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SIC/AL COMPOSITE IN AEROSPACE OPTOELECTRONIC

Ugersan Dangi
Desh Bhagat University
Department of Aerospace Engineering
Ugersaindangi@gmail.com

ABSTRACT

The use of composite materials in aerospace and optoelectronic applications has become increasingly popular due to their lightweight, high strength, and corrosion-resistant properties. One such composite is the SIC/AL composite, which is a combination of silicon carbide (SIC) and aluminum (AL). The SIC/AL composite offers several advantages for aerospace and optoelectronic applications. To begin with, its high thermal conductivity makes it a good choice for uses where rapid heat dissipation is required, such as in electronic equipment. Second, it's great for usage in places with wide temperature swings since its coefficient of thermal expansion is so little. Finally, its strength-to-weight ratio is excellent, making it a prime candidate for use in lightweight applications like airplanes and spaceships. The SIC/AL composite is also very resistant to wear and corrosion, making it a great choice for usage in severe conditions. It is also chemically and thermally stable, meaning that it retains its original qualities in a wide variety of environments.

INTRODUCTION

Composite materials have been increasingly used in aerospace and optoelectronic applications due to their unique properties. Silicon carbide (SIC) and aluminum (AL) composite, known as SIC/AL composite, is a material that offers several advantages over traditional materials used in these industries. The aerospace industry demands lightweight materials with high strength and corrosion-resistant properties. SIC/AL composite offers these properties and also has a high thermal conductivity and a low coefficient of thermal expansion. These features make it an ideal material for use in electronic devices, where heat dissipation is crucial, and in environments with extreme temperature fluctuations. Furthermore, the SIC/AL composite is appropriate for severe situations because to its outstanding wear and corrosion resistance. Because of its excellent stability, it can keep its qualities even when exposed to different substances and temperatures.

The optoelectronic industry requires materials that are strong, lightweight, and can maintain their properties over a wide range of temperatures. The SIC/AL composite is a suitable material for use in this industry because of its unique combination of properties. the SIC/AL composite has several features that make it a valuable material for use in aerospace and optoelectronic applications. Its properties can enhance the performance of various devices used in these industries, including spacecraft, satellites, and electronic devices.

Fabrication of Multi-functional SiC/Al Composites

The fabrication of multi-functional SiC/Al composites involves the incorporation of SiC particles into an aluminum matrix to create a material with a unique combination of properties.

The SiC particles can improve the mechanical properties, such as strength and stiffness, of the composite, while also providing other functionalities such as thermal conductivity, wear resistance, and corrosion resistance. Several processing techniques have been developed for the fabrication of multi-functional SiC/Al composites, including powder metallurgy, stir casting, and infiltration methods. The choice of processing technique depends on the desired properties and the specific application of the composite. The addition of other reinforcement materials, such as carbon nanotubes or graphene, can further enhance the properties of multi-functional SiC/Al composites. The optimization of processing parameters, such as temperature and pressure, can also improve the quality and properties of the composite. **(Arab, N,2020).**

The resulting SiC/Al composites have remarkable properties and can be employed in a wide range of aeronautical, automotive, and electrical applications. Because of their excellent thermal conductivity and low coefficient of thermal expansion, SiC/Al composites, for example, are well-suited for use in electronic device thermal management systems. Because of their flexibility to customize properties with the inclusion of different reinforcement components, multi-functional SiC/Al composites provide versatility and the capacity to develop materials suitable for a wide range of technical applications. The development of SiC/Al composites with multiple applications is an intriguing promise for the future of materials science. The optimization of processing parameters and the addition of other reinforcement materials can result in the development of composites with desirable properties for various applications, including aerospace, automotive, and electronics industries.

