Seminar

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Institute for Plasma Research

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Title: Synthesis and application studies of MAX phase Ti_3AlC_2

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Date: 06th June 2024 (Thursday)

Time: 10.30 AM

Venue: Seminar Hall, IPR

Abstract

MAX phases, characterized by their hexagonal layered carbide/nitride structures, exhibit a distinctive combination of metallic and ceramic properties. MAX phases, denoted as $M_{n+1}AX_n$ (where M is a transition metal, A is an A-group element, and X is carbon or nitrogen), and base on value n there are various MAX phases like Cr_2AlC, Ti_3AlC_2, Ti_3SiC_2, Ta_4AlC3 [1,2]. 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, thermal conductivities, and oxidation resistance. Although various synthesis methods such as hot pressing, hot isostatic pressing and spark plasma sintering exist for Ti_3AlC_2, these are complex processes which are a hindrance for bulk production. Pressureless sintering with the ease of processing emerges as a viable 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 [3].
Furthermore, the role of Ti_3AlC_2 MAX phases in improving wear properties of Al alloys was investigated. The synthesized 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 for studying the performance enhancement. 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 [4,5]. 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.

References

1. Jesus Gonzalez-Julian; *Processing of MAX phases: from synthesis to applications*, **Journal of American Ceramic Society** 104 (2) (**2021**) 659–690

2. Desai, Vyom, Aroh Srivastava, Arunsinh B. Zala, Tejas Parekh, Surojit Gupta, N.I. Jamnapara; *Manufacturing of High Purity Cr2AlC MAX Phase Material and Its Characterization*, **Journal of Materials Engineering and Performance** (**2024**): 1-9.

3. Desai, Vyom, Aroh Srivastava, Arunsinh B. Zala, Tejas Parekh, Surojit Gupta, N.I. Jamnapara, *Pressureless manufacturing of high purity Ti_3AlC_2 MAX phase material: Synthesis and characterization*, **Vacuum** 214 (**2023**): 112221.

4. Desai, Vyom, Vishvesh Badheka, Arunsinh B. Zala, Tejas Parekh, N.I. Jamnapara, *Fabrication of Al6061/Ti_3AlC_2 MAX phase surface composite by friction stir processing and investigation of wear properties*, **Tribology International** 195 (**2024**): 109594.

5. Desai, Vyom, Vishvesh Badheka, Arunsinh B. Zala, Tejas Parekh, N.I. Jamnapara, *Al7075 / Ti_3AlC_2 MAX-phase surface composite generated by friction stir processing: microstructure, microhardness, and tribological characteristics* (Manuscript in process with Journal of material engineering and performance)