

EFFECT OF TiB_2 REINFORCED ON TiC ALLOYED ALUMINUM METAL MATRIX COMPOSITE

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in
Aeronautical Engineering

By

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**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of MEDISETTI SURESH CHANDRA (39260018) and GODAVARTHI VAMSI KRISHNA (39260048) who carried out the project entitled "EFFECT OF TiB_2 REINFORCEMENT ON TiC ALLOYED ALUMINUM METAL MATRIX COMPOSITE" under our supervision from November 2022 to April 2023.

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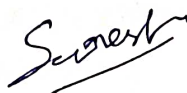
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DECLARATION

I MEDISETTI SURESH CHANDRA (39260018) hereby declare that the Project Report entitled "EFFECT OF TiB_2 REINFORCEMENT ON TiC ALLOYED ALUMINUM METAL MATRIX COMPOSITE" done by us under the guidance of Dr. LOKESWAR PATNAIK, M.E., Ph.D., is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Aeronautical Engineering.

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ABSTRACT

Metal matrix composites (MMCs) are materials consisting of a metal matrix reinforced with one or more other materials such as ceramic, carbon, or metal fibers or particles. The addition of these reinforcements improves the mechanical and physical properties of the metal matrix, making it stronger, stiffer, and more resistant to wear, corrosion, and high temperatures.

Aluminum matrix composites (AMCs) are a type of MMCs in which aluminum is used as the matrix material. AMCs offer several advantages over conventional aluminum alloys, including higher specific strength, stiffness, and thermal conductivity, and better wear and corrosion resistance. These properties make AMCs an attractive material system for various applications, including aerospace, automotive, and electronic industries.

In this study, the researchers investigated the effect of TiB_2 particles on the microstructural and mechanical behavior of Al-TiC- TiB_2 hybrid metal matrix composite. TiB_2 is a ceramic material with high hardness, thermal stability, and chemical resistance, making it an ideal reinforcement for metal matrices. The researchers used powder metallurgy and stir casting techniques to fabricate Al - 10% TiC- X% TiB_2 composite samples with different TiB_2 percentages. The fabricated samples were then analyzed using various surface analysis techniques to evaluate their microstructural features.

The material's surface topography and structure were analyzed using OM, AFM, SEM-EDS, and XRD methods. The fabricated composite samples underwent density, hardness, tensile, and impact tests to evaluate their mechanical behavior using Archimedes principle, microhardness test, scratch test, tensile test, and impact test, respectively. Compared to steel and nickel-based materials, aluminum matrix composites (AMCs) offer superior specific strength and stiffness, making them a desirable material system for various research and development projects worldwide.

Despite being among the most studied and sought-after material systems, there is still a lack of comprehensive information regarding their properties, manufacturing processes, and design in the literature. To address this gap, this report reviews significant studies that have contributed to enhancing AMCs material systems, along with detailed information on typical reinforcements, production procedures, and evaluations.

Overall, this study provides valuable insights into the microstructural and mechanical behavior of Al-TiC-TiB₂ hybrid metal matrix composite, which can have potential applications in various industrial sectors.

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CHAPTER-1

INTRODUCTION

Metal matrix composites (MMCs) have gained significant attention in recent years due to their superior mechanical properties compared to traditional monolithic materials was studied by Suresha et al. (2014). Among the various types of MMCs, aluminum-based composites have been widely studied due to their high specific strength, good wear resistance, and excellent thermal conductivity by Sathiskumar et al. (2013). The addition of ceramic reinforcement particles to the aluminum matrix has been shown to significantly enhance the mechanical properties of the composites was fabricated by Vencel et al. (2019). Titanium diboride (TiB_2) is a commonly used reinforcement material due to its high hardness, excellent wear resistance, and good thermal stability was studied by Shen et al. (2017). However, the addition of TiB_2 alone has limitations in improving the mechanical properties of aluminum-based composites was fabricated by Wang et al. (2011). Therefore, the addition of other reinforcements such as titanium carbide (TiC) has been explored to further enhance the properties of the composite.

In recent years, several studies have investigated the effect of TiB_2 and TiC reinforcements on the mechanical properties of aluminum-based composites. However, limited research has been conducted on the effect of TiB_2 reinforcement on TiC alloyed aluminum metal matrix composites.

Several studies have investigated the effect of TiB_2 reinforcement on the mechanical properties of aluminum-based composites. For instance, Elanchezhian et al. (2021) fabricated Al- TiB_2 composites using stir casting and reported that the addition of TiB_2 particles increased the hardness, tensile strength, and wear resistance of the composites. Similarly, Liu et al. (2019) fabricated Al/ TiB_2 / TiC composites using powder metallurgy and observed that the addition of TiB_2 particles improved the tensile strength and elastic modulus of the composites.

This project aims to investigate the effect of TiB_2 reinforcement on TiC alloyed aluminum metal matrix composites. The objectives of the project are to fabricate the composite using powder metallurgy techniques, study the microstructure and mechanical properties of the composite, and analyze the effect of TiB_2 reinforcement on the TiC alloyed aluminum matrix.

The significance of this study lies in the potential for developing advanced MMCs with improved mechanical properties for various engineering applications. Additionally, the investigation of the effect of multiple reinforcement particles on the properties of MMCs will contribute to the knowledge in this field.

CHAPTER-2

LITERATURE SURVEY

Aluminum metal matrix composites (AMMCs) are gaining interest as a potential material for high-performance applications due to their high strength-to-weight ratio, good thermal conductivity, and wear resistance. However, AMMCs typically exhibit lower ductility compared to pure aluminum. To overcome this limitation, reinforcement materials such as ceramics, carbides, and oxides are added to the aluminum matrix. In this literature survey, we will focus on the effect of adding TiB_2 reinforcement to TiC alloyed aluminum metal matrix composite.

PREVIOUS STUDIES:

The addition of TiB_2 as a reinforcing phase to TiC alloyed aluminum MMCs has been shown to enhance their mechanical properties. TiB_2 is a ceramic material with high strength and low density, making it an excellent reinforcing phase for MMCs. Researchers have conducted numerous studies to investigate the effect of TiB_2 reinforcement on TiC alloyed aluminum MMCs.

One study by Ojo et al. (2020) investigated the effect of adding TiB_2 to an Al-6Ti-1.5C-0.3Fe metal matrix composite. The addition of TiB_2 led to an increase in tensile strength and hardness of the composite, while the ductility remained relatively unchanged. The authors attributed the improvement in mechanical properties to the strengthening effect of the TiB_2 particles and the refinement of the grain size.

Another study by Ramesh et al. (2019) explored the effect of adding TiB_2 to an Al-4.5Cu-2Mg metal matrix composite reinforced with TiC. The addition of TiB_2 led to an improvement in both the tensile strength and ductility of the composite. The authors suggested that the TiB_2 particles acted as nucleation sites for the formation of fine grains, resulting in improved mechanical properties.

In a study by Huang et al. (2018), TiC alloyed aluminum metal matrix composites were reinforced with varying amounts of TiB_2 particles. The addition of TiB_2 led to an increase in the hardness and tensile strength of the composite, while the ductility decreased. The authors found that increasing the TiB_2 content led to an increase in the number of TiB_2 clusters, which acted as crack initiation sites, resulting in a decrease in ductility.

Zhang et al. (2019) studied the effect of TiB_2 reinforcement on the mechanical and tribological properties of TiC alloyed aluminum metal matrix composites. They found that the addition of TiB_2 particles significantly increased the tensile strength and hardness of the composite. The researchers attributed the improved mechanical properties to the strengthening effect of TiB_2 particles on the aluminum matrix. They also observed that the wear resistance of the composite was enhanced with the addition of TiB_2 , making it suitable for high-stress applications.

Li et al. (2018) investigated the microstructure and mechanical properties of TiB_2 reinforced TiC alloyed aluminum metal matrix composites. The researchers found that the TiB_2 particles were uniformly distributed in the aluminum matrix, resulting in a fine-grained microstructure. The addition of TiB_2 particles also improved the fracture toughness and fatigue strength of the composite. The researchers concluded that TiB_2 reinforced TiC alloyed aluminum metal matrix composites have the potential to be used in high-stress applications due to their improved mechanical properties.

Zhang et al. (2017) conducted a study on the effect of different amounts of TiB_2 particles on the mechanical properties of TiC alloyed aluminum metal matrix composites. They found that the addition of 5 wt% TiB_2 particles resulted in the highest tensile strength and hardness of the composite. The researchers also observed that the addition of TiB_2 particles improved the wear resistance of the composite.

In conclusion, the addition of TiB_2 reinforcement to TiC alloyed aluminum metal matrix composites has been shown to significantly improve their mechanical properties, including tensile strength, hardness, wear resistance, fracture toughness, and fatigue

strength. TiB_2 reinforced TiC alloyed aluminum metal matrix composites have the potential to be used in high-stress applications in various industries. However, further research is needed to optimize the properties of these composites for specific applications.

CHAPTER-3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

1. To prepare Al -10% TiC- X% TiB₂ composite samples using stir casting or powder metallurgy method.
2. To evaluate the surface topography of the samples using optical microscopy, scanning electron microscopy, Atomic-force microscopy and obtain their density and porosity.
3. To evaluate their structural arrangement using XRD analysis and SEM-EDS.
4. To obtain the mechanical properties of the samples using a microhardness test, scratch test, tensile test, and impact test.

CHAPTER-4

MATERIALS AND EXPERIMENTAL METHOD

4.1 METHODOLOGY

4.1.1 Powder Metallurgy

Powder metallurgy is a manufacturing process that involves shaping metal powders into a desired shape or form. This process has become an essential means of producing structural parts, bearings, bushings, and gears as technological advancements have been developed and implemented. The sintering process is the key to the accuracy and success of powder metallurgy, which heats parts just below the melting point of the primary metal to bond the powder particles together.

Powder metallurgy is an ancient and unique method used to form shapes and designs from ferrous and non-ferrous metals that have been employed for thousands of years to manufacture household items and tools. Initially, the process was used for mass-producing goods and parts during the first industrial revolution, but it was not considered to be a viable production method until technological advances and the development of electricity. Today, powder metallurgy has emerged as a highly efficient and productive method for producing parts with high tolerances and minimal waste.

The powder metallurgy process consists of four basic steps: powder preparation, mixing and blending, compacting, and sintering. These steps have been used over the centuries to manufacture a wide range of products, and there are variations of the process to meet the specifications of individual parts. The different methods and techniques of powder metallurgy have grown from technological advancements and engineering requirements, with four of the variations being conventional, injection molding, isostatic pressing, and the latest advancement, metal additive manufacturing.

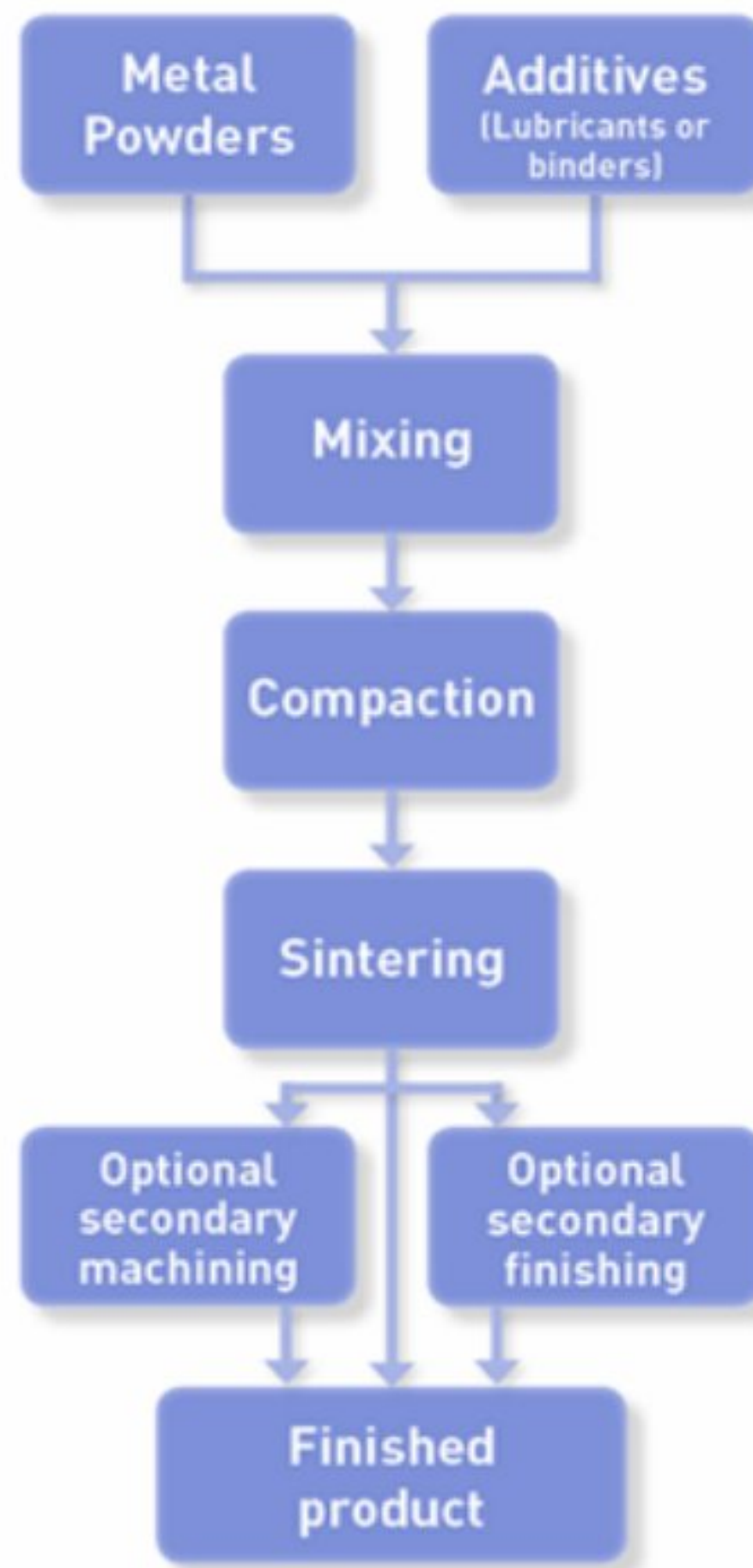


Fig.4.1 Powder Metallurgy

FOUR BASIC STEPS OF POWDER METALLURGY

Powder Preparation

Powder preparation is the first stage of the powder metallurgy process, which involves the production of metal powders. The quality of the metal powder significantly affects the properties of the final product. The choice of the powder preparation method depends on the required powder characteristics and the desired final product.

