# EFFECT OF CNT/$TIB_2$ PARTICLE ON MECHANICAL, METALLURGICAL BEHAVIOUR OF MAGNESIUM (AZ91D) COMPOSITES

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V.Velmurugan*, Dr.B.Mohan**

*Research Scholar, Department of Mechanical Engineering, CEG, Anna University ,Chennai, India.

**Professor, Department of Mechanical Engineering, CEG, Anna University ,Chennai, India

*Email: velmurugan2003@gmail.com; Corresponding Author

## ABSTRACT

Carbon Nano tubes (CNT) and Titanium di Boride particles ($TiB_2$) with different weight percentages reinforced composite magnesium alloy (AZ91D) were fabricated and the impact of changes in the mechanical and metallurgical properties of composites was assessed. Different weight percentage strengths of CNT (1.5 percent) and $TiB_2$ particles (5 %, 10%, 15 %) were applied to AZ91D grade magnesium alloy for various stir casting system process parameters in this study. For reinforcement-matrix interfacial reactions, SiC and $Al_2O_3$ were also added. The composites with 10% $TiB_2$ and (1.5 % CNT+1 % SiC+1% $Al_2O_3$) reinforcement show high hardness, whereas other reinforcements show increased elongation. The presence of elements revealed by energy dispersive X-ray spectroscopy also characterizes the composites using optical and scanning electron microscopy.

***Keywords***: AZ91D, Carbon nanotubes, $TiB_2$, hardness, microstructure

## INTRODUCTION

Magnesium and its alloys are now gaining broad demand as promising materials for lightweight structural applications , high specific strength and strong damping properties make Mg alloy the best materials for load-bearing structures (B. Ratna Sunil et al.,2016). Lowest density of all metal, construction materials, good castability, good usability in regulating atmosphere, enhanced resistance to corrosion, resistance to aging (B.L.Mordike et al.,2001). The modern computations and characterization tools will give way to the design of new magnesium alloys and engineering products to increase the use of magnesium(Alan A et al.,2013) . CNTs are used as reinforcements in the Mg alloy matrix due to its high elastic modulus, excellent tensile strength and low density, which is exactly the same as with magnesium. In order to obtain good properties, it is necessary that the CNTs are well distributed and dispersed in a composite metal matrix, the CNT reinforcement content is less than 2%( advanced materials technology, Germany). It has been documented in recent years that mg alloy and TiB2 particles have been found to act as heterogeneous alpha-grain nucleus in magnesium alloys(Shengafu liuet al.,2009).$TiB_2$ ceramic particles are considered suitable reinforcement particles due to their low density (4.5g / cm3), high elastic modulus (565GPa), strong wear resistance and the same magnesium crystal structure(Peng Xiao et al ., 2018). MMCs with silicone (SiC) and aluminium oxide ($Al_2O_3$) as reinforcement have a major advantage over traditional materials(S.Gopalakannan et al .,2013). In this paper the stir casting technique was used to prepare CNT&$TiB_2$ reinforcement AZ91D composite alloys, the mechanical and microstructure, properties of AZ91D composites comprising 1.5 % CNT and 5 %$TiB_2$, 10 % $TiB_2$, 15 %$TiB_2$ were analysed in detail.

## EXPERIMENTATION

2.1 Fabrication of CNT and $TiB_2$ reinforced AZ91D magnesium composites:

In this analysis, a bulk AZ91D magnesium alloy was used as matrix material. The chemical composition of AZ91D is shown in Table 1.1. CNT reinforcements with an average diameter of50 nm and a length of 1-5 m have been used.. In the fabricating process, a two-step stir casting method was adopted, because AZ91D with different hybrid ratios was synthesised using the stir casting method (Xia Zhou et al., 2012, Yan Wang et al.,& Qianqian Li et al 2009). The experiments were carried out in the presence of N2, which prevented magnesium alloys from evaporating and molten magnesium alloys from burning. The first 1 kg of AZ91D was melted at 720$^{o}$C and then cooled to 560$^{o}$C at which the matrix alloy was semi-solid. The pre-treated CNT, $TiB_2$ particle and SiC, $Al_2O_3$ were fed into the semi-solid Mg alloy. Semi-solid melting temperature, stirring speed and time for composites with a different percentage of $TiB_2$ (5%, 10%, 15%) were 700$^{o}$C to 800$^{o}$C, 300-400 RPM, 15-25 min, respectively, after a sufficient string melts since Titanium having a high hardness and low density (Sameer Kumar D et al.,2017), the melt was easily reheated at 700$^{o}$C for 5 min and 5 specimens were fabricated with different process parameters.

