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Synthesis of Two-Dimensional Metal Nitrides

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Abstract

The family of two-dimensional (2D) materials – solids with high aspect ratios and thicknesses consisting of a few atomic layers – has grown far beyond graphene. 2D transition metal carbides, nitrides and carbonitrides, known as MXenes, are one of the latest additions to this family. This rapidly growing class of two-dimensional (2D) materials finds applications in fields ranging from energy storage to electromagnetic interference shielding and transparent conductive coatings. However, while more than 20 carbide MXenes have been synthesized, Ti_4N_3 and Ti_2N are the only nitride MXenes reported so far. 2D metal nitrides, including nitride MXenes, have several potential advantages over their carbide analogs. They have theoretically higher values of electrical conductivity than carbide MXenes, which has implications on outperforming carbides in electrochemical and other applications. 2D metal nitrides also offer applications that carbide MXenes cannot offer. 2D metal nitrides are excellent candidates for promising plasmonic devices and spintronic devices that incorporate magnetic 2D materials. Although there are theoretically as many nitride MXenes as carbide MXenes predicted, synthesizing nitride MXenes and 2D metal nitrides in general faces several challenges. Synthesis methods that have produced nearly two dozen 2D metal carbides (MXenes) have failed to yield 2D metal nitrides. The major focus of this study will be investigating routes of synthesizing 2D metal nitrides not limited to selective etching of layered bulk metal nitride precursors. In this study, three promising routes of synthesis are explored. Synthesizing 2D metal nitrides offers the potential to produce devices that outperform current energy storage systems and are expected to later yield several novel devices.