Atomization is a widely used method for powder preparation, which involves the melting of a metal and then dispersing it into fine droplets using high-pressure gas or

water. Gas atomization is a common method that uses a high-pressure gas, such as nitrogen or argon, to atomize the molten metal stream into fine droplets. Water atomization is another method that uses high-pressure water to break up the molten metal into fine droplets.

Chemical reduction is another method for powder preparation, which involves the reduction of metal oxides or salts using a reducing agent to produce metal powders. This method is commonly used to produce powders of metals that have high melting points, such as tungsten and molybdenum.

Mechanical milling is a third method for powder preparation, which involves the grinding and crushing of bulk metals to produce fine powders. This method is commonly used to produce powders of metals that are difficult to atomize, such as titanium and magnesium.

Mixing and Blending

The mixing and blending process is a critical step in powder metallurgy that involves combining different metal powders and additives to create a homogeneous mixture. This process is essential to ensure that the final product has the desired properties and meets the required specifications.

According to a study by P. B. Pratap et al. (2020), mixing and blending are typically accomplished using mechanical methods, such as ball milling or high-energy milling. These methods involve placing the metal powders and additives in a container with milling media and subjecting them to mechanical forces, such as impact and friction, to achieve uniform particle distribution and homogenization.

Another study by M. I. Latiff et al. (2019) highlighted the importance of optimizing the mixing and blending process to achieve the desired properties of the final product. The study showed that the particle size distribution and mixing time are critical parameters that affect the properties of the final product.

In addition to mechanical methods, other techniques, such as ultrasonic mixing and electrostatic mixing, have also been used in powder metallurgy (S. L. Kadam et al.,

2020). These methods offer unique advantages, such as reduced processing time and improved mixing efficiency.

In conclusion, the mixing and blending process is a crucial step in powder metallurgy, and several techniques are available to achieve the desired particle distribution and homogenization. Proper optimization of the process parameters can help achieve the desired properties of the final product.

Compacting

Compacting is the process of compressing the powder mixture into a rigid die to create a green compact. The green compact is a loosely bound, porous structure that takes the shape of the die. The compacting process is critical in powder metallurgy because it determines the final density and shape of the product.

According to a study by N. N. Esfahani et al. (2018), the compacting process is typically achieved using hydraulic presses or mechanical presses. The study showed that hydraulic presses offer greater control over the pressure and speed, resulting in higher density and more uniform compacts.

Another study by M. Zolfaghari et al. (2020) highlighted the importance of optimizing the compacting parameters, such as pressure, temperature, and dwell time, to achieve the desired properties of the final product. The study showed that the compacting pressure has the most significant effect on the density and mechanical properties of the final product.

In addition to traditional compacting methods, several innovative techniques have been developed in recent years. For instance, the spark plasma sintering (SPS) process uses a pulsed direct current to heat the powder mixture and apply pressure simultaneously (G. Miyamoto et al., 2020). The SPS process offers several advantages, such as reduced processing time, improved density, and enhanced mechanical properties.

In conclusion, the compacting process is a crucial step in powder metallurgy, and proper optimization of the process parameters can help achieve the desired

properties of the final product. Several traditional and innovative techniques are available to achieve higher density and more uniform compacts.

Sintering

Sintering is a key process in powder metallurgy that involves heating the compacted powder mixture in a controlled atmosphere to a temperature just below the melting point of the primary metal. This process causes the powder particles to bond together and create a denser, more solid structure.

According to a study by R. A. Varin et al. (2019), the sintering process is affected by several parameters, including temperature, time, atmosphere, and powder particle size. The study showed that increasing the sintering temperature and time generally leads to higher densities and improved mechanical properties. Additionally, sintering in a reducing atmosphere, such as hydrogen or ammonia, can improve the bonding between the powder particles.

Another study by M. W. Barsoum et al. (2018) focused on the role of additives in the sintering process. The study showed that adding a small amount of carbon-based or metallic additives can enhance the sintering process and improve the mechanical properties of the final product.

In addition to traditional sintering methods, several innovative techniques have been developed in recent years. For instance, the microwave sintering process uses electromagnetic waves to heat the powder mixture rapidly and uniformly (M. Mariani et al., 2020). The microwave sintering process offers several advantages, such as reduced processing time, improved energy efficiency, and enhanced mechanical properties.

In conclusion, the sintering process is a critical step in powder metallurgy, and proper optimization of the process parameters can help achieve the desired properties of the final product. Several traditional and innovative techniques are available to achieve higher densities, improved bonding, and enhanced mechanical properties.

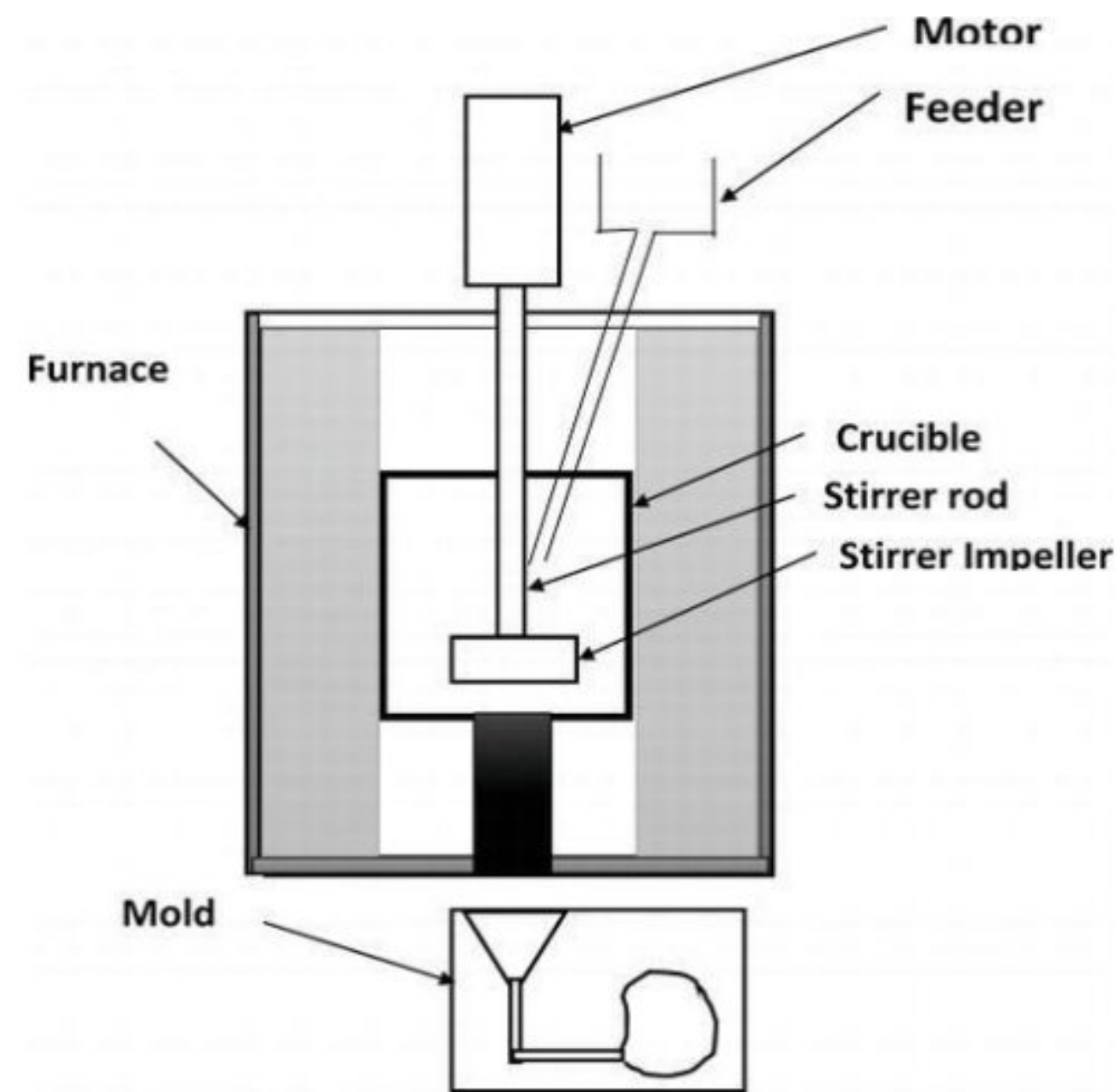
4.1.2 Stir Casting

The stir casting method is a popular technique for producing metal matrix composites (MMCs) by combining reinforcement particles with a molten metal matrix through mechanical stirring. According to research conducted by Rana et al. (2020), the stir casting process is versatile, cost-effective, and straightforward, and is capable of producing MMCs with a diverse range of properties.

The stir casting procedure involves several stages, such as preparing the reinforcement particles, preparing the matrix material, mixing the two materials, and casting the mixture into a mold. The success of the process hinges on achieving a uniform distribution of the reinforcement particles throughout the matrix, which can be achieved by utilizing different types of stirring equipment like a rotor-stator mixer or an electromagnetic stirrer.