Microstructures of Multi-functional SiC/ Al Composites

The microstructure of multi-functional SiC/Al composites is an essential aspect of their properties and performance. The microstructure is influenced by the processing techniques, the size and volume fraction of SiC particles, the presence of other reinforcement materials, and the post-processing treatments. Multi-functional SiC/Al composites have a microstructure that consists of SiC particles dispersed throughout an aluminum matrix or grouped together. The mechanical and thermal properties of a composite can be enhanced by distributing the SiC particles evenly throughout the material, while the opposite is true if the particles are clustered together. Optical microscopy, scanning electron microscopy, and transmission electron microscopy are just a few of the methods that may be used to examine the microstructure of multi-functional SiC/Al composites. The size, shape, and location of the SiC particles embedded in the aluminum matrix can be determined using these methods**. (Bhagwat T.et al,2017)**

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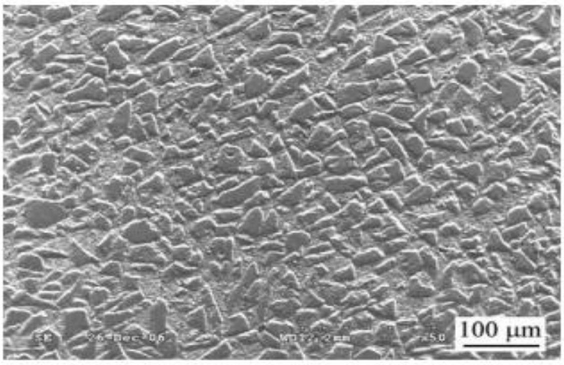

Fig.1 SEM micrograph of SiC/Al composites.

Moreover, the microstructure of multi-functional SiC/Al composites can be tailored through different processing techniques, such as powder metallurgy, stir casting, and infiltration methods. The use of other reinforcement materials, such as carbon nanotubes or graphene, can also influence the microstructure of the composite.

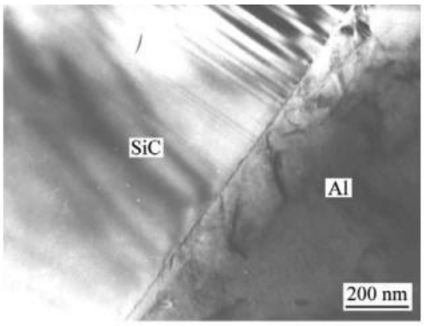

Fig.2 TEM micrograph of SiC/Al interface.

The microstructure of multi-functional SiC/Al composites plays a critical role in their properties and performance. The optimization of processing parameters and the addition of other reinforcement materials can lead to the development of composites with desirable microstructures and improved properties for various applications, including aerospace, automotive, and electronics industries.

Properties of Multi-functional SiC/Al Composites

Engineers can take advantage of the diverse range of qualities offered by multi-functional SiC/Al composites. Many parameters, such as processing methods, SiC particle size and volume percentage, other reinforcement materials present, and post-processing treatments, all affect the final composite material's characteristics.

The properties of multi-functional SiC/Al composites typically include:

High strength: The addition of SiC particles to the aluminum matrix can improve the strength and stiffness of the composite, making it suitable for use in structural applications.

High thermal conductivity: SiC/Al composites have a high thermal conductivity, making them ideal for use in thermal management applications in electronic devices.

Low coefficient of thermal expansion: SiC/Al composites have a low coefficient of thermal expansion, which makes them suitable for use in environments with extreme temperature fluctuations.

Wear resistance: The addition of SiC particles to the aluminum matrix can improve the wear resistance of the composite, making it suitable for use in applications where wear is a concern.

Corrosion resistance: SiC/Al composites have excellent corrosion resistance, making them suitable for use in harsh environments.

Tailorability: The properties of multi-functional SiC/Al composites can be tailored through different processing techniques, the addition of other reinforcement materials, and the post-processing treatments.

Multi-functional SiC/Al composites offer a versatile material with a unique combination of properties suitable for various engineering applications, including aerospace, automotive, and electronics industries. The optimization of processing parameters and the addition of other reinforcement materials can lead to the development of composites with desirable properties for specific applications.

LITERATURE REVIEW

Yan, C., Lifeng, W., et al, (2008). As their excellent mechanical, thermal, and functional qualities have drawn more and more attention, multi-functional SiC/Al composites have found widespread use in aerospace applications. Incorporating aluminum (Al) into silicon carbide (SiC) creates a material with exceptional wear and corrosion resistance, low coefficient of thermal expansion, and high strength-to-weight ratio. SiC/Al composites can be used in a variety of structural components, thermal management systems, and electronic devices in the aerospace industry thanks to their exceptional performance in these areas. Additionally, the ability to tailor the properties of SiC/Al composites through different fabrication methods enables customization of the material for specific applications. Moreover, SiC/Al composites can be functionalized through the addition of different materials, such as carbon nanotubes, to enhance their properties further. This multifunctionality allows for the development of advanced composites that can perform multiple tasks simultaneously, such as structural support and thermal management.

