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ABSTRACT

Exploring Bottom-Up Synthesis and Characterization of 2D Transition Metal Carbides

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Two-dimensional transition metal carbides (TMCs), including the expanding family of MXenes, have emerged as key candidates for applications in next-generation energy storage, electronics, catalysis, and sensing. These materials combine metallic conductivity, structural robustness, and tunable surface chemistry, making them ideal for integration into multifunctional devices. However, most existing synthesis approaches rely on top-down chemical etching, which often introduces unwanted surface terminations and defects that compromise performance and long-term stability. To address these limitations, we explore bottom-up chemical vapor deposition (CVD) strategies as a route to achieve high-quality, low-dimensional TMC crystals. Our research focuses on optimizing growth through advanced metal foil stacking methods, which enhance compositional control and mitigate oxidation challenges. Particular attention is given to the development of foil encapsulation techniques for oxygen-sensitive systems, enabling the formation of phase-pure carbides with well-defined morphologies.A suite of advanced characterization techniques, including Raman spectroscopy, X-ray diffraction (XRD), and transmission electron microscopy (TEM), is employed to assess structural and vibrational properties, crystal orientation, and growth behavior. These results provide new insights into the mechanisms governing the CVD growth of 2D TMCs and demonstrate the versatility of our approach for producing a range of pristine, functional nanomaterials. This work underscores the potential of tailored synthesis for advancing the fundamental understanding and practical utility of low-dimensional carbide systems.