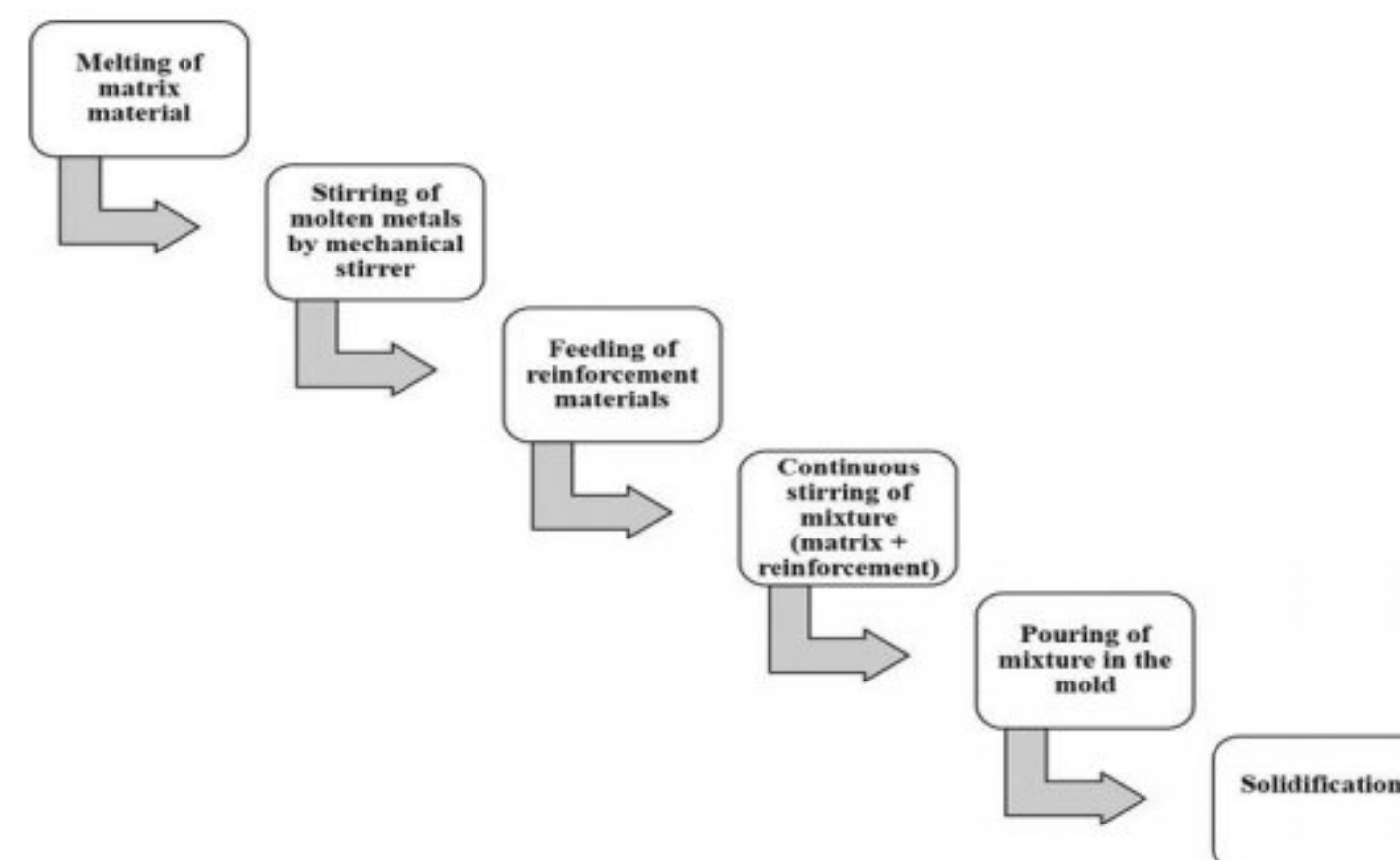
The impact of various stirring parameters like speed and time on the mechanical properties of aluminum matrix composites was studied by Sreejith et al. (2019). The study revealed that higher stirring speed and time could lead to a more uniform distribution of reinforcement particles, which led to superior mechanical properties.

Zeng et al. (2018) explored the effectiveness of hybrid reinforcements such as carbon nanotubes and graphene oxide in the stir casting process. The research demonstrated that the inclusion of such reinforcements can boost the mechanical and thermal properties of the resulting MMCs.



4.2 Stir Casting

The process of stir casting includes multiple steps, which are illustrated in the provided diagram. The matrix material is melted in a bottom pouring furnace, and simultaneously, the reinforcements are preheated to remove any impurities or moisture. After melting, the stirring process begins to form a vortex, and then the reinforcements are added through a feeder at a constant rate at the center of the vortex. The stirring continues until the feeding of the reinforcements is completed, after which the molten mixture is poured into a preheated mold and allowed to cool and solidify naturally. Post-casting processes like heat treatment, testing, and inspection are then performed. Various impeller blade geometries are available, and melting of the matrix material is the initial step of this procedure.



4.3 Stir Casting Steps

4.2 MATERIALS

4.2.1 Aluminum Powder (Al):

Aluminum powder is also commonly used as a filler material in composite materials. Composite materials are made by combining two or more materials to create a material with improved properties. The addition of aluminum powder can enhance the strength, stiffness, and thermal conductivity of composite materials.

One common application of aluminum powder in composite materials is in the aerospace industry. Aluminum powder is often added to polymers to create composites with improved strength-to-weight ratios, making them ideal for use in aircraft components. In addition, the thermal conductivity of aluminum powder can improve the heat dissipation properties of composite materials, making them more resistant to heat damage studied by Shokrieh et al. (2012).

Aluminum powder can also be added to ceramic materials to create composites with improved strength and toughness. The addition of aluminum powder can increase the ductility of ceramics, making them less prone to brittle fracture studied by Kumar et al. (2016).

Furthermore, aluminum powder can be used in metal matrix composites (MMCs). MMCs are materials made by combining a metal matrix, such as aluminum, with a reinforcing material, such as ceramic or carbon fibers. The addition of aluminum powder to MMCs can enhance the strength and stiffness of the material, while also improving its thermal conductivity was studied by Khorrami et al. (2018).

Overall, the addition of aluminum powder to composite materials can improve their properties, making them more suitable for a wide range of applications in various industries.



Fig.4.4 Aluminum Powder

Properties:

1. **Reactivity:** Aluminum powder is highly reactive and can ignite or explode when exposed to heat, flame, or sparks. This makes it useful for applications such as rocket fuel and explosives.
2. **Density:** Aluminum powder has a relatively low density of about 2.7 g/cm³, which makes it useful in applications requiring lightweight materials.
3. **Melting point:** The melting point of aluminum powder is around 660°C (1220°F), making it suitable for high-temperature applications such as casting.
4. **Conductivity:** Aluminum powder is an excellent conductor of both heat and electricity, making it useful in applications such as heat sinks, electrical wiring, and electronic components.
5. **Corrosion resistance:** The thin oxide layer that forms on the surface of aluminum powder when exposed to air provides excellent corrosion resistance. This property makes it useful in applications where exposure to harsh environments is expected, such as marine or offshore structures.
6. **Reflectivity:** Aluminum powder has a high reflectivity of about 80-90%, making it useful in applications such as reflective coatings and mirrors.
7. **Malleability and ductility:** The high malleability and ductility of aluminum powder allow it to be easily shaped into various forms, such as sheets, rods, and wires.

This property makes it useful in the production of a wide range of products, including packaging materials, automotive parts, and building materials.

In summary, the unique properties of aluminum powder make it a versatile material that has a wide range of applications in various industries.

Applications:

Aluminum powder has a wide range of applications due to its unique physical and chemical properties. Here are some of the common applications of aluminum powder:

1. **Pyrotechnics:** Aluminum powder is a key ingredient in many types of fireworks and pyrotechnic displays. When mixed with other chemicals, it produces a bright white light, which is used to create dazzling visual effects in pyrotechnic displays.
2. **Thermite reactions:** Aluminum powder is used in thermite reactions, which are highly exothermic chemical reactions that produce a large amount of heat and light. In these reactions, aluminum powder is combined with a metal oxide, such as iron oxide, to produce a mixture that burns at extremely high temperatures. Thermite reactions are used in welding and metal cutting applications, as well as in military and industrial applications.
3. **Solid rocket fuel:** The high reactivity of aluminum powder makes it a valuable fuel additive in solid rocket fuel. In addition, the fine particle size of aluminum powder allows it to burn more efficiently, producing a more complete combustion and reducing the amount of unburned fuel that is expelled into the atmosphere.
4. **Composite materials:** Aluminum powder is often used as a filler material in composite materials to improve their strength, stiffness, and thermal conductivity. It is commonly added to polymers, ceramics, and metal matrix composites to enhance their properties.
5. **Pigments:** Aluminum powder is often used as a pigment in paints, coatings, and printing inks. It produces a metallic finish that is highly reflective and visually appealing.

6. Chemical reactions: Aluminum powder is used in a variety of chemical reactions, including the production of hydrogen gas in the presence of an acid and the reduction of metal salts to their corresponding metals.
7. Additive manufacturing: Aluminum powder is used in additive manufacturing, also known as 3D printing, to produce metal parts and components. The powder is melted and fused together layer by layer to create a solid object.

These are just some of the common applications of aluminum powder, but there are many others, including in the production of explosives, as a desiccant, and in the manufacturing of aluminum alloys.

Industrial uses:

Aluminum is a versatile metal that finds numerous uses in various industries due to its unique properties. Here are some common examples of aluminum uses in different industries:

1. Aerospace: Aluminum is widely used in the aerospace industry due to its lightweight nature and high strength-to-weight ratio. It is used in the construction of aircraft frames, wings, fuselages, and other structural components, as well as in engine components, such as fan blades and housings.
2. Automotive: Aluminum is used in the automotive industry to reduce vehicle weight and improve fuel efficiency. It is used in the production of engine blocks, wheels, transmission cases, and various other components to reduce overall vehicle weight and enhance performance.
3. Construction: Aluminum is used in the construction industry for a wide range of applications. It is used in windows, doors, roofing, siding, curtain walls, and structural framing due to its lightweight, corrosion-resistant, and durable properties.
4. Packaging: Aluminum is commonly used in packaging materials, such as cans, foils, and containers, due to its excellent barrier properties, which protect contents from light, air, moisture, and contaminants. Aluminum packaging is

widely used in the food and beverage industry, pharmaceuticals, and other consumer goods.

5. **Electrical and Electronics:** Aluminum is used in the electrical and electronics industry for a variety of applications. It is used in electrical transmission lines, conductors, and cables due to its high electrical conductivity. Aluminum is also used in heat sinks, casings, and frames for electronic devices due to its excellent thermal conductivity and light weight.
6. **Marine:** Aluminum is used in the marine industry for constructing boats, ships, and offshore structures due to its corrosion resistance, lightweight, and strength. It is used in hulls, superstructures, and other components, including shipbuilding and offshore drilling equipment.
7. **Packaging:** Aluminum is used in the packaging industry for a wide range of applications. It is used in cans, foils, and containers due to its excellent barrier properties, which protect contents from light, air, moisture, and contaminants. Aluminum packaging is widely used in the food and beverage industry, pharmaceuticals, and other consumer goods.
8. **Sports and Recreation:** Aluminum is used in various sports and recreational equipment, such as bicycles, golf clubs, baseball bats, and camping gear, due to its light weight, durability, and corrosion resistance.

These are just a few examples of the many industries that utilize aluminum due to its unique properties. Aluminum's versatility, light weight, corrosion resistance, and strength make it a popular choice in a wide range of applications across different sectors.

4.2.2 Titanium Carbide Powder (TiC):

Titanium carbide (TiC) powder is a ceramic material that has excellent mechanical properties, such as high hardness and wear resistance. Due to these properties, TiC powder is often used as a reinforcing material in composite materials.

One common application of TiC powder in composite materials is in metal matrix composites (MMCs). MMCs are materials made by combining a metal matrix, such as aluminum, with a reinforcing material, such as TiC powder. The addition of TiC powder to MMCs can improve the mechanical properties of the material, such as its strength and wear resistance was studied by Lai et al. (2017).

TiC powder can also be added to polymer composites to improve their mechanical properties. The addition of TiC powder can increase the hardness and wear resistance of polymer composites, making them more suitable for high-stress applications was studied by Zhang F et al. (2018).

Furthermore, TiC powder can be used in ceramic matrix composites (CMCs). CMCs are materials made by combining a ceramic matrix, such as silicon carbide, with a reinforcing material, such as TiC powder. The addition of TiC powder to CMCs can improve the strength and toughness of the material, making it more suitable for high-temperature and high-stress applications was studied by Zhang Y et al. (2019).

Overall, the addition of TiC powder to composite materials can improve their mechanical properties, making them more suitable for a wide range of applications in various industries.



Fig.4.5 Titanium Carbide Powder

Properties:

Titanium carbide (TiC) powder is a type of ceramic material that possesses several key properties, including:

1. **Hardness:** Titanium carbide powder is extremely hard, with a hardness level comparable to that of diamond. It has a Mohs hardness of 9-9.5, making it one of the hardest materials known. This property makes TiC powder highly resistant to wear, abrasion, and erosion, and it is often used in applications where extreme hardness is required, such as cutting tools, wear-resistant coatings, and high-temperature applications.
2. **High melting point:** Titanium carbide powder has a high melting point, typically around 3,160°C (5,720°F), which makes it suitable for use in high-temperature applications, such as aerospace and defense, where materials need to withstand extreme temperatures without melting or deforming.
3. **Excellent thermal stability:** TiC powder exhibits excellent thermal stability, making it resistant to thermal shock and degradation even at high temperatures. This property makes it suitable for use in applications where thermal cycling or rapid heating/cooling is involved, such as in aerospace, automotive, and electronics industries.
4. **Good electrical conductivity:** Titanium carbide powder has relatively high electrical conductivity, which makes it useful for applications that require good electrical properties, such as in electrical contacts, electrodes, and conductive coatings.
5. **Chemical resistance:** TiC powder is highly inert and resistant to many chemicals, including acids, alkalis, and corrosive environments, due to its strong covalent bonding. This property makes it suitable for use in harsh chemical environments, such as in chemical processing, oil and gas industries, and other corrosive environments.
6. **Low density:** Titanium carbide powder has a relatively low density compared to other high-performance materials, such as tungsten carbide or diamond, making it lighter in weight. This property can be advantageous in applications

where weight reduction is important, such as aerospace, automotive, and sports equipment.

