Optimized porous Ti_3AlC_2 MAX phase for enhanced synthesis of $Ti_3C_2T_x$ MXene

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Abstract

MXenes, a rapidly expanding family of two-dimensional carbides and nitrides, are widely studied due to their structural diversity and unique properties enabling applications in electronics, energy storage, and beyond. They are typically produced by selective etching of layered MAX phase ceramics, which, however, are still synthesized using methods originally designed for structural applications rather than optimized for MXene production.
The MAX phase can be fabricated via powder-metallurgical routes, including reactive hot-pressing or hot-isostatic pressing, pres-sureless sintering under an inert environment, self-propagating high-temperature synthesis (SHS), spark plasma sintering and other methods. Most of those methods, except for SHS [1], lead to hard sintered bodies that require crushing and high-energy milling to produce powders.
In this work, we present an optimized synthesis route for MAX phases tailored to MXene manufacturing. A highly porous Ti_3AlC_2 MAX phase (≈70% porosity) was developed, which can be easily ground into individual grains without the need for drilling or intensive ball-milling. Notably, the synthesis employs inexpensive titanium sponge as a precursor instead of high-purity titanium powder. The mechanisms of reaction sintering and porous phase formation are discussed [2-3].
The resulting MXene, $Ti_3C_2T_x$, exhibits larger flake sizes and significantly higher electrical conductivity in thin films compared to MXenes derived from conventional fine titanium powders. This cost-effective and scalable approach may be extended to other MAX phases, offering new opportunities for advancing MXene synthesis and applications.

References

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[3] Y. Gogotsi, O. Gogotsi, I. Roslyk, V. Zahorodna, I. Baginskiy, and R. Lord, Highly Porous MAX Phase Precursor for MXene. Patent Application 20250136452, May 1, 2025.

Figures

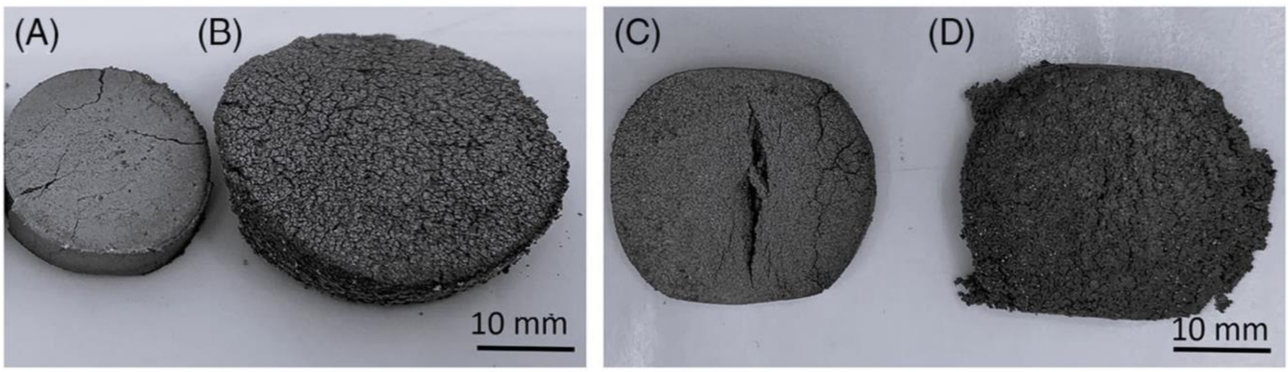

Figure 1: Pictures of sintered bodies after MAX synthesis. (A) fine Ti and fine Al, (B) sponge Ti and fine Al, (C) sponge Ti (fraction less than 75µm) and fine Al, and (D) fine Ti and coarse Al.