# Seminar

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# Institute for Plasma Research

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| **Title:** | Synthesis and application studies of Ti3AlC2 MAX phase material |
| **Speaker:** | Mr. Vyom Desai<br>Institute for Plasma Research, Gandhinagar |
| **Date:** | 2nd April 2025 (Wednesday) |
| **Time:** | 02.00 PM |
| **Venue:** | Seminar Hall, IPR |

## Abstract


MAX phases, characterized by their hexagonal layered carbide/nitride structures, exhibit a distinctive combination of metallic and ceramic properties. Among these, $Ti_3AlC_2$ stands out as a lightweight and oxidation-resistant ternary carbide. $Ti_3AlC_2$ is noted for its exceptional fracture toughness, electrical and thermal conductivities, and oxidation resistance. Although various synthesis methods exist for $Ti_3AlC_2$, techniques such as Hot Pressing, Hot Isostatic Pressing, and Spark Plasma Sintering are not cost-effective for continuous or bulk production. Pressureless sintering emerges as a viable, cost-effective method for synthesizing MAX phase $Ti_3AlC_2$, capable of producing complex and large shapes.

In this study, high-purity $Ti_3AlC_2$ was synthesized using $TiH_2$, Al, and TiC (1:1.1:2) as raw materials through pressureless sintering. The synthesized $Ti_3AlC_2$ samples were characterized by X-ray diffraction (XRD) and Raman Spectroscopy for phase identification, followed by Scanning Electron Microscopy (SEM) and Energy-Dispersive X-ray Spectroscopy (EDS) for morphological and elemental analysis. X-ray Photoelectron Spectroscopy (XPS) was performed to investigate the chemical environment and bonding nature of the elements. Differential Scanning Calorimetry (DSC) and in situ X-ray diffraction were employed to assess the high-temperature thermal stability of pure $Ti_3AlC_2$ in a vacuum environment at temperatures up to 1400°C and 1000°C, respectively.

Furthermore, $Ti_3AlC_2$ MAX phases were used as a reinforcement to improve the tribological properties. This work involved fabricating metallic and graphite-based composites using $Ti_3AlC_2$ as a reinforcing phase. Surface composites with $Ti_3AlC_2$ reinforcement in Al 6061 and Al 7075 alloys were prepared via friction stir processing (FSP), and their effects were analyzed. Microstructural examination using optical microscopy and SEM revealed a reduction in grain size of the bare FSPed and the Al-$Ti_3AlC_2$ composites. Area mapping showed a uniform dispersion of $Ti_3AlC_2$ particles within the FSPed zone. This microstructural refinement resulted in increased microhardness, with the average values for the base metal, base metal FSPed and Al-$Ti_3AlC_2$ composites being 65 $HV_{0.2}$, 85 $HV_{0.2}$, and 135 $HV_{0.2}$ for Al 6061, and 100 $HV_{0.2}$, 180 $HV_{0.2}$, and 350 $HV_{0.2}$ for Al 7075. The grain refinement and uniform particle distribution significantly improved wear properties, with wear resistance increasing by more than 10 times in Al 6061 and 5 times in Al 7075 compared to their parent metals.

Additionally, a preliminary study on the formation of metallized graphite and $Ti_3AlC_2$ composites was conducted using Spark Plasma Sintering (SPS). Phase analysis indicated the presence of TiC along with $Ti_3AlC_2$. The microhardness of the composites varied between 1100 HV and 2200 HV, demonstrating substantial enhancement in mechanical properties.