7. Good thermal conductivity: TiC powder has a relatively high thermal conductivity, which makes it suitable for applications that require efficient heat transfer, such as in heat sinks, high-temperature applications, and thermal management systems.
8. Excellent mechanical properties: Titanium carbide powder exhibits high strength, stiffness, and toughness, which make it suitable for applications that require strong and durable materials, such as cutting tools, wear-resistant coatings, and structural components.

It's important to note that the properties of titanium carbide powder can vary depending on the manufacturing process, purity, particle size, and other factors. Therefore, it's essential to consult specific technical data sheets and conduct thorough testing to determine the exact properties of a particular TiC powder for a given application.

Applications:

Titanium carbide (TiC) powder has a wide range of applications due to its unique properties. Here are some of the common applications of titanium carbide powder:

1. Wear-resistant coatings: TiC powder is often used as a reinforcing material in wear-resistant coatings due to its high hardness and wear resistance. These coatings are used to protect surfaces from wear and corrosion in applications such as cutting tools, automotive parts, and aerospace components.
2. Cutting tools: TiC powder is used as a cutting tool material due to its high hardness and wear resistance. It is often used in the manufacture of cutting inserts, drills, and milling cutters.
3. Refractory materials: TiC powder is used as a refractory material in the production of high-temperature materials. It is often added to materials such as tungsten carbide to improve their high-temperature performance.

4. **Armor materials:** TiC powder is used as a reinforcing material in armor materials due to its high hardness and strength. It is often added to materials such as boron carbide to improve their ballistic performance.
5. **Composite materials:** TiC powder is often used as a reinforcing material in composite materials, including metal matrix composites, polymer composites, and ceramic matrix composites. The addition of TiC powder can improve the mechanical properties of these materials, such as their strength and wear resistance.
6. **Energy storage:** TiC powder is being investigated as a potential electrode material for lithium-ion batteries due to its high electrical conductivity and low toxicity.

These are just some of the common applications of titanium carbide powder, but there are many others, including in the production of cutting fluids, in the manufacture of thermal spray coatings, and as a catalyst in chemical reactions.

Industrial uses:

Titanium carbide (TiC) is a high-performance ceramic material with unique properties that make it suitable for various industrial applications. Some of the common uses of titanium carbide in several industries include:

1. **Aerospace and Defense:** TiC is used in aerospace and defense applications due to its high melting point, excellent thermal stability, and extreme hardness. It is used in the production of components such as turbine blades, nozzles, and combustion chambers, where materials need to withstand high temperatures, wear, and abrasion.
2. **Automotive:** TiC is used in the automotive industry for wear-resistant coatings on engine components, such as piston rings, valve seats, and camshafts, to reduce friction, extend service life, and improve fuel efficiency. It is also used in cutting tools for machining engine blocks and other high-strength materials.
3. **Oil and Gas:** TiC is used in the oil and gas industry for wear-resistant coatings on drilling tools, drill bits, and other components that are subjected to harsh

conditions, such as high temperatures, abrasive materials, and corrosive environments. TiC coatings help improve the durability and performance of these components, reducing downtime and maintenance costs.

4. Mining and Construction: TiC is used in the mining and construction industries for cutting tools, wear-resistant coatings, and abrasives. TiC-based cutting tools and wear-resistant coatings can withstand the abrasive and harsh conditions encountered in mining and construction activities, enhancing the performance and durability of tools and equipment.
5. Energy and Power Generation: TiC is used in the energy and power generation industries for components such as gas turbine blades, boiler tubes, and heat exchangers. TiC coatings provide excellent wear resistance, high-temperature performance, and corrosion resistance, making them suitable for these demanding applications.
6. Electronics: TiC is used in the electronics industry for electrical contacts, connectors, and switches due to its good electrical conductivity. TiC-based electrical contacts provide reliable electrical performance, especially in high-temperature and high-voltage applications.
7. Additive Manufacturing: TiC is used as a feedstock material in additive manufacturing or 3D printing for the production of high-performance components in various industries. TiC-based additive manufacturing processes can produce complex-shaped parts with excellent mechanical properties, wear resistance, and thermal stability.
8. Other Industries: TiC is also used in other industries, such as cutting tools for machining hard materials, wear-resistant coatings for textiles and plastics, and as a reinforcing material in composites for improved strength, stiffness, and thermal stability.

It's important to note that the specific uses of TiC in different industries may vary depending on factors such as particle size, purity, and manufacturing process, and it's crucial to consult technical data sheets and conduct proper testing to determine the suitability of TiC for a particular application.

4.2.3 Titanium Diboride Powder (TiB_2):

Titanium diboride (TiB_2) powder is a ceramic material that has excellent mechanical and electrical properties, including high hardness, strength, and conductivity. Due to these properties, TiB_2 powder is often used as a reinforcing material in composite materials.

One common application of TiB_2 powder in composite materials is in metal matrix composites (MMCs). MMCs are materials made by combining a metal matrix, such as aluminum, with a reinforcing material, such as TiB_2 powder. The addition of TiB_2 powder to MMCs can improve the mechanical properties of the material, such as its strength and wear resistance was investigated by Li Y et al. (2019).

TiB_2 powder can also be added to polymer composites to improve their mechanical and electrical properties. The addition of TiB_2 powder can increase the hardness, strength, and electrical conductivity of polymer composites, making them more suitable for high-stress and electrical applications was investigated by Liu C et al. (2019).

Furthermore, TiB_2 powder can be used in ceramic matrix composites (CMCs). CMCs are materials made by combining a ceramic matrix, such as silicon carbide, with a reinforcing material, such as TiB_2 powder. The addition of TiB_2 powder to CMCs can improve the strength and toughness of the material, making it more suitable for high-temperature and high-stress applications was studied by Lee S et al. (2015).

Overall, the addition of TiB_2 powder to composite materials can improve their mechanical and electrical properties, making them more suitable for a wide range of applications in various industries.



Fig.4.6 Titanium Diboride Powder

Properties:

Titanium diboride (TiB_2) is a ceramic material that possesses several properties that make it suitable for various applications. Some of the key properties of titanium diboride include:

1. **High Hardness:** TiB_2 is an extremely hard material, with a hardness level comparable to that of diamond. Its hardness makes it highly resistant to wear, abrasion, and erosion, making it suitable for applications where materials need to withstand harsh conditions and high levels of mechanical stress.
2. **High Melting Point:** TiB_2 has a high melting point of around 2980°C (5396°F), which makes it suitable for use in high-temperature applications. It can withstand extreme temperatures without significant degradation, making it ideal for use in environments with high thermal stress and high-temperature processing applications.
3. **Excellent Electrical Conductivity:** TiB_2 is a good electrical conductor, making it suitable for use in electrical contacts, electrodes, and other applications that require electrical conductivity. Its electrical properties make it useful in various electronic and electrochemical applications.
4. **Good Thermal Conductivity:** TiB_2 has relatively high thermal conductivity, which makes it suitable for applications that require efficient heat transfer. It can

dissipate heat effectively, making it useful in applications where temperature management is critical.

5. **High Chemical Stability:** TiB_2 is highly chemically stable and inert, which means it does not react with most chemicals, acids, or alkalis. This makes it suitable for use in chemically aggressive environments where materials need to resist corrosion and chemical attack.
6. **Low Density:** TiB_2 has a relatively low density compared to other ceramic materials, which makes it attractive for applications where weight reduction is a priority, such as aerospace and automotive industries.
7. **Excellent Tribological Properties:** TiB_2 exhibits low friction coefficient and good wear resistance, making it ideal for use in applications that involve sliding or rubbing surfaces, such as cutting tools, bearings, and seals.
8. **Refractory Properties:** TiB_2 has excellent refractory properties, meaning it can withstand high temperatures without significant deformation or softening. This makes it suitable for use in high-temperature applications, such as in furnaces, crucibles, and other heat-resistant components.
9. These properties make titanium diboride suitable for a wide range of applications, including aerospace, automotive, electronics, energy, cutting tools, wear-resistant coatings, and high-temperature environments where its unique combination of properties can provide superior performance and durability. However, it's important to consider specific material specifications, processing conditions, and application requirements to ensure the optimal performance of titanium diboride in a given application.

Applications:

Titanium diboride (TiB_2) powder has a wide range of applications due to its unique properties. Here are some of the common applications of titanium diboride powder:

1. **Wear-resistant coatings:** TiB_2 powder is often used as a reinforcing material in wear-resistant coatings due to its high hardness and wear resistance. These coatings are used to protect surfaces from wear and corrosion in applications such as cutting tools, automotive parts, and aerospace components.

2. Cutting tools: TiB_2 powder is used as a cutting tool material due to its high hardness and wear resistance. It is often used in the manufacture of cutting inserts, drills, and milling cutters.
3. Refractory materials: TiB_2 powder is used as a refractory material in the production of high-temperature materials. It is often added to materials such as tungsten carbide to improve their high-temperature performance.
4. Armor materials: TiB_2 powder is used as a reinforcing material in armor materials due to its high hardness and strength. It is often added to materials such as boron carbide to improve their ballistic performance.
5. Composite materials: TiB_2 powder is often used as a reinforcing material in composite materials, including metal matrix composites, polymer composites, and ceramic matrix composites. The addition of TiB_2 powder can improve the mechanical properties of these materials, such as their strength and wear resistance.
6. Electrical contacts: TiB_2 powder is used as a contact material in electrical applications due to its high electrical conductivity and low electrical contact resistance.
7. Electrodes: TiB_2 powder is being investigated as a potential electrode material for lithium-ion batteries due to its high electrical conductivity and low toxicity.

These are just some of the common applications of titanium diboride powder, but there are many others, including in the production of cutting fluids, in the manufacture of thermal spray coatings, and as a catalyst in chemical reactions.

Industrial uses:

Titanium diboride (TiB_2) has a wide range of industrial uses across various industries. Some of the common applications of TiB_2 include:

1. Aerospace and Defense: TiB_2 is used in aerospace and defense industries for its high melting point, excellent thermal stability, and high hardness. It is used in the production of components for gas turbine engines, rocket nozzles, and

other high-temperature applications where its properties of high temperature resistance and wear resistance are crucial.

2. Cutting Tools: TiB_2 is used in the manufacturing of cutting tools, such as drills, end mills, and inserts, due to its exceptional hardness, wear resistance, and low friction coefficient. TiB_2 coatings on cutting tools improve their performance by extending their lifespan, reducing wear, and increasing cutting speeds.
3. Automotive: TiB_2 is used in the automotive industry for its lightweight properties and wear resistance. It can be used in the production of engine components, such as pistons, valves, and turbocharger parts, to reduce weight and improve performance.
4. Electronics: TiB_2 is used in the electronics industry for its excellent electrical conductivity and thermal stability. It can be used in electrical contacts, electrodes, and other electronic components.
5. Energy: TiB_2 is used in energy-related applications, such as in the production of electrodes for electrolysis processes, where its high electrical conductivity and chemical stability are advantageous.
6. Coatings: TiB_2 coatings are used in various industries, including aerospace, automotive, and cutting tool manufacturing, for their wear resistance, low friction coefficient, and high hardness. TiB_2 coatings can improve the performance and durability of components, tools, and equipment in demanding environments.
7. High-temperature Applications: TiB_2 is used in high-temperature applications, such as in furnaces, crucibles, and heat-resistant components, due to its high melting point, thermal stability, and refractory properties.
8. Other Applications: TiB_2 finds uses in other industries, such as in the production of wear-resistant coatings for industrial equipment, cutting and grinding wheels, and as a reinforcement material in composites.

It's worth noting that the specific applications of TiB_2 may vary depending on the industry, processing conditions, and requirements of a particular application. Careful consideration of material specifications, processing methods, and

performance requirements is necessary to ensure the optimal use of TiB_2 in a given industry or application.

4.3 TESTS

4.3.1 SURFACE TOPOGRAPHY - OM, AFM & SEM-EDS, WETTABILITY

Surface topography refers to the study of the physical and chemical properties of surfaces at the micro- and nanometer scales. It includes the characterization of surface roughness, shape, texture, and composition, which play a crucial role in various fields such as material science, physics, chemistry, and biology. Surface topography can be measured using a variety of techniques, each with its advantages and limitations. In this article, we will discuss three common techniques used to analyze surface topography: Optical Microscopy (OM), Atomic Force Microscopy (AFM), Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy (SEM-EDS), and Wettability.

Optical microscopy (OM) is a non-destructive, non-contact imaging technique that uses visible light to visualize the surface features of samples. It is widely used in material science, biology, and physics to study surface topography, surface roughness, and morphology. OM works by focusing visible light on a sample and collecting the reflected or transmitted light using a microscope objective. The collected light is then magnified and projected onto an image sensor, such as a camera or CCD detector, to produce a two-dimensional image of the surface features. OM has several advantages, including high spatial resolution, large field of view, and ease of use. However, it is limited by the diffraction limit of visible light, which restricts the minimum resolvable feature size to approximately half the wavelength of the light used. Therefore, OM is best suited for the analysis of relatively large surface features.