**Table 1** Chemical composition of AZ91D

| ELEMENT | Al | Zn | Mn | Mg |
|---|---|---|---|---|
| Wt% | 8.5-9.5 | 0.45-0.9 | 0.17-0.40 | balance |

2.2 Micro Vickers hardness and tensile test

Micro hardness [ASTME3-11 (RA17)] & [(ASTME407-07 (RA15)] and tensile (E8-16a) test specimens were prepared in compliance with the ASTM guidelines. Micro hardness testing using the Vickers hardness tester (MAKE: Wolpert group) and the tensile test using the mechanically operated UTM (model: UTN40, make: FIE) was performed to determine the hardness and tensile strength of the composites produced. The specimens were shown in fig.1.1(a) and fig.1.1 (b) respectively

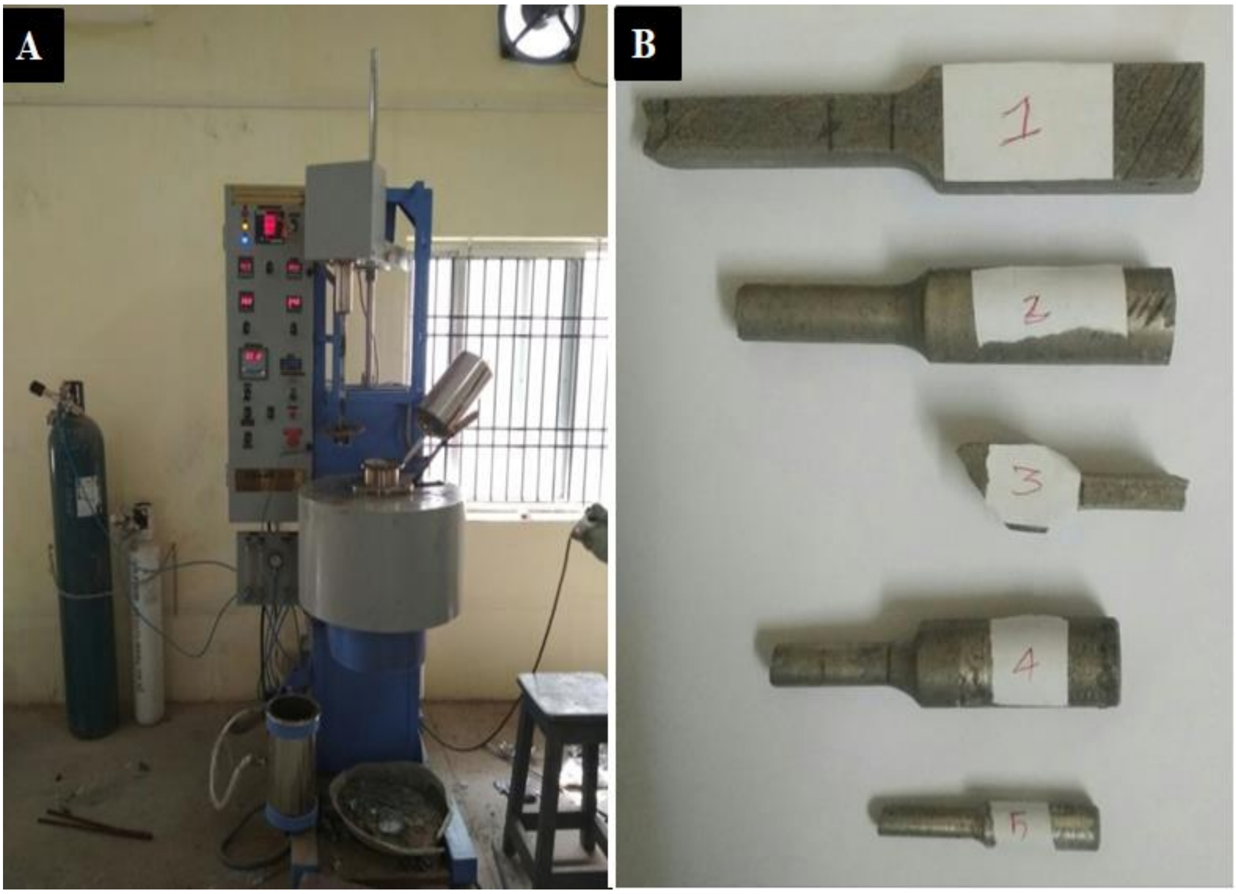


**Fig 1** The experimental work; **Fig1.1 (a)** stir casting setup **Fig 1.1 (b)** fabricated specimens (after tensile test)

2.3 Metallurgical tests

Microstructural characterization was tested using an advanced optical microscope to verify the proper diffusion of the reinforcement in the matrix in order to determine its homogeneity. The specimens are mechanically polished by means of an automated disc polishing unit, after which the specimen was placed at the microscope observation stage [dewinter tech]. Fig.2 displays the optical microscopic view of the CNT / $TiB_2$ reinforced AZ91D stir cast, which demonstrates that particulate dissemination is almost homogeneous and without deformity. The microstructure is then examined and photographs of the microstructure were taken at various magnifications to apprehend the grain boundary and the corresponding grain structures, the fractured surface was analysed with the aid of SEM [ZEISS]. The energy dispersive X-ray analysis [EDAX] was conducted to ensure the existence of elements within the MMC.