Chen, M., Bai, Y et al (2021). SiC/Al composites with a high volume fraction of SiC and high thermal conductivity are desirable materials for various aerospace and optoelectronic applications. The vacuum pressure infiltration (VPI) method is a promising technique for the preparation of these composites. In the VPI method, molten aluminum is forced into a preform of SiC particles under vacuum and pressure. The pressure helps to ensure complete infiltration of the molten aluminum into the preform, resulting in a composite with a high volume fraction of SiC. The use of a vacuum during the infiltration process reduces the porosity of the composite, which can enhance its mechanical and thermal properties. Several factors can influence the quality and properties of the SiC/Al composites produced by the VPI method, including the preform structure, infiltration parameters, and post-processing techniques.

Optimization of these parameters can lead to the production of composites with a high volume fraction of SiC and high thermal conductivity.

Singla, M., Dwivedi, D. D., et al,(2009). Due to its exceptional mechanical and thermal qualities, aluminum-based silicon carbide (SiC) particulate metal matrix composites (MMCs) have attracted a great deal of research and development interest. Strength, stiffness, and wear resistance can all be improved by incorporating SiC particles into the aluminum matrix. Stir casting, powder metallurgy, and infiltration are just a few of the processing techniques that have been developed for the manufacture of aluminum-based SiC particulate MMCs. The choice of processing technique can significantly influence the properties of the composite, and optimization of the parameters is crucial to achieve the desired properties. The properties of aluminium-based SiC particulate MMCs can be further improved through the addition of other reinforcement materials, such as carbon nanotubes, graphene, or ceramic fibers. The addition of these materials can enhance the mechanical and thermal properties of the composite and provide additional functionalities.

Arab, N. (2020). Many research have looked into how the percentage of SiC in an Al/SiC nano composite made through mechanical alloying, sintering, and milling affects the material's microstructure and mechanical properties. The mechanical properties of the composite, such as strength, stiffness, and wear resistance, can be enhanced by incorporating SiC particles into the Al matrix. The mechanical alloying technique can better attach the SiC particles to the Al matrix and guarantee that they are evenly distributed inside the matrix. The proportion of SiC to Al in the nano composite significantly affects its microstructure. The composite's grain size reduces and the SiC particles become more evenly dispersed in the Al matrix as the SiC content rises. However, the production of SiC clusters due to an excess of SiC concentration can diminish the composite's mechanical characteristics. Hardness, tensile strength, and wear resistance are only few of the mechanical properties of the Al/SiC nano composite that are affected by the SiC percentage.

Bhagwat T. Dhekwar, et al, (2017) The investigation of mechanical properties of aluminum silicon carbide (Al/SiC) hybrid metal matrix composites (MMCs) has gained significant attention due to their potential for various engineering applications. The Al/SiC hybrid MMCs combine the properties of the Al matrix and SiC particles to produce a material with improved mechanical properties, such as high strength, stiffness, and wear resistance. The mechanical properties of Al/SiC hybrid MMCs can be influenced by several factors, including the processing technique, the volume fraction and size of the SiC particles, and the presence of other reinforcing materials, such as carbon nanotubes or graphene. Several mechanical testing methods have been used to investigate the properties of Al/SiC hybrid MMCs, including tensile testing, compression testing, hardness testing, and wear testing. These tests have revealed that the addition of SiC particles to the Al matrix can significantly improve the mechanical properties of the composite. With increasing volume fraction of SiC particles, the strength and stiffness of the composite increase, while the ductility decreases.

Aluminum (AL) Composite

An aluminum (Al) composite is a material that consists of an aluminum matrix reinforced with one or more other materials, such as SiC, graphite, or carbon fibers. The aluminum matrix can be enhanced in mechanical, thermal, and electrical properties by including these reinforcement materials. Matrix and reinforcing materials in aluminum composites interact to determine their final qualities. Adding SiC particles, for instance, can boost the composite's strength, stiffness, and wear resistance; graphite or carbon fibers, meanwhile, can boost the composite's thermal and electrical conductivity.