Atomic force microscopy (AFM) is a high-resolution imaging technique that can visualize surface topography at the nanometer scale. It works by scanning a sharp tip over the surface of a sample, and measuring the forces between the tip and the

sample. AFM uses a cantilever with a sharp tip at its end to scan the surface of a sample. The tip interacts with the surface forces such as van der Waals forces and electrostatic forces. These interactions cause the cantilever to deflect, which is measured using a laser beam and position-sensitive detector. By scanning the tip over the surface, AFM can produce a three-dimensional image of the surface features with high spatial resolution. AFM has several advantages, including high spatial resolution, non-destructive imaging, and the ability to operate in air, liquid, and vacuum environments. However, it is limited by the scanning speed and can be affected by tip-sample interactions, which can damage the surface or cause artifacts in the image.

Scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS) is a powerful imaging and analytical technique that can provide information about the surface topography, composition, and chemical bonding of samples. It works by scanning a focused beam of electrons over the surface of a sample, and collecting the emitted secondary electrons and X-rays. The emitted secondary electrons and X-rays are detected and analyzed using detectors, such as the backscatter electron detector and energy-dispersive X-ray detector. The backscatter electron detector can provide information about the surface topography and composition, while the energy-dispersive X-ray detector can provide information about the chemical composition of the sample. SEM-EDS has several advantages, including high spatial resolution, the ability to analyze a wide range.

Wettability tests are used to characterize the surface energy of composite materials. They involve measuring the contact angle of a liquid droplet on the material's surface. The contact angle is a measure of the material's wettability, which is affected by its surface chemistry and topography. Wettability tests can be used to determine the suitability of a material for specific applications, such as adhesion or coating.

In summary, surface topography characterization techniques such as OM, AFM & SEM-EDS, and wettability tests are important tools for understanding the surface properties of composite materials. By characterizing the surface topography,

researchers can gain insights into the mechanical and physical properties of the material, which can be useful for optimizing its performance for specific applications.

4.3.2 MECHANICAL PROPERTIES - MICROHARDNESS, SCRATCH, TENSILE, IMPACT

Microhardness Test :

Microhardness testing is a non-destructive method used to measure the hardness of materials, particularly those with small or thin samples that cannot be tested using traditional methods. It is widely used in material science, metallurgy, and engineering to evaluate the mechanical properties of materials at the microscale. The test involves indenting the surface of the sample with a diamond or tungsten carbide indenter under a load, and measuring the size of the resulting indentation. The hardness of the material is determined by the size of the indentation and the load applied. Microhardness testing is commonly used to evaluate the mechanical properties of materials such as metals, ceramics, and polymers. It can provide information on the hardness, toughness, strength, and wear resistance of materials at the microscale, which is useful for evaluating the performance and durability of materials in various applications.

Types of Microhardness Tests:

There are two types of microhardness tests commonly used: Vickers and Knoop.

Vickers Microhardness Test:

The Vickers microhardness test is a widely used method for measuring the hardness of materials. It involves indenting the surface of the sample with a diamond indenter under a load, and measuring the diagonal length of the resulting indentation. The Vickers test can be used to measure the hardness of a wide range of materials, including metals, ceramics, and polymers. It is particularly useful for testing thin or

small samples, as the size of the indentation can be adjusted by changing the load and the size of the diamond indenter.

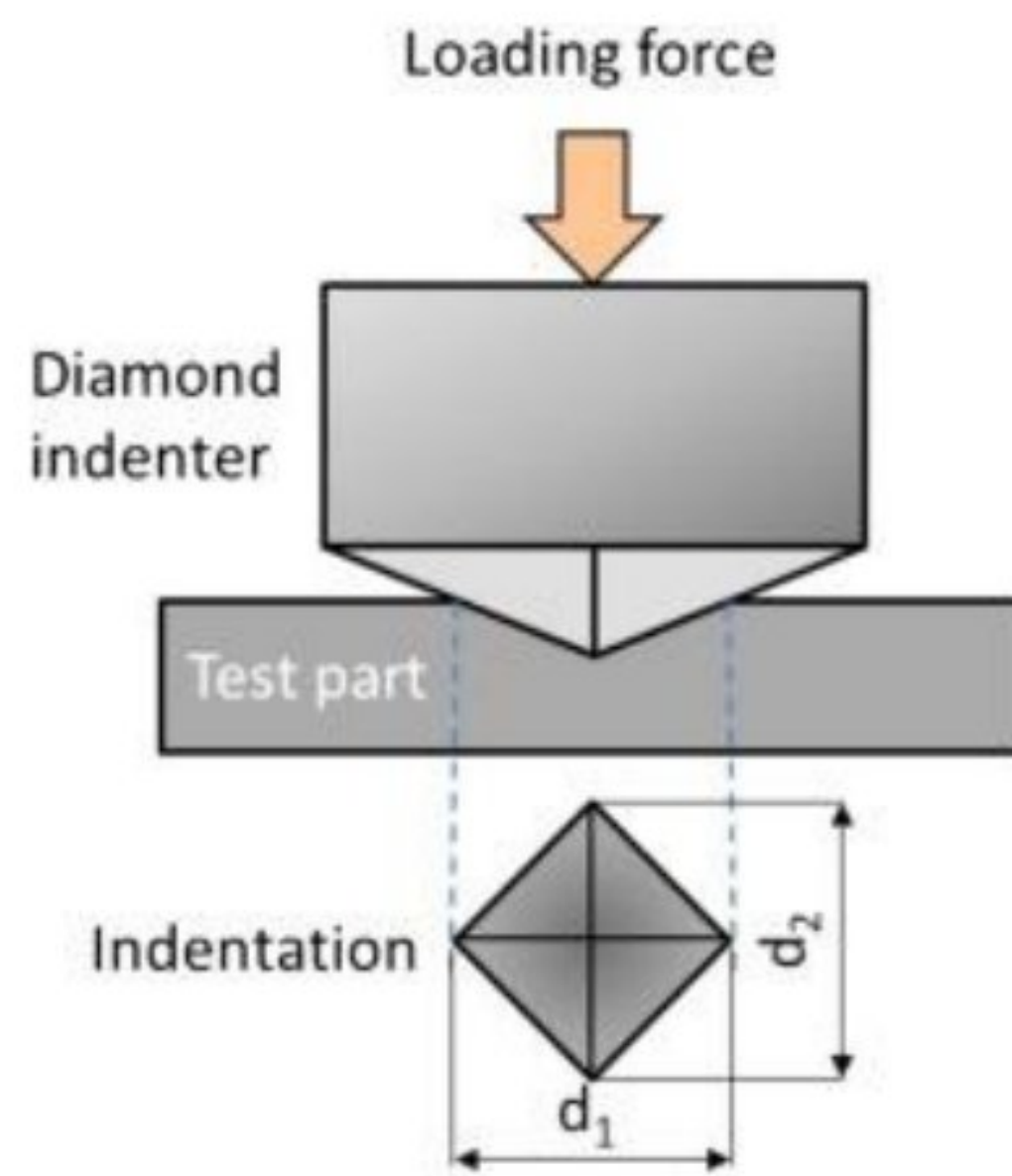


Fig.4.7 Vickers Hardness Test

Knoop Microhardness Test:

The Knoop microhardness test is a similar method to the Vickers test, but uses a different indenter shape. The Knoop indenter has a rhombic shape, which allows for a more precise and repeatable indentation size. The Knoop test is particularly useful for measuring the hardness of materials with anisotropic properties, as the indentation size is less affected by variations in the material's crystal orientation. It is also useful for measuring the hardness of thin coatings or layers on a substrate, as the indentation size is smaller and less likely to damage the underlying material.

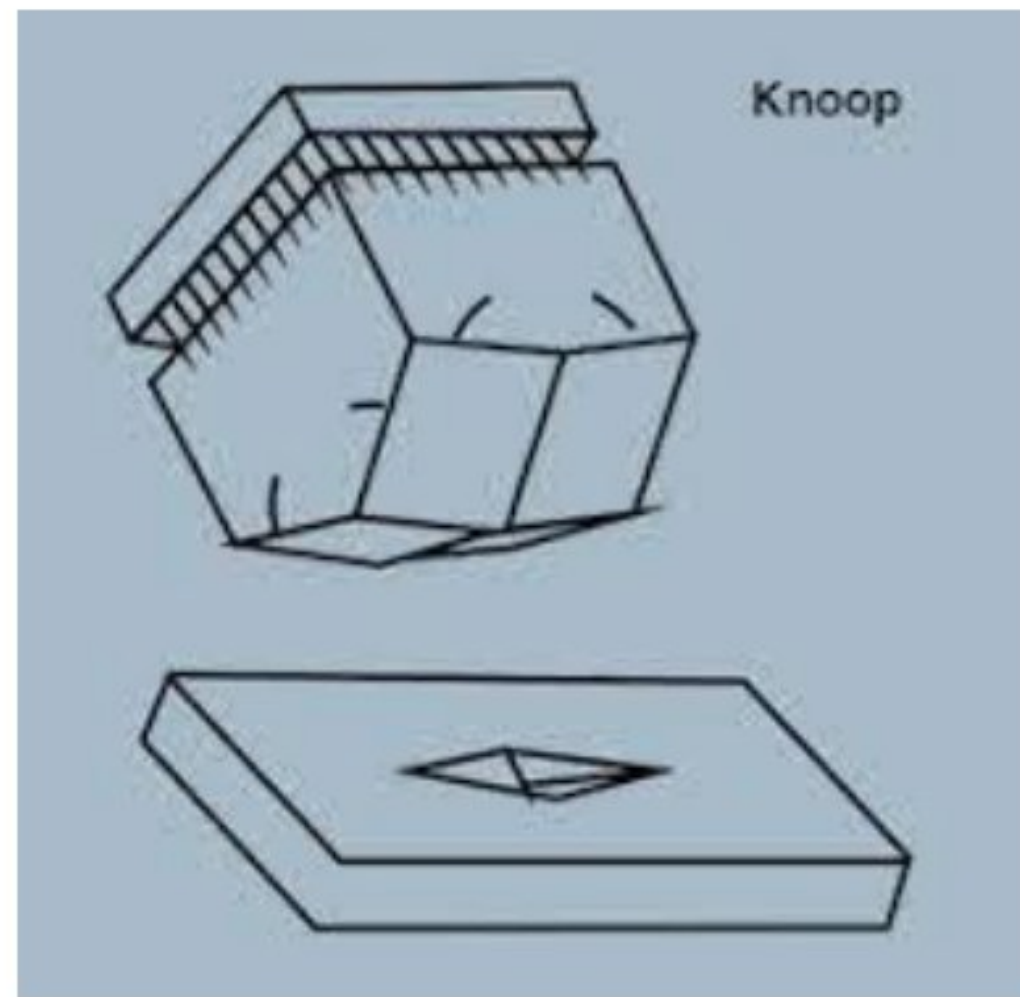


Fig.4.8 Knoop Hardness Test

Benefits of Microhardness Testing

Microhardness testing has several advantages over traditional hardness testing methods, including:

Non-destructive testing: Microhardness testing is a non-destructive method, which means that it can be used to evaluate the mechanical properties of materials without damaging or destroying the sample.

High precision: Microhardness testing can provide precise and repeatable measurements of the hardness of materials at the microscale, which is useful for evaluating the uniformity and consistency of materials.

Small sample size: Microhardness testing can be used to evaluate the mechanical properties of small or thin samples, which may not be suitable for traditional hardness testing methods.

Versatility: Microhardness testing can be used to evaluate the hardness of a wide range of materials, including metals, ceramics, and polymers.

Microhardness testing is a valuable method for evaluating the mechanical properties of materials at the microscale. It can provide precise and repeatable measurements of hardness, toughness, strength, and wear resistance, which are useful for evaluating

the performance and durability of materials in various applications. The Vickers and Knoop tests are two common methods used for microhardness testing, and each has its advantages depending on the material and application.

Scratch test :

A scratch test is a mechanical evaluation used to assess a material's hardness and resistance to abrasion. This type of test is frequently employed in materials science and engineering to determine the wear resistance and durability of various materials.

To conduct a scratch test, a small diamond or other hard object is applied with a known force to the surface of the material being tested and moved along it. The force required to produce a visible scratch is recorded, along with the scratch's length and depth.

The scratch test is useful for comparing the hardness of different materials and assessing the efficacy of coatings or treatments used to enhance wear resistance. It can also help identify unknown materials based on their scratch resistance properties.

The scratch test is advantageous because it's a relatively simple and low-cost method, requiring only a few specialized tools and equipment. However, it's important to note that several factors can influence the scratch test's accuracy, such as the scratch's angle, the scratching tool's size and shape, and any surface defects or imperfections present on the material being tested. Thus, it's essential to control these variables carefully to obtain precise and consistent results.

