HIGHLY STABLE NANOLAMELLAR MXENE-DERIVED CARBIDES BY PHASE TRANSFORMATION OF $Ti_3C_2T_x$ AND $Mo_2TiC_2T_x$ MXENES

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Two-dimensional transition metal carbides, nitrides, and carbonitrides, known as MXenes, have a wide array of impressive material properties due to their inherent transition metal carbide and nitride core with abundant surface functionalities. Although MXenes' properties have been extensively investigated for energy storage and catalysis, few studies take advantage of the inherent stability of the interior transition metal carbide core. In this talk, we present the high-temperature behavior of $Ti_3C_2T_x$ from room temperature to 2000 °C in an inert atmosphere. We annealed $Ti_3C_2T_x$ MXene using *in-situ* two-dimensional x-ray diffraction (XRD^2) hot-stage up to 1100 ºC and spark plasma sintering (SPS) up to 2000 ºC. We utilized XRD^2, cross-sectional scanning electron microscopy and energy dispersive spectroscopy methods to analyze the formed microstructures of $Ti_3C_2T_x$ MXene films annealed up to 2,000 °C. The combination of these methods identified the resulting nano-sized lamellar and micron-sized cubic grain morphology of the 3D crystals depend on the starting $Ti_3C_2T_x$ MXene form. While annealing the multi-layer clay $Ti_3C_2T_x$ MXene creates TiC_y grains with cubic and irregular morphology, the grains of 3D Ti_2C and TiC_y formed by annealing $Ti_3C_2T_x$ MXene single-flake films keep MXenes' lamellar morphology (Figure 1). Additionally, the resulting nanolamellar cubic TiC_y showed strong preferential (111) plane orientation and was stable up to 2000 °C in inert environments.

We also expand these methods with other *in-situ* techniques to measure the micro- and nano-scale structures to characterize the phase transformation behavior in the more exotic ordered double-transition metal MXene $Mo_2TiC_2T_x$. These findings identify a unique capability of MXenes for future studies, which utilize their transition metal carbide and nitride core to form highly stable MXene-derived carbides and nitrides with controlled morphology for extreme environment applications.

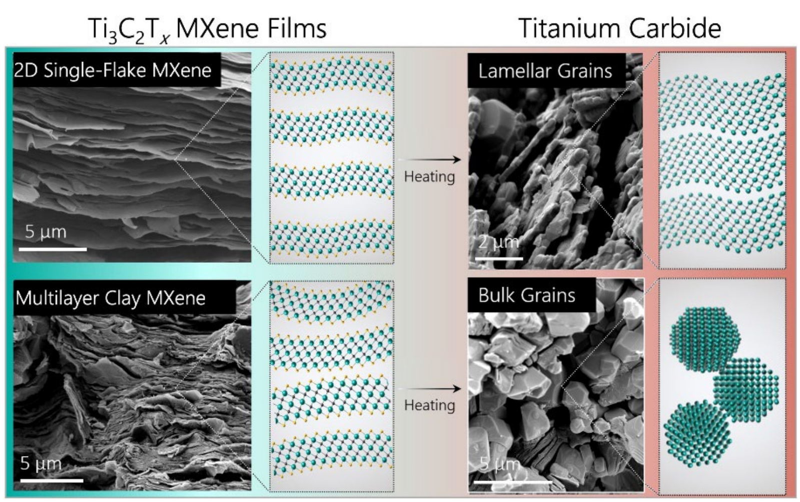

Figure 1 – Phase transformation of $Ti_3C_2T_x$ MXene to TiC_y.

Reference

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