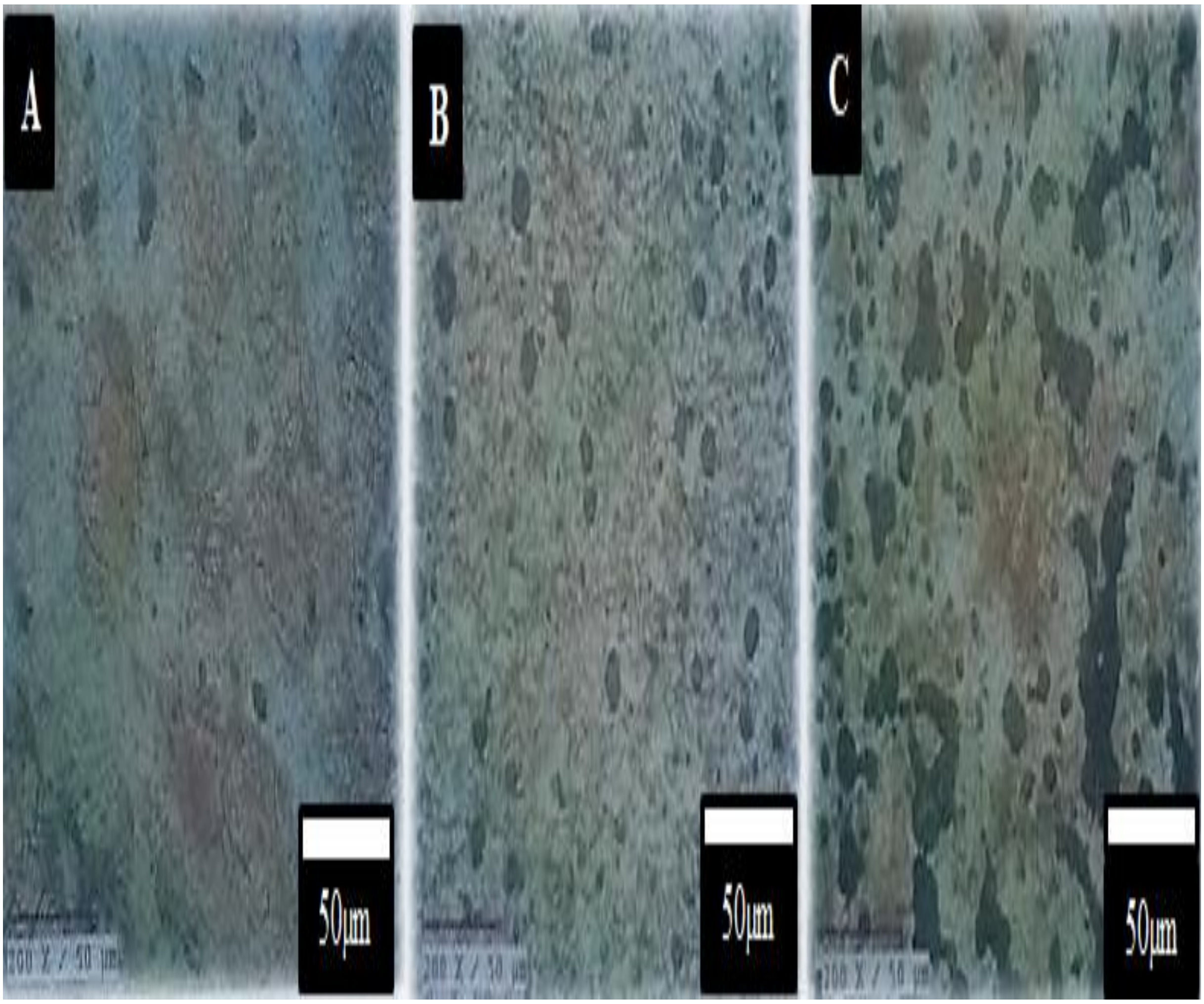


**Fig 2** Optical microscope analysis. **Fig, 2.1(a)** Metal matrix composite with 5%$TiB_2$ ,**Fig.2.1 (b)** Metal matrix composite with 10 %$TiB_2$ and **Fig.2.1(c)** Metal matrix composite with15%$TiB_2$
matrix composite with 10 %$TiB_2$ and **Fig.2.1(c)** Metal matrix composite with15%$TiB_2$

## RESULT AND DISCUSSION

### 3.1 Tensile strength and micro hardness

The results of the mechanical test show that the mechanical properties have been improved to increase the percentage of CNT and $TiB_2$ particulates by weight. Improvements have been made to the ultimate and compressive strength(Qianqian Li et al., 2009). Figure 3 shows the specimen1 fabricated with 1.5% CNT and 5% $TiB_2$ particulate reinforcement resulting in a 1 percent increase in yield strength and 2 percentage increase in hardness, elongation also improved. The specimen 2 fabricated with the reinforcement of 1.5% CNT and 10% $TiB_2$ particulate average result shows a 10.5 percent increase in hardness with the same base material tensile strength. The specimen 3 produced with 1.5 % CNT reinforcement and 10 % $TiB_2$ particulate result shows a 31.5 percent hardness increase with a 5 percent reduction in tensile strength and a 3 percent reduction in the yield strength of the base material. Specimen 4 produced with 1.5 % CNT reinforcement and 15 %$TiB_2$ particulate production shows a 28 percent improvement in hardness with the same base material tensile strength. The AZ91D-Boron composite hardness value is high compared to the AZ91D alloy (I. Aatthisugan et al., 201). The specimen 5 produced with 1.5 % CNT reinforcement and 15 % $TiB_2$ particulate result shows a hardness increase of 25 percent with a tensile strength increase of 7 percentage. During consolidation, the coarse intermetallic compounds diminished the composite's tensile properties, which significantly decreased and ensured tensile strength due to the regulated distribution of temperature during the addition of CNT and $TiB_2$ particles to the molten metal in the liquid state. Reduction of CNT and $TiB_2$ segregation in the tensile strength specimens shown in figure 3