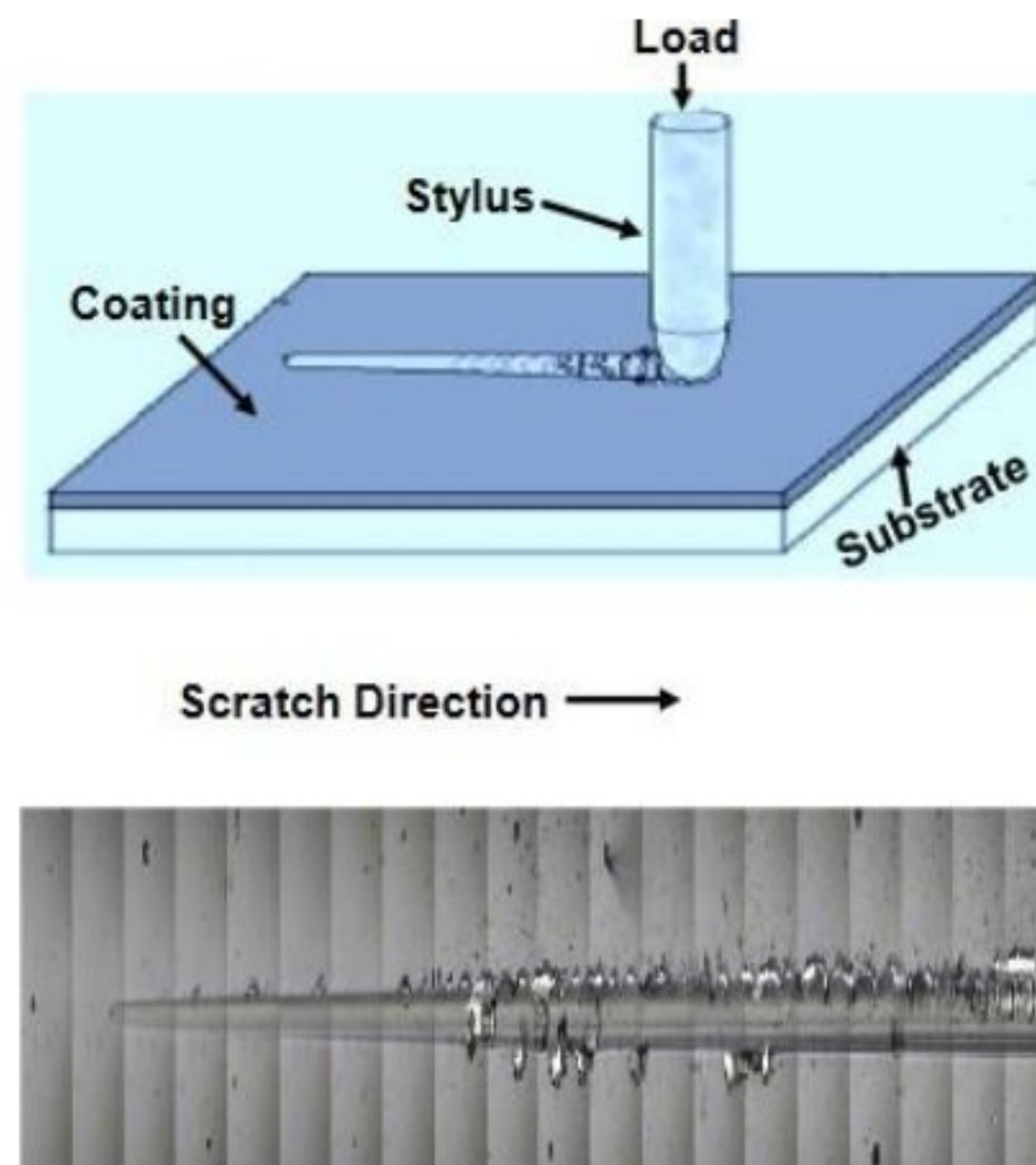


Fig.4.9 Scratch Test

Tensile test:

A tensile test is a mechanical procedure utilized to assess a material's strength and elasticity by applying stretching or pulling forces. This test is frequently used in materials science and engineering to investigate various materials' behavior under tensile stress, including metals, polymers, composites, and ceramics.

To conduct a tensile test, a small sample of the material is cut into a specific shape, such as a thin rod or wire. The sample is clamped at both ends and stretched using a tensile testing machine. The machine applies an increasing force to the sample while simultaneously measuring the amount of deformation that occurs using a load cell and extensometer. The test continues until the sample fractures or reaches a predetermined elongation point.

The results of the tensile test provide several key parameters, including the material's yield strength, ultimate tensile strength, elongation at break, and modulus of elasticity. These parameters provide valuable insights into a material's strength, ductility, toughness, and elasticity.

The tensile test provides a standardized method for comparing the mechanical properties of different materials. However, several factors can affect the test results, such as the sample's size and shape, the testing speed, and the temperature and humidity conditions. Therefore, controlling these variables is crucial to ensure accurate and reproducible results.

In summary, the tensile test is an important tool for investigating a material's mechanical properties and behavior under tensile stress. It provides critical information for designing new materials and structures, as well as ensuring the safety and reliability of existing ones.



Fig.4.10 Tensile Test (UTM)

Impact test:

The impact test is a mechanical procedure that measures a material's ability to absorb energy when subjected to a sudden, forceful impact. This test is commonly used in materials science and engineering to assess the toughness and impact resistance of various materials, such as metals, polymers, and composites.

To conduct an impact test, a standardized specimen of the material is fixed to a testing machine, which may be a pendulum or a drop weight impact tester. The machine then delivers a sudden force to the specimen, mimicking the impact of a

heavy load or object. The energy absorbed by the material during the impact is recorded.

The results of the impact test reveal valuable information about a material's ductility, fracture toughness, and impact strength. For example, the impact test can determine whether the material can withstand sudden impacts or shocks without breaking or fracturing. It can also identify any defects, such as cracks or voids, that may weaken the material's impact resistance.

The impact test is useful because it simulates real-world situations where materials experience unexpected and sudden impacts, such as in industrial applications or accidents. However, it's important to note that the impact test results can be influenced by several factors, including the specimen's size and geometry, the testing temperature, and the velocity and direction of the impact force. Therefore, it's crucial to control these variables carefully to obtain accurate and reliable results.

In conclusion, the impact test is a critical tool for evaluating a material's ability to absorb energy under forceful and sudden impacts. It provides valuable information about a material's toughness, impact strength, and ductility, making it an important tool for designing and selecting materials for a wide range of applications.

Purpose of impact testing:

An impact test is conducted to assess a material's ability to absorb energy during collisions. It provides valuable information about material properties, such as toughness, impact strength, fracture resistance, impact resistance, or fracture toughness, depending on the specific test method and characteristic being evaluated. These properties are crucial in determining a material's ability to withstand rapid loading processes, such as vehicular collisions.

Toughness measures a material's capacity to resist fracturing under sudden impact or shock. Impact strength quantifies how much energy a material can absorb before fracturing. Fracture resistance refers to a material's ability to resist crack propagation or fracture under impact loading. Impact resistance gauges a material's ability to

endure repeated impacts without sustaining damage. Fracture toughness measures a material's resistance to crack propagation, and it is particularly important in applications involving dynamic loading.

The results of an impact test play a critical role in material selection for applications that demand high performance under rapid loading conditions, such as in the automotive and aerospace industries. By evaluating a material's performance under impact loading, engineers can make informed decisions about material choices to design safer and more durable products.

Types of Impact test

The Charpy V-notch test, the Izod test, and the Tensile Impact test are the three most commonly used types of tests for a single impact test. These tests share the same objective of evaluating the material's properties, but they differ in terms of the orientation of the test sample. This variation in orientation leads to different stress directions on the specimen during the test. In all three tests, a known weight is dropped from a known height, colliding with the specimen in its test fixture. Each of these tests is useful in determining the impact behavior of the test specimen.

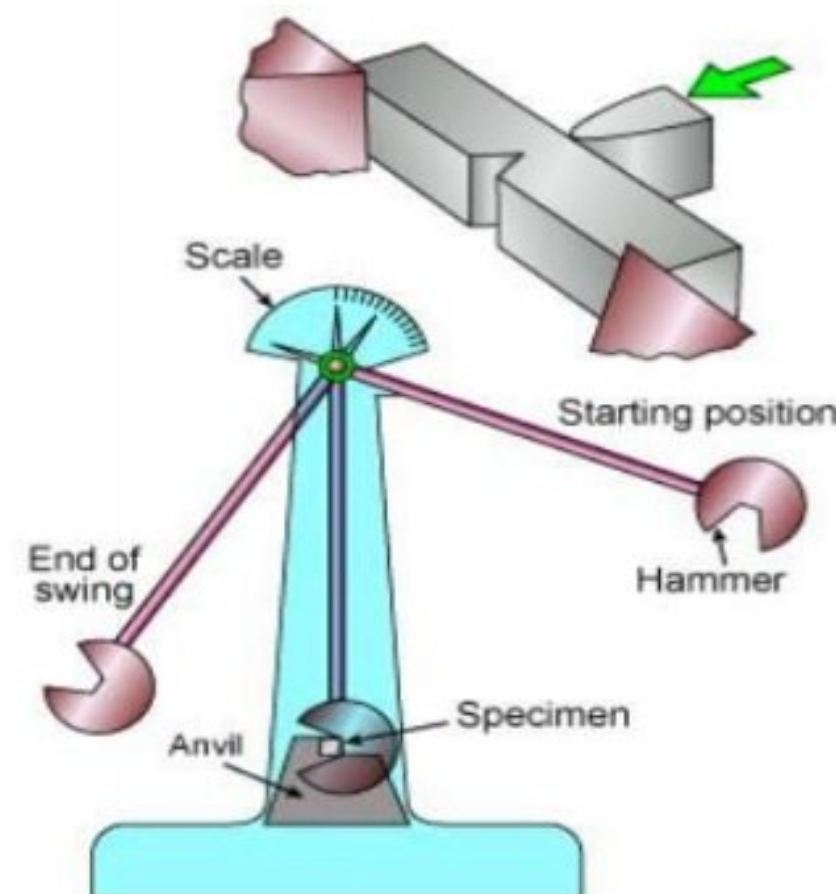


Fig.4.11 Charpy test

4.3.3 Fractography – SEM-EDS

Fractography is the study of fractured surfaces of materials, and SEM-EDS (Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscopy) is a powerful analytical technique used to investigate the elemental composition of materials at the microscale. When combined, SEM-EDS can provide valuable insights into the chemical composition and morphology of fractured surfaces.

Fractography using SEM-EDS involves the examination of fractured surfaces of materials using a scanning electron microscope (SEM), which provides high-resolution images of the surface morphology. SEM allows for the observation of fracture features, such as crack propagation, fracture modes (e.g., ductile or brittle), and other characteristic patterns or markings on the fracture surface. The SEM images can reveal information about the topography, fracture roughness, and other surface features that can be used to deduce the fracture mechanism and understand the material's failure behavior.

EDS is used in conjunction with SEM to analyze the elemental composition of the fractured surface. EDS detectors attached to the SEM can detect and quantify the X-rays emitted by the sample when it is bombarded with an electron beam. This allows for the identification and mapping of elements present on the fractured surface, which can provide insights into the chemical composition of the material, elemental distribution, and potential causes of fracture or failure.

The combination of SEM and EDS in fractography can provide valuable information about the fracture characteristics, morphology, and elemental composition of materials, helping researchers and engineers understand the mechanisms and causes of material failure, identify potential issues in material performance, and optimize material design and processing for improved performance and reliability in various industrial applications.

CHAPTER-5

RESULTS AND DISCUSSION

XRD and SEM results for TiC and TiB₂ reinforced Al matrix

X-ray diffraction (XRD) is an analytical technique used to study the crystal structure and phase composition of materials. In the case of TiC and TiB₂ reinforced on an Al matrix, XRD analysis can be used to identify the crystal structure and phase composition of the reinforcement phases and the Al matrix. To obtain XRD results, a sample of the composite material is exposed to a beam of X-rays. As the X-rays pass through the material, they interact with the atoms in the crystal lattice, causing them to diffract. The diffracted X-rays produce a diffraction pattern that can be analyzed to determine the crystal structure and phase composition of the material. The XRD pattern is unique to each crystal structure, allowing for the identification of the phases present in the composite material.

Scanning electron microscopy (SEM) is an analytical technique used to study the surface morphology and elemental composition of materials. In the case of TiC and TiB₂ reinforced on an Al matrix, SEM analysis can be used to investigate the surface morphology and elemental composition of the composite material. To obtain SEM results, a sample of the composite material is scanned with a focused beam of electrons. The emitted secondary electrons or backscattered electrons are then detected to obtain high-resolution images of the surface. Additionally, SEM can be equipped with an energy-dispersive X-ray spectroscopy (EDS) detector to identify the elemental composition of the sample.

