Challenges and Opportunities in Integrating MXene into Ceramic Nanocomposites

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MXene materials have garnered significant attention due to their versatility and potential to enhance metal or ceramic matrices in advanced nanocomposites. This study presents a method for producing bulk MXene/ceramic nanocomposites through the mixing of MXene with ceramic particles, followed by field-assisted sintering. Using the $Ti_3C_2T_z$/alumina system as a model, we investigated the impact of MXene addition on the densification behavior and properties of the nanocomposites.

Our findings reveal that MXene significantly accelerates the densification process at lower temperatures when $Ti_3C_2T_z$ is uniformly distributed along the alumina grain boundaries. The resulting $Ti_3C_2T_z$/alumina nanocomposites exhibit notable electrical conductivity and strong light absorption capabilities. However, the presence of intergranular MXene layers leads to a reduction in hardness due to the weakening of grain boundaries.

Additionally, we explored the use of multilayered $Ti_3C_2T_z$ as a precursor, resulting in the formation of composites with a plate-like TiC_x morphology. The MXene-derived $TiC_{0.67}/Al_2O_3$ composites exhibited the presence of AlF_3 and $Ti_{2.25}Al_{0.75}O_5$ phases alongside $TiC_{0.67}$ particles. These additional phases, due to the fluorine present in the MXene precursor, impacted the alumina matrix, causing significant grain growth and affecting the mechanical integrity of the composite.

Despite these challenges, the approach shows considerable promise. We achieved the desired preferred orientation, with particles elongated perpendicular to the applied pressure during sintering. This new morphology reached the percolation threshold and demonstrated high electrical conductivity with approximately one-third of the TiC content required in conventional composites. The findings highlight the need for optimizing MXene precursor preparation and controlling surface terminations to fully leverage the benefits of MXene-derived reinforcements in ceramic composites.