

Electrochemically reshaped MXenes - as versatile platforms for sensing and catalysis

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The increasing demand for highly sensitive, selective, and robust electrochemical sensors has positioned MXenes, two-dimensional transition metal carbides and nitrides, at the forefront of surface modification research for chemical and biochemical sensing. While these materials were traditionally synthesized via hazardous hydrofluoric acid etching, there is a growing shift towards electrochemical methods that employ milder, safer conditions. Electrochemical synthesis not only offers improved environmental sustainability and user safety but also provides precise control over parameters such as applied voltage, current density, electrolyte composition, and etching duration. This level of control facilitates the tailoring of MXene flake size, surface chemistry, and defect density, which are key attributes for optimizing sensor performance.

Recent studies have demonstrated that a top-down electrochemical approach, particularly via cyclic voltammetry, enables the direct transformation of the two-dimensional Ti_3AlC_2 MAX phase into unique microspherical MXene structures. In this template-free method, MAX phase powder is suspended in electrolyte containing tetramethylammonium tetrafluoroborate and tetrafluoroboric acid, with glassy carbon serving as both the working and counter electrodes. Proposed configuration eliminates the need for binders or pre-fabricated solid electrodes, simplifying the fabrication process, enhancing reproducibility, and facilitating scalable production comparing to the other electrochemical approaches, where precursor MAX phase is in the form of tablet or layer deposited onto the conducting substrate.

Although the primary focus of this research is the controlled synthesis and morphological modulation of MXenes using sustainable electrochemical routes, it is also important to highlight the broad versatility these materials offer for surface modification. Electrochemically synthesized MXenes exhibit robust electrical conductivity, high hydrophilicity, and notable biocompatibility, while their surfaces can be readily functionalized with bioelements. These characteristics make them promising candidates for integration into chemical and biochemical sensors capable of detecting biomarkers, pharmaceutical compounds, and environmental pollutants. Notably, recent advances have leveraged MXene-based platforms for hormone sensing, where surface biofunctionalization with aptamers or antibodies enables highly selective and sensitive detection at trace levels.

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