The XRD and SEM analyses for TiC and TiB₂ reinforced on an Al matrix can provide valuable information on the microstructure and composition of the composite material. The XRD analysis can reveal the crystal structure, phase composition, and orientation of the crystal planes in the sample, while SEM-EDS analysis can provide elemental

composition and surface morphology information. These results can be used to optimize the processing and properties of the composite material.

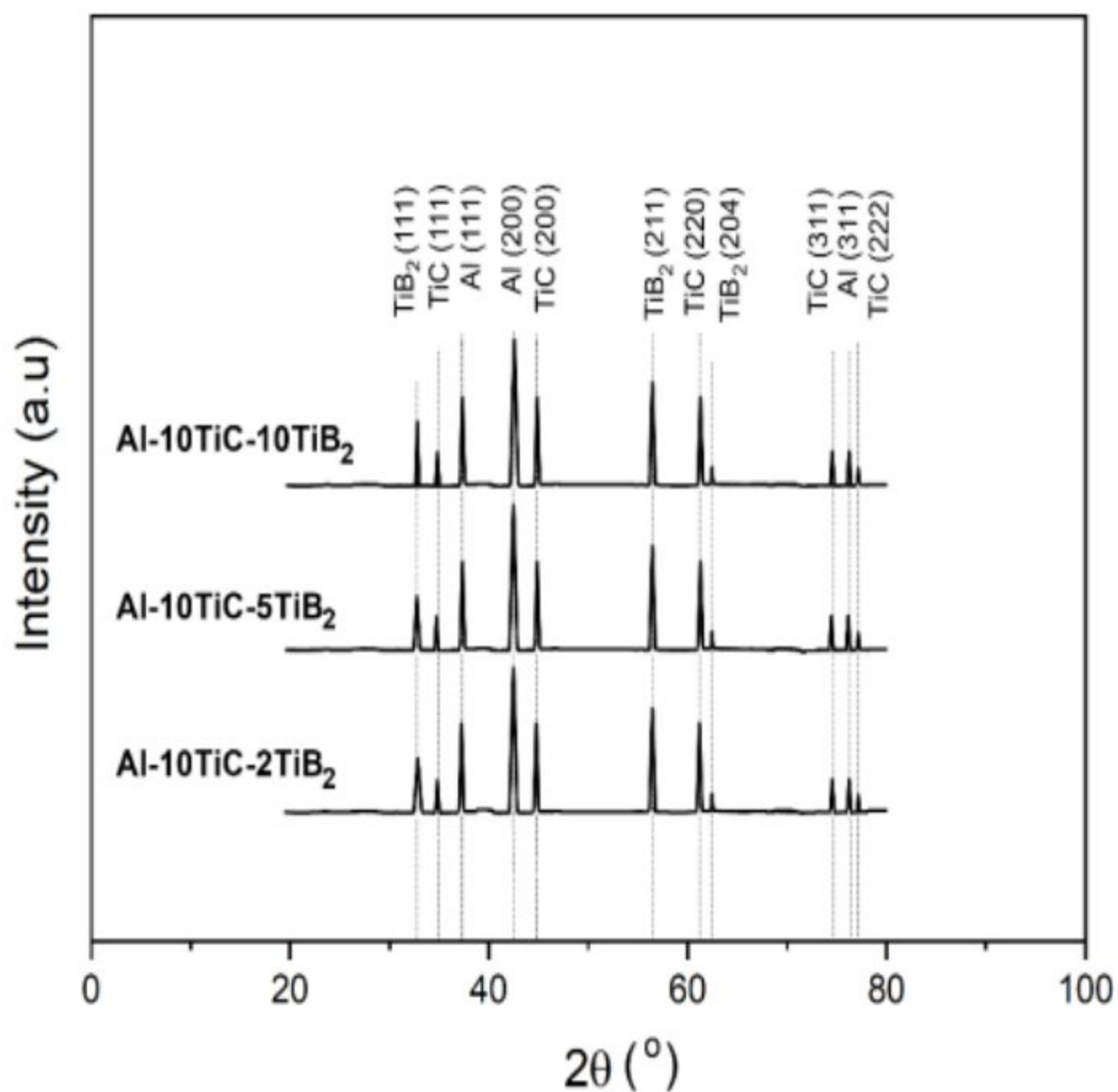


Fig.5.1 XRD pattern of Al-TiC-TiB₂ composites

Al peaks: 38.33° (111), 42.48° (200), 77.91° (311) in accordance with JCPDS card # 04-0787.

TiC peaks: 35.36° (111), 44.53° (200), 61.23° (220), 74.05° (311), 78.31° (311) in accordance with

JCPDS card # 01-071-0298.

TiB₂ peaks: 34.12° (111), 56.23° (211), 62.36° (204) in accordance with JCPDS card # 35-0741.

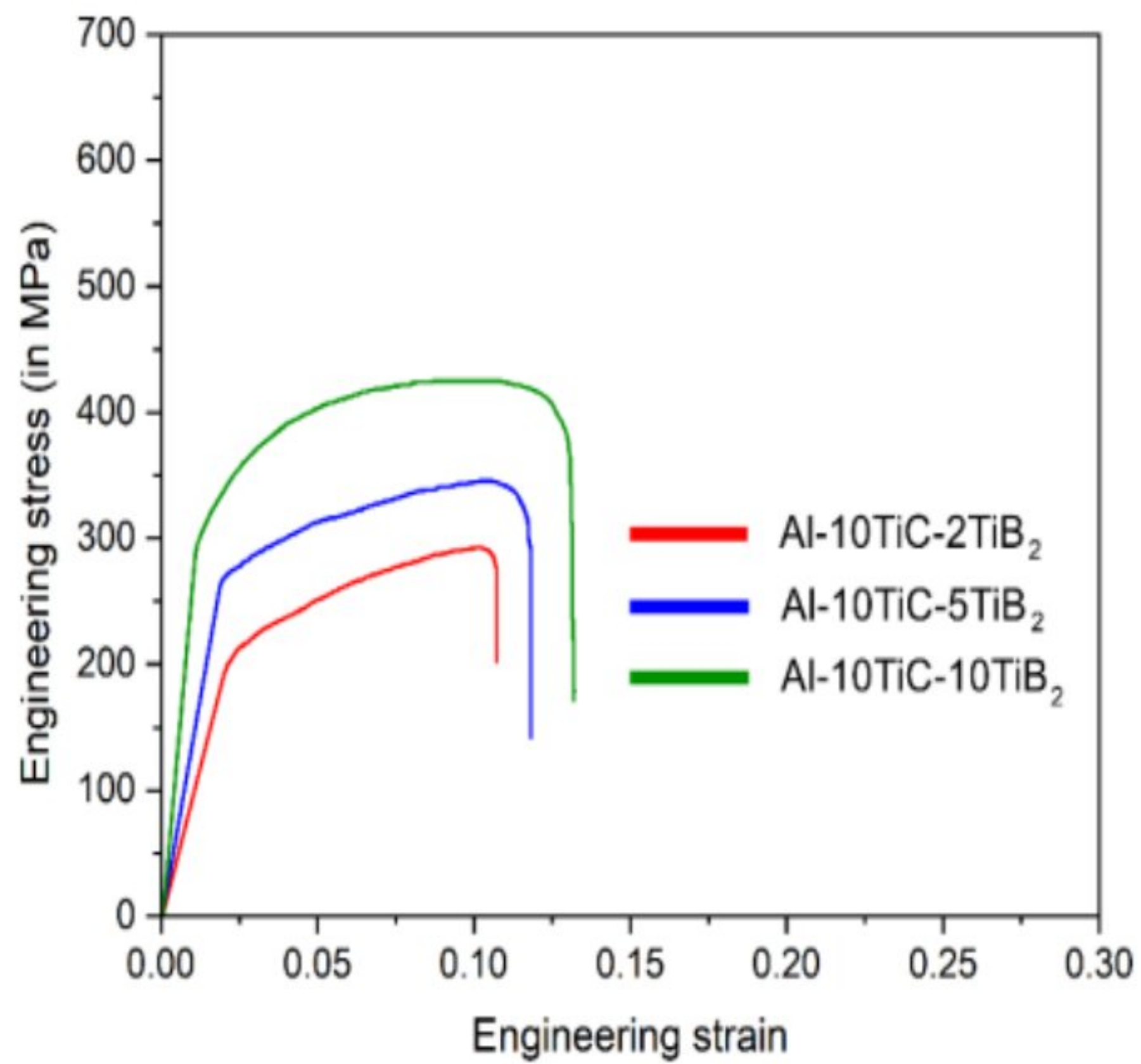


Fig.5.2 Stress-Strain diagram of Al-TiC-TiB₂ composites

Table.5.1 Mechanical properties of Al-TiC-TiB₂ composites

Metal matrix composites	UTS (in MPa)	0.2% YS (in MPa)	Ductility	Vickers microhardness (in HV)
Al-10TiC-2TiB ₂	254	198	7.6	102
Al-10TiC-5TiB ₂	352	262	9.9	136
Al-10TiC-10TiB ₂	426	282	11.2	171