Various processing techniques have been developed for the manufacture of aluminum composites, including stir casting, powder metallurgy, and infiltration processes. The choice of processing procedure depends on the desired qualities and the specific use of the composite. Aluminum composites can find multiple applications in several industries, including aerospace, automotive, and electronics. The high strength-to-weight ratio, thermal stability, and outstanding electrical conductivity of these composites make them appropriate for usage in diverse components, such as structural components, heat sinks, and electrical conductors.

Advantages of Aluminium

Aluminum (Al) has numerous advantages that make it a versatile and widely used material in various industries, including aerospace, automotive, construction, and electronics. Some of the advantages of aluminum include: **(D. B. Miracle,2005)**

Lightweight: Aluminum has a low density compared to other metals, making it lightweight and ideal for applications where weight is a concern.

High strength-to-weight ratio: Aluminum alloys have a high strength-to-weight ratio, which makes them ideal for use in structural applications where strength and weight are critical.

Corrosion resistance: Aluminum has excellent corrosion resistance due to its ability to form a protective oxide layer on its surface when exposed to air, water, or other corrosive agents.

Ductility: Aluminum's strong ductility allows it to be easily molded into a variety of configurations without breaking or cracking.

Thermal conductivity: Aluminum is frequently used for heat sinks and other thermal management components due to its great thermal conductivity.

Electrical conductivity: Aluminum has a high electrical conductivity, which makes it suitable for use in electrical conductors and other electronic applications.

Recyclability: Aluminum is 100% recyclable and can be recycled repeatedly without losing its properties or quality.

The advantages of aluminum make it a versatile and widely used material in various industries. The unique properties of aluminum can be further enhanced by combining it with other materials, such as SiC, graphite, or carbon fibers, to form composites with even more desirable properties for specific applications.

SiC (Silicon Carbide) composite

SiC (Silicon Carbide) composite is a material that consists of a SiC matrix reinforced with one or more other materials, such as carbon fibers, SiC whiskers, or nanoparticles. The addition of these reinforcement materials can improve the mechanical, thermal, and electrical properties of the SiC matrix, making it suitable for various engineering applications.

SiC composites are known for their high strength, stiffness, and thermal stability. The SiC matrix provides excellent thermal conductivity and high-temperature resistance, while the reinforcement materials can improve the strength, toughness, and wear resistance of the composite.

Many different technologies, including as chemical vapor infiltration (CVI), polymer infiltration and pyrolysis (PIP), and hot pressing, have been developed for the manufacture of SiC composites. The processing method selected is determined by the composite's intended use and its desired qualities.

SiC composites can find numerous applications in various industries, including aerospace, defense, energy, and electronics. The high strength-to-weight ratio, thermal stability, and excellent thermal conductivity of these composites make them suitable for use in various components, such as structural components, heat exchangers, and electronic devices.

SiC composites offer a versatile material with a unique combination of properties suitable for various engineering applications. The optimization of processing parameters and the addition of other reinforcement materials can lead to the development of composites with desirable properties for specific applications. **(S. Vijayabhaskar et al,2019)**

Manufacturing Processes for SiC/Al Composite Components

The manufacturing of SiC/Al composite components involves several steps, including material selection, processing, shaping, and finishing. The specific manufacturing process depends on the desired properties, shape, and size of the component. The manufacturing process typically begins with the selection of SiC and aluminum materials with appropriate properties for the desired application. The SiC and aluminum materials are then processed to produce a uniform mixture with a desired volume fraction of SiC particles. The processing techniques for SiC/Al composites include powder metallurgy, stir casting, and infiltration methods. The processing technique used depends on the desired properties and the specific application of the component.