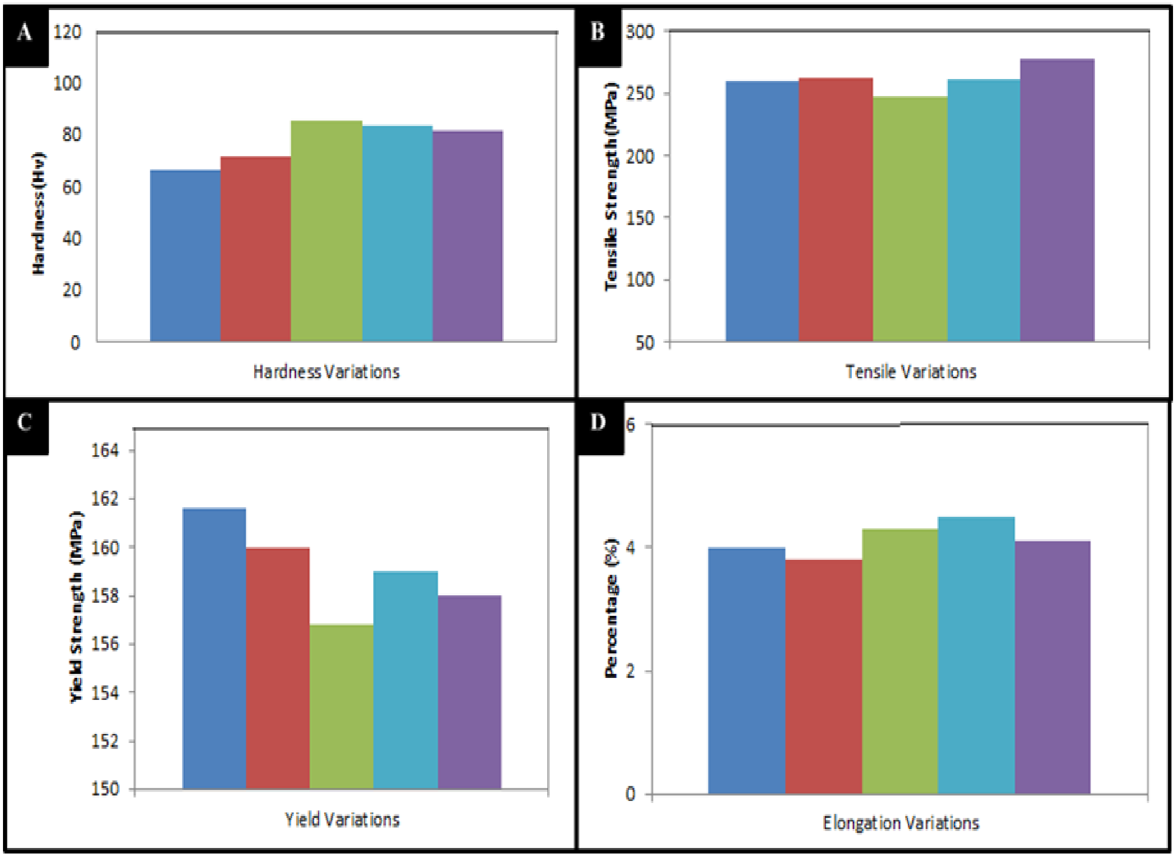


**Fig 3** The mechanical property variation **Fig 3.1(a)** Hardness variations **Fig 3.1(b)** tensile strength variations **Fig 3.1(c)** yield strength variations **Fig 3.1(d)** elongations variations

3.2 Micro structural analysis

The optical micrograph analysis of composite shows refined micro structural features and dendritic cast structure consisting of CNT and $TiB_2$ particles in the eutectic matrix when compared to the unreinforced magnesium alloy. The SEM analysis also shows the porous formed at the time of manufacture of the composites and composites were also analysed to find out the mode of failure in the composites produced are shown in Fig.4. It can be interpreted that the abrasion and delamination are generally observed in the wear sample(A.B.Gurcan et al .,1995).