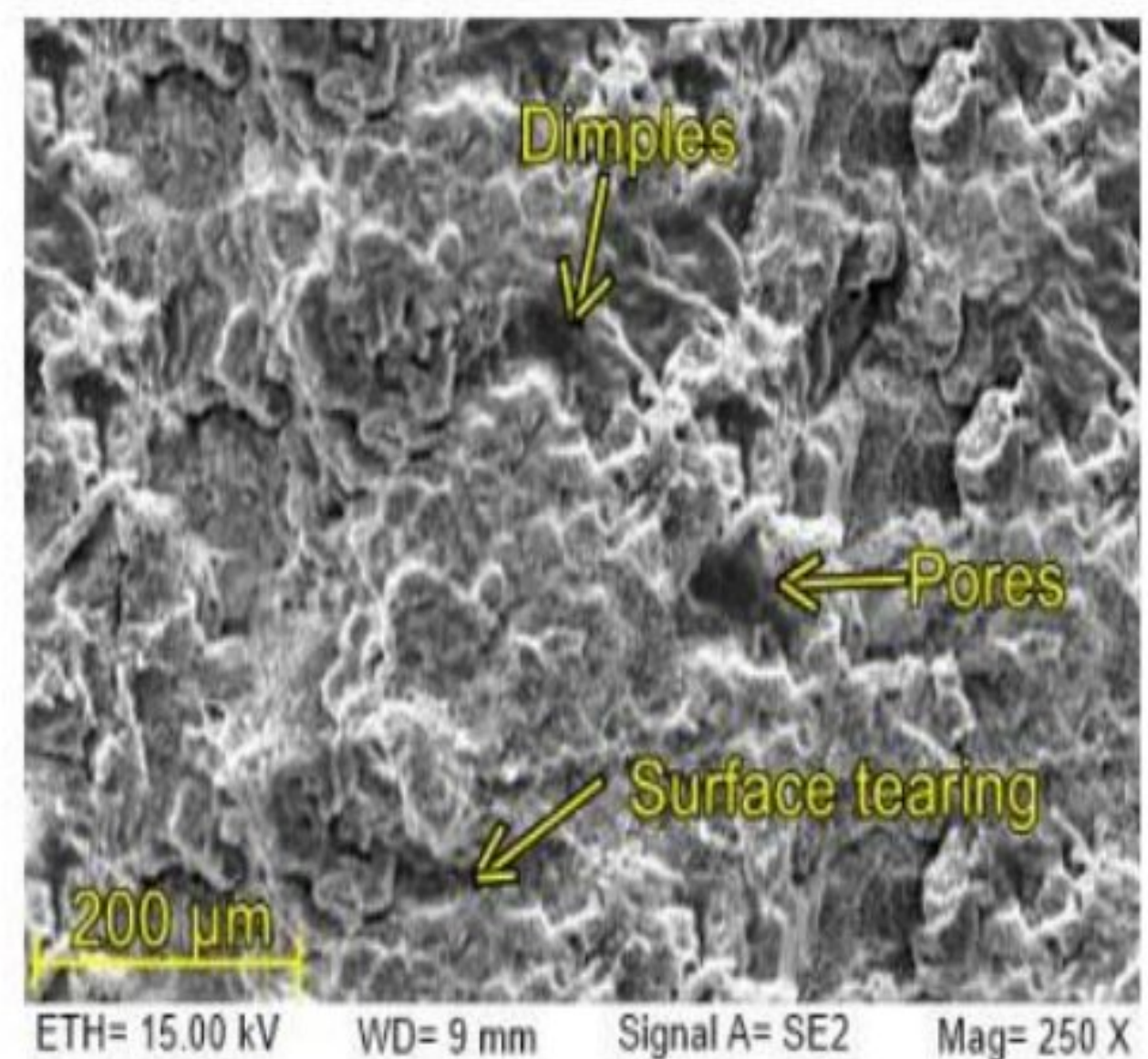
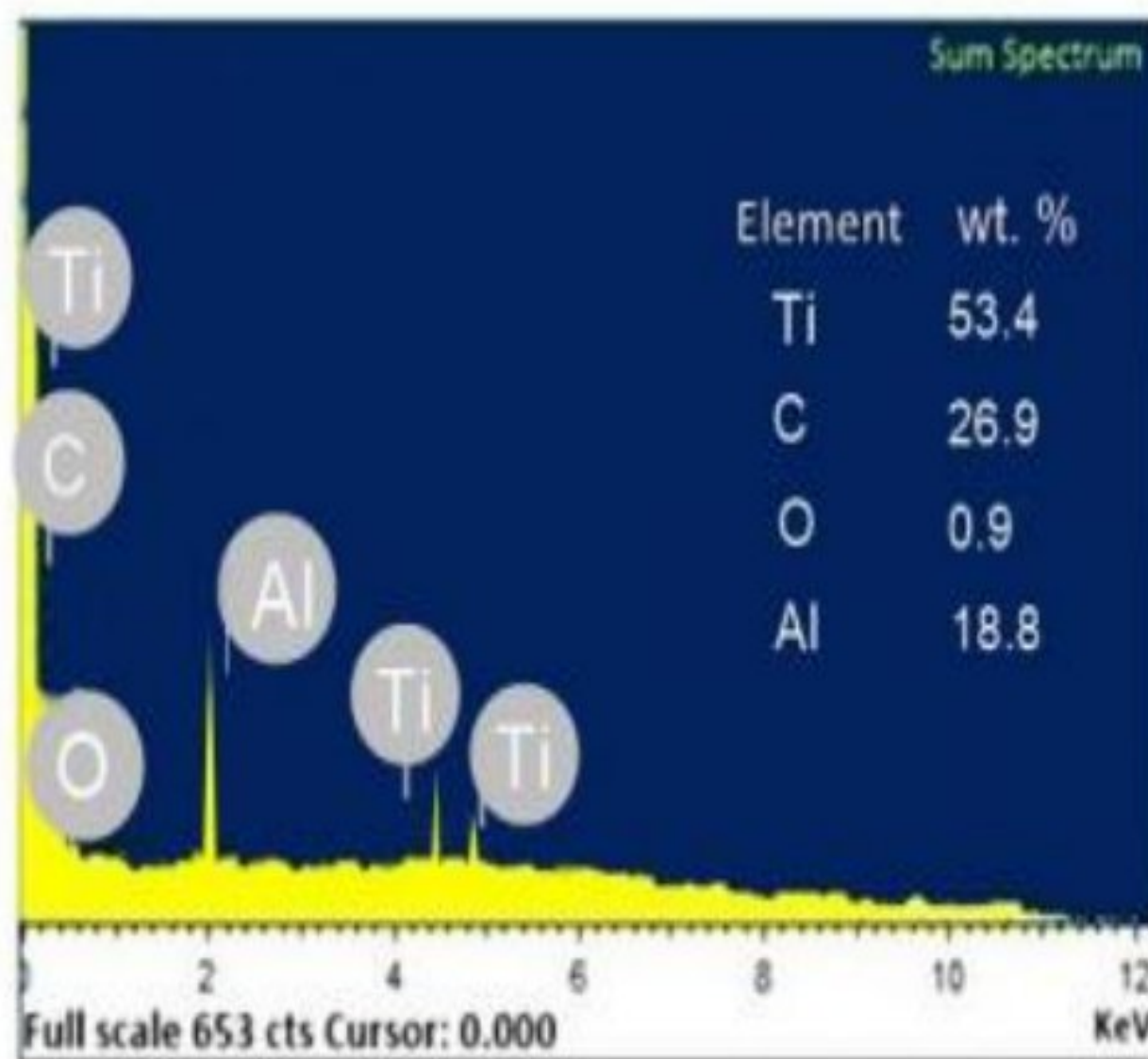
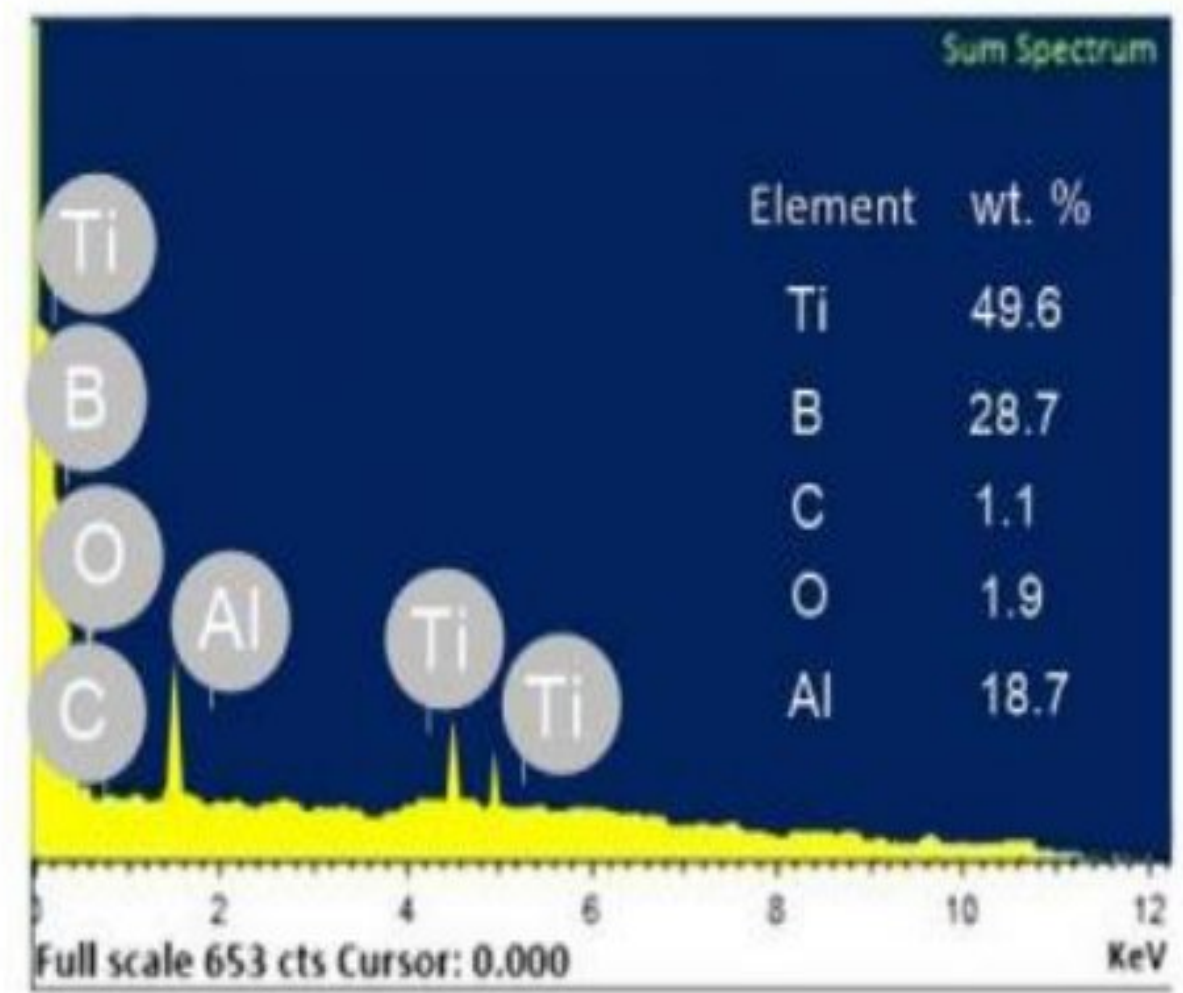
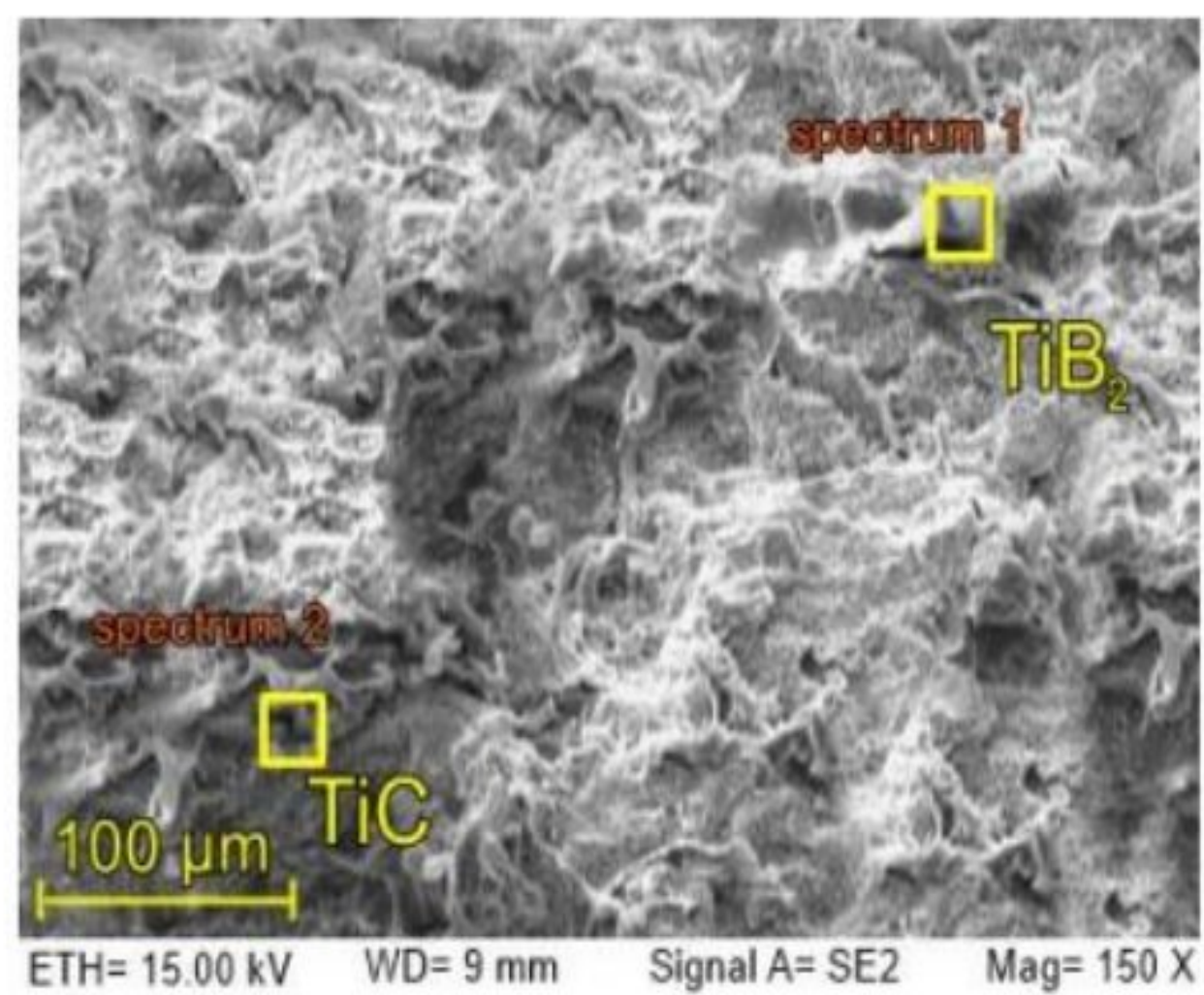


Fig.5.3 SEM micrograph of fractured surface showing (a) TiC and TiB₂ particles and their (b-c) corresponding EDS spectrum and (d) fracturing method

CHAPTER-6

CONCLUSION

The report provides a detailed description of the manufacturing process, focusing specifically on the mechanical and wear properties of aluminum metal matrix composites (MMCs) that incorporate different reinforcements. The advantages and disadvantages of the method are briefly mentioned. The density, hardness, and microstructure of the composite material were significantly impacted by the sintering temperature. The report also presents a thorough analysis of the underlying mechanisms responsible for the increase in tensile strength, impact strength, and hardness. The mechanical strength of the composites is mainly influenced by the Hall-Petch and Orowan strengthening mechanisms. The report also briefly discusses various wear surface mechanisms and cites relevant research in this field. Overall, the incorporation of various reinforcements into the main metal has resulted in high hardness, high specific strength, and greater resistance to indentation and compressive forces, as compared to composites without reinforcement. The report concludes by noting that this study could aid in identifying research gaps and challenges related to producing titanium composites, while also highlighting their potential for various applications.

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