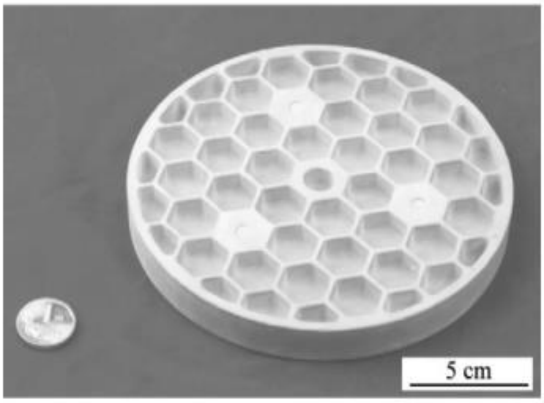

Figure 3 Precisely-formed SiC preform

After processing, the SiC/Al composite material is shaped into the desired component using different techniques such as casting, forging, or machining. The shaping process should be carefully controlled to ensure uniform distribution of SiC particles within the aluminum matrix.

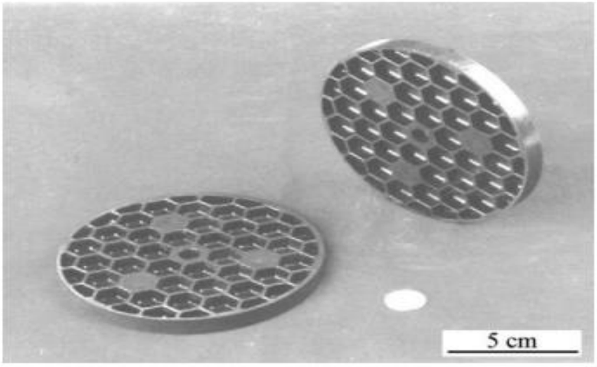

Figure 4 SiCp/Al composite components

The finishing process involves different treatments such as heat treatment, surface treatment, and coating. The finishing process can improve the properties and surface finish of the component, and protect the component from environmental factors such as corrosion. Moreover, the manufacture of SiC/Al composite components can be challenging due to the presence of SiC particles, which can lead to wear and damage of the manufacturing tools. The manufacturing process should, therefore, be carefully designed to minimize the impact of SiC particles on the manufacturing tools. **(L M. Tham et al,2001)**

Applications of Multi-functional SiC/Al Composites in Aerospace Engineering

Multi-functional SiC/Al composites offer a unique set of properties that make them suitable for various aerospace applications. The high strength-to-weight ratio, low coefficient of thermal expansion, and high thermal conductivity of these composites can improve the performance and efficiency of various aerospace components.

Some potential aerospace applications of multi-functional SiC/Al composites include:

Structural components: The high strength and stiffness of SiC/Al composites make them suitable for use in structural components of aircraft and spacecraft.

Thermal management systems: The high thermal conductivity of SiC/Al composites makes them ideal for use in thermal management systems of electronic devices used in aerospace applications.

Engine components: The wear and corrosion resistance of SiC/Al composites make them suitable for use in engine components, such as fan blades and turbine components.

Electrical and electronic components: The low coefficient of thermal expansion of SiC/Al composites makes them ideal for use in electrical and electronic components, where dimensional stability is critical.

Radar systems: The low dielectric constant of SiC/Al composites makes them suitable for use in radar systems where low signal attenuation is required.

The unique properties of multi-functional SiC/Al composites make them suitable for various aerospace applications, from structural components to thermal management systems and electrical and electronic components. The continued research and development of these materials are expected to result in the development of new and improved composites suitable for even more advanced aerospace applications.

CONCLUSION

As a result of its exceptional mix of features, the SIC/AL composite has emerged as a potential material for use in aerospace and optoelectronic applications. Aerospace applications ranging from structural parts to thermal management systems and electronic devices can take use of the composite's excellent thermal conductivity, low coefficient of thermal expansion, and high strength-to-weight ratio. The use of the SIC/AL composite can enhance the performance of various components in the aerospace and optoelectronic industries, such as spacecraft, satellites, and electronic devices. The ability to tailor the properties of the composite through different processing techniques and the addition of other reinforcement materials further enhances its versatility and potential for various applications. In addition, the investigation of the mechanical properties of aluminum silicon carbide hybrid metal matrix composites and the development of high-volume fraction SiC/Al composites with high thermal conductivity via vacuum pressure infiltration provide valuable insights into the potential of these materials for advanced material development. The SIC/AL composite provides an exciting new avenue for research and development in high-tech materials for use in aerospace and optoelectronics. The continued research and development of this material will undoubtedly lead to the development of new and improved materials with even more desirable properties for various engineering applications.

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