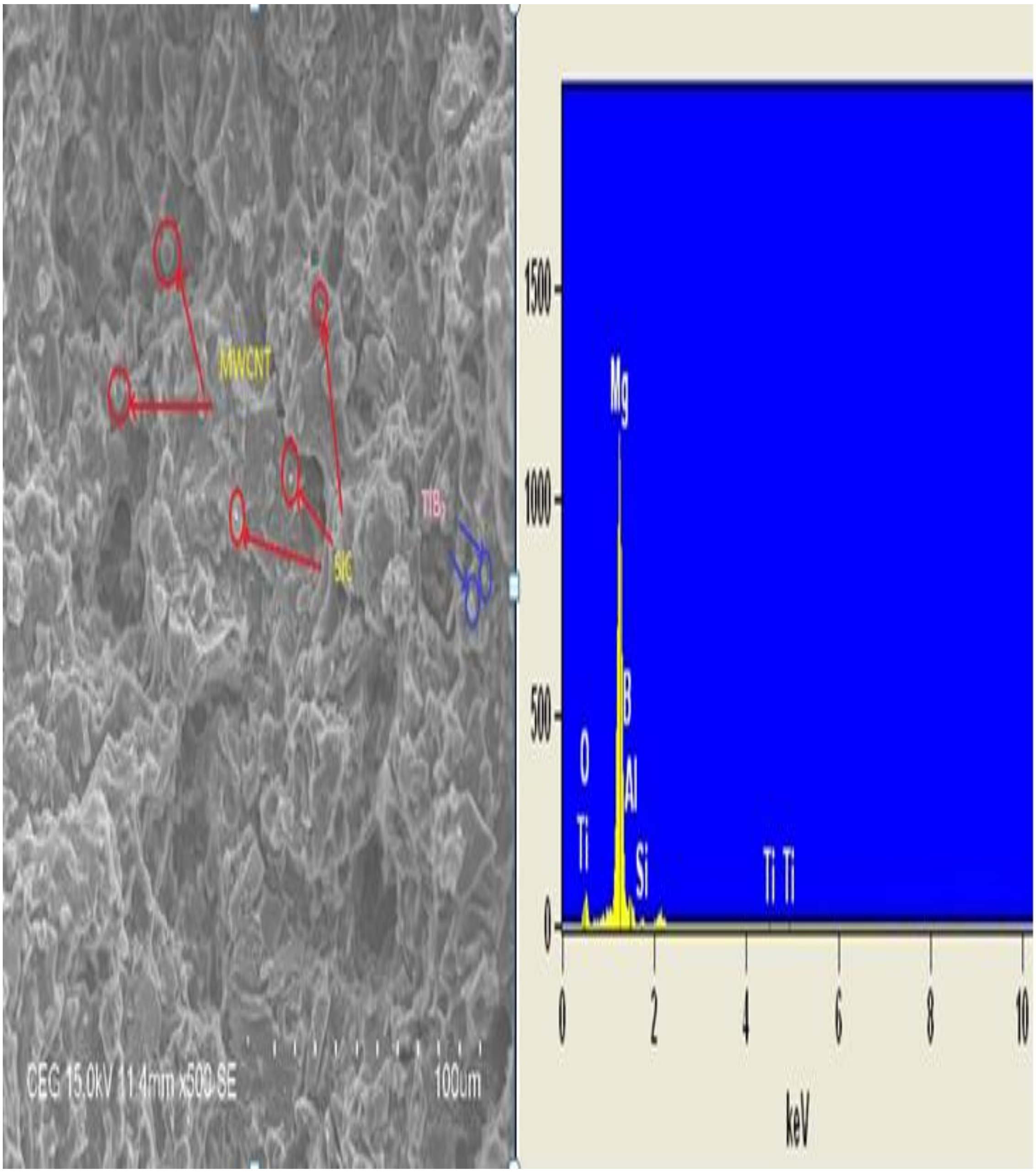


**Fig 4** The Scanning Electron Microscope and EDAX analysis, **Fig 4.1 (a)** The SEM and EDAX analysis of composite with 5%$TiB_2$

