Scalable Synthesis of MXenes

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2D carbides, nitrides, and carbonitrides of early transition metals known as MXenes are among the few nanomaterials that have jumped into the limelight not only because of their exotic structure, an infinite number of possible compositions, or attractive properties but also because of numerous practical applications [1]. The family of MXenes has been expanding rapidly since the discovery of Ti_3C_2 at Drexel University in 2011. This presentation will describe the state of the art in manufacturing those new 2D materials and their delamination into single-layer 2D flakes and assembly into films [2-4]. The most common published processes for MXene synthesis include:

- Aqueous and non-aqueous HF etching of MAX phases, M_2A_2X and other layered precursors
- Aqueous HCl/HF, HCl-LiF (NaF or other fluoride silts), or NH_4HF_2
- Electrochemical etching in aqueous fluoride or chloride solutions
- Alkali etching (autoclave assisted)
- Supercritical CO_2 solution etching
- Halogen etching of MAX phases (solution or high-temperature gas)
- Molten salt etching of MAX (elevated temperatures of over 600°C)
- CVD synthesis from metal chlorides and methane
- Topochemical transformation of 2D oxides, transition metal chalcogenides, or graphene/graphite

The synthesis method largely determines the surface chemistry of the material. The versatile chemistry of the MXene family renders their properties tunable for a large variety of energy-related, electronic, optical, biomedical, and other applications. In particular, the applications of MXenes in electrochemical energy storage and harvesting, electrocatalytic water splitting and water purification/desalination are promising [1]. However, MXene antennas, sensors, actuators, epidermal and implantable electronics as well as coatings for EMI shielding and thermal regulation are equally attractive.

References

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