Barsoum and Dr. Yury Gogotsi, professors in Drexel's College of Engineering, discovered atomically thin, two-dimensional materials -similar to graphene- that have good electrical conductivity and a surface that is hydrophilic, or can hold liquids. They named these new materials "MXenes," which hearkens to their genesis through the process of etching and exfoliating atomically thin layers of aluminum from layered carbide "MAX phases." The latter also discovered at Drexel about 15 years ago by Barsoum.

II. MXenes and Its Characteristics

MXenes are a new family of 2D transition metal carbides and/or nitrides discovered and being developed in collaboration with Prof. Barsoum's group, that can be used in many applications such as energy storage systems (e.g. lithium ion batteries). The 2D layers of those carbides are labeled as "MXene" because it is produced by etching a layer from MAX phases and the suffix "ene" to emphasize their similarity to graphene.

MAX phases are a large family (+60 members) of hexagonal layered ternary transition metal carbides and/or nitrides with composition of $Mn+1AX_n$, where M stands for an early transition metal (such as: Ti, V, Cr, Nb, etc.), A stands for a group A element (such as: Al, Si, Sn, In, etc.), X stands for carbon and/or nitrogen, and $n=1, 2$, or 3.

IA	IIA											IIIA	IVA	VA	VIA	VII	VIII
																	H
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Lr	Unq	Unp	Unh	Uns	Uno	Une									

M

early transition metal

A

group A element

X

C and/or N

Elements in the periodic table that react together to form the MAX phases. The red squares represent the M-elements; the blue are the A elements; the black is X, or C and/or N.

The etching process is carried out by simply immersing MAX phase in hydrofluoric acid at room temperature. MXenes are produced with compositions of M_2X , M_3X_2 , and M_4X_3 . DFT calculations showed that MXenes' band gap can be tuned by changing the surface termination, for example bare MXene is metallic conductors, while OH or F terminated are semiconductors with small band gap. Multilayer MXenes are electronically conductive with conductivity similar to multilayer graphene. Unlike graphene, MXenes show hydrophilic behavior that allow for easy dispersion in aqueous solutions.

MXenes can be intercalated with a variety of organic molecules and inorganic salts which not only enables synthesis of different intercalation compounds but also leads to new applications for these materials. We continue investigating MXene synthesis by exploring structure and surface termination of MXenes in order to define their chemical formulas and control chemical composition and also by studying the intercalation process, understanding the involved mechanisms and the structure of intercalated MXenes.

MXenes can accommodate various ions and molecules between their layers by a process known as intercalation.

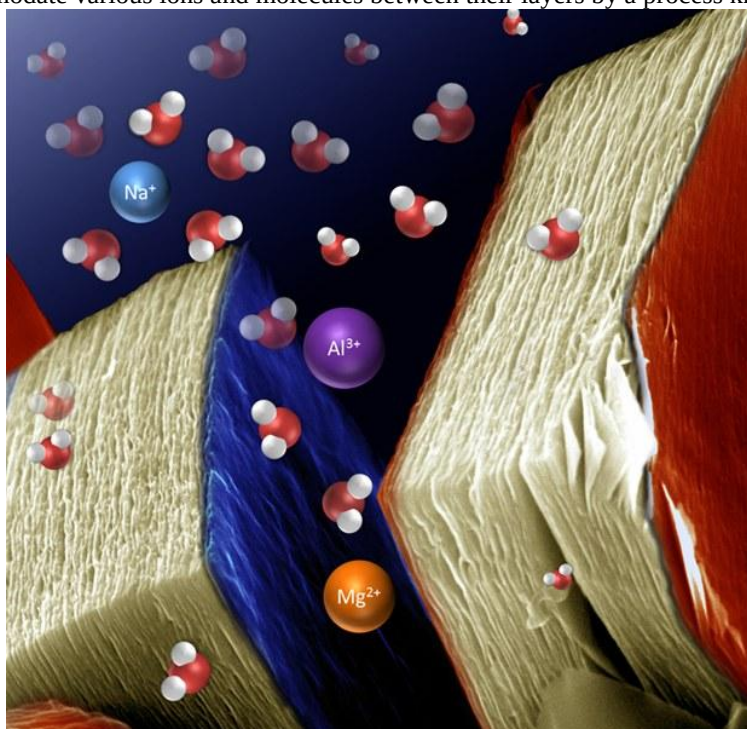


Illustration of MXene layers with intercalated ions

Intercalation is sometimes a necessary step in order to exploit the unique properties of two-dimensional materials. For example, placing lithium ions between the MXene sheets makes them good candidates for use as anodes in lithium-ion batteries. The fact that MXenes can accommodate ions and molecules in this way is significant because it expands their ability to store energy.

III. APPLICATIONS

MXenes could be used for a wide range of applications including electronic devices, sensors, reinforcement for composites, and energy storage materials.

- ✓ Intercalation of magnesium and aluminum ions may pave the way to development of new kinds of metal ion batteries.
- ✓ Two-dimensional, titanium carbide MXene electrodes show excellent volumetric super capacitance of up to 350 F/cm³ due to intercalation of cations between its layers. "This capacity is significantly higher than what is currently possible with porous carbon electrodes. In other words, more energy can be stored in smaller volumes, an important consideration as mobile devices get smaller and require more energy"
- ✓ MXene "paper" electrodes, instead of conventional rolled powder electrodes with a polymer binder may also be useful in flexible and wearable energy storage devices.

IV. CONCLUSION

Thus, MXenes with its unique characteristics are very useful tool for Lithium Ion Batteries that revolutionized the battery world. It is an incredible source of storing more energy in small space providing new horizons to technology world.

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