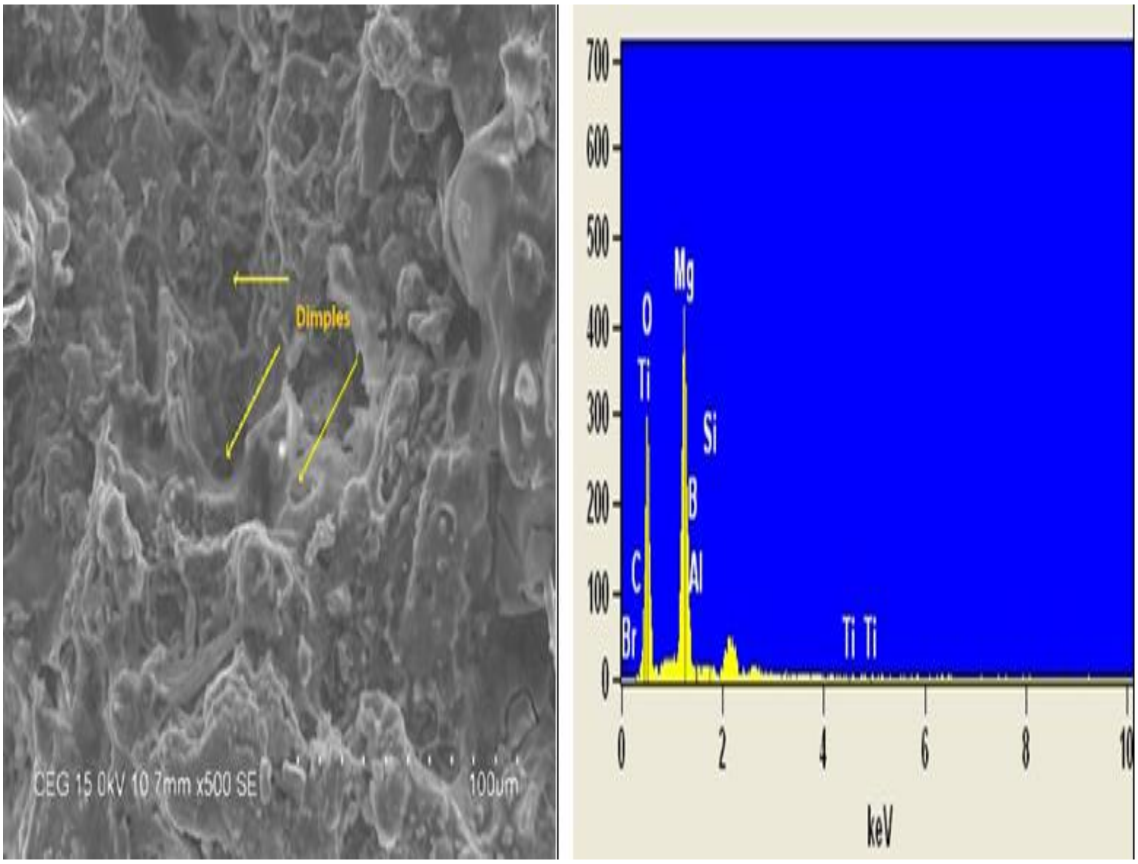


**Fig 4.2 (b)** The SEM and EDAX analysis of composite with 10%$TiB_2$

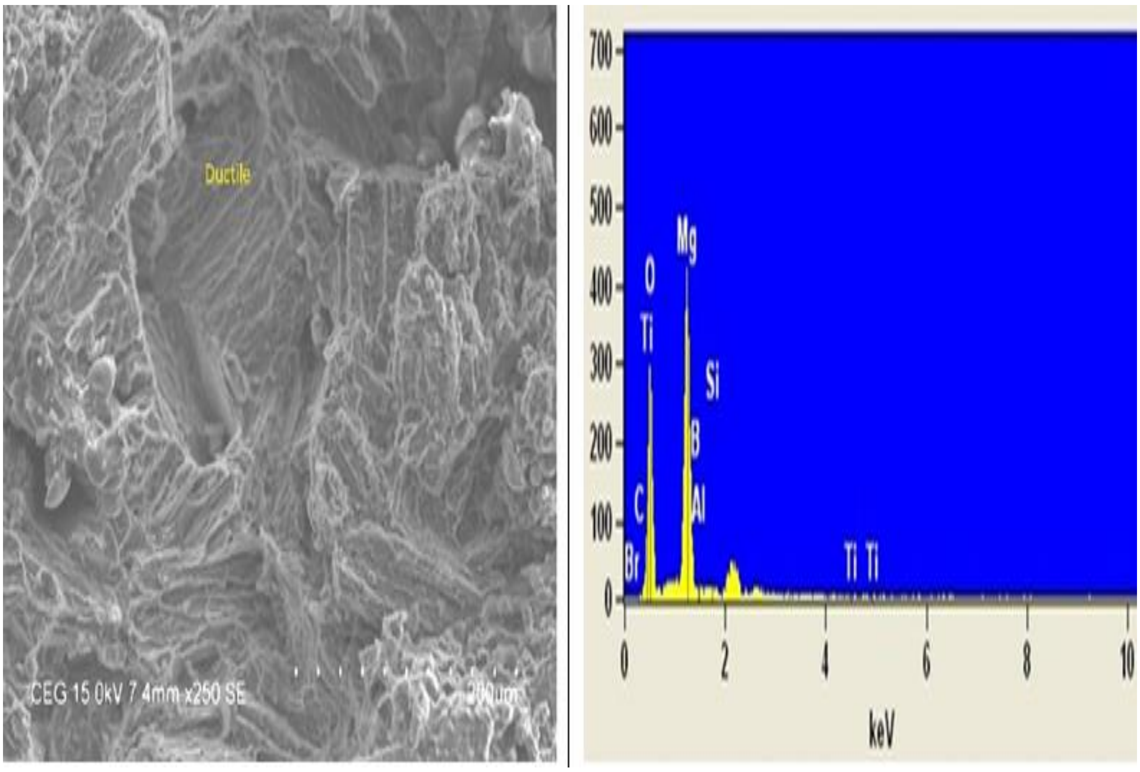


**Fig 4.3(c)** The SEM and EDAX analysis of composite with 15%$TiB_2$

Specimen 1 exhibits ductile mode due to reduced fracture strength. Specimen 5 shows the ductile mode of fracture due to increased tensile strength. Nano composites produced were examined for voids , cracks and separation between AZ91D / CNT / $TiB_2$ composites with SEM.CNTs stimulated by slipping and twining, resulting in high ductility of Nano composites(Zhirui li et al.,2020).It was determined that there is no separation in Nano composites, so the use of special processing temperatures and other parameters results in a robust bond and great moistening between the matrix and the reinforcement. Fractography showed that the fracture behaviour of the magnesium matrix changes from brittle to ductile due to the presence of Nano particles(S.F.Hassan et al 2006). Figure.4.2 indicates the tensile fractured surface morphological of AZ91D / CNT / $TiB_2$ composites under different conditions. The dimples on the fractured surfaces of the composites are larger and deeper than those on the AZ91D matrix, indicating that the AZ91D / CNT / $TiB_2$ composites have greater ductility than the matrix alloy.

## CONCLUSION

The following conclusions were made from the experiment carried out. AZ91D /CNT/$TiB_2$ composites were well fabricated using semisolid stir casting technique with discrete weight percentages. A strong dispersion of CNT / $TiB_2$ in the AZ91D matrix was achieved using a two-step technique, which revealed increased hardness, yield, tensile strength and elongation of the composites with CNT / $TiB_2$ and decreased with the addition of $TiB_2$ particles also the ductility of The composite element has a greater density than the AZ91D matrix.. The action of tensile strain has obscured dislocations in high strain zones. The micro structural analysis revealed a uniform distribution of CNT and $TiB_2$ particles in the matrix structure, as well as strong bonds with the method used.

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