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The Effect of Mechanical milling on the Microstructure and Particle Morphology of ZnAl40Cu2/B_4C/Graphene Hybrid Nanocomposites

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Abstract

In this study, Zn-Al based metal matrix composite reinforced with 1% B_4C and %1 graphene nanoparticles was processed and characterized. The mechanical milling and hot-pressing method were used for the fabrication of hybrid nanocomposite materials. The powder mixtures were milled from 1h to 8h in a planetary ball mill machine. Scanning Electron Microscope (SEM) and Energy Dispersive Spectrum (EDS) was used for microstructural evolution of this nanocomposite materials. The effects of milling time on the microstructure and particle morphology of ZnAl40Cu2/B_4C/Graphene hybrid nanocomposites were determined. The results showed that more homogenous dispersion of B_4C and Graphene powders was obtained in the Zn-Al based matrix using the mechanical milling time of 8h. The particle size of hybrid powder was decreased with increasing milling time.

1 INTRODUCTION

Metal matrix composites (MMC) are materials produced by reinforcing ceramic particles to a metal matrix as evenly as possible. Due to the low density/high strength, their ability to be produced in different combinations and geometries; high toughness and fatigue strength, high temperature, oxidation and abrasion resistance, the use of these materials covers many industrial areas from the automotive industry to the aerospace industry. New engineering materials were needed to achieve better performance, especially in the aerospace and defence industries, and this demand led to the development of MMCs. Most of the work on composite materials consists of composites containing nano-sized matrix and/or reinforcement phases [1]. Researchers are working on ceramic particle reinforced composites with aluminum metal matrix. However, in recent years, the production and properties of zinc-matrix ceramic reinforced composites has been an area of interest for many researchers. Zinc-based alloys are now very useful as matrix materials. The main reasons for this are low melting temperatures and low cost [2].

These alloys have superior tribological properties because the phases of aluminum oxide (alumina) and zinc oxide can easily form on the surface during the wear phenomenon. Alumina that is a hard phase makes the wear resistance high while zinc oxide that is a soft phase gives the lubricating properties to the body. The main problem of ZA alloys is that their mechanical properties decrease at temperatures above 100 ° C. This problem can be avoided by adding ceramic phases such as SiC, Al_2O_3, TiC and B_4C [3]. High stiffness, hardness and small density difference between B_4C, aluminum, and aluminum alloys make B_4C an attractive reinforcement. Its high cost compared to SiC and poor wetting by molten aluminum alloys below 1100 ^{0}C limits its choice as reinforcement [4,5]. Graphene made up of carbon atoms graphene has been attractive due to their extremely high thermal conductivity, extraordinarily high stiffness and elasticity, good optical, electrical properties and also has unique friction and wear properties which finds its application in a lot of fields like micro electro mechanical systems, wear resistance materials, coatings, additives and, liquid/solid lubricants [6-7].

Mechanical milling process can be used to refine the microstructure and provide the homogeneous dispersion of ceramic reinforcements in the metallic matrix within powder metallurgy[8]. This method can use to produce large quantities of materials as inexpensive. Thus, it is a well-known technique to produce advanced materials such as amorphous alloys and nanocomposites[9].

The purpose of this investigation is to produce 1wt. % graphene and 1wt. % B_4C reinforced hybrid nano composites by mechanical alloying and hot pressing and to investigate the effect of milling time on milling on the microstructure and particle morphology of ZnAl40Cu2/B4C/Graphene hybrid nanocomposites

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2 MATERIAL AND METHOD

ZnAl40Cu2 powders with an average particle size of 65 μm and density of 4.28 g/cm_3 were used as matrix powders. The chemical composition of ZnAl40Cu2 matrix powders (wt.%) is 57.6 Zn %, 2,01Cu %, 40,3 Al. The SEM images of as-received matrix powders were shown in Figure 1. As seen in Figure 1, the morphologies of matrix powder are ligamental.

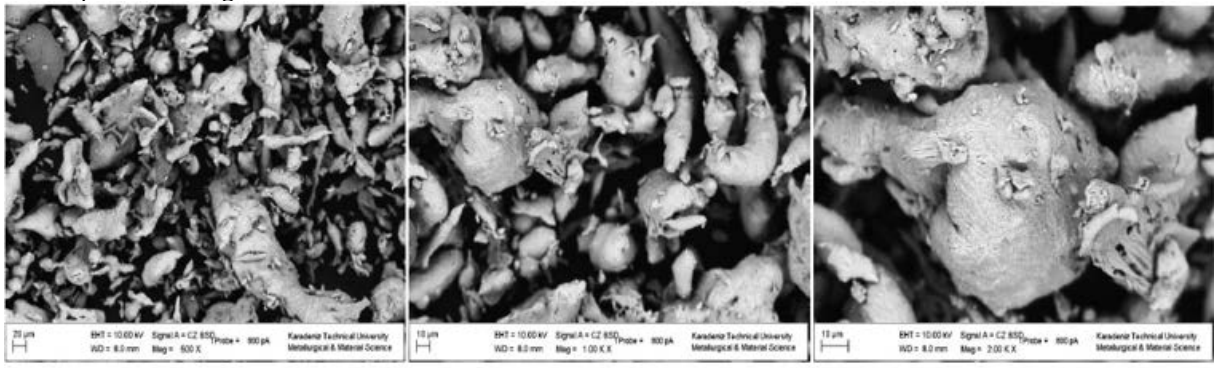


Figure 1. SEM images of ZnAl40Cu2 powders at different magnifications a) 500X b) 1000X c) 2000X

B_4C particles with the theoretical density of 2.53 g/cm^3 and average particle size of 50 nm and Graphene particles with the theoretical density of 2.26 g/cm^3 and average particle size of 40nm were used as reinforcements. Figure 2 shows the morphology of as-received B_4C and Graphene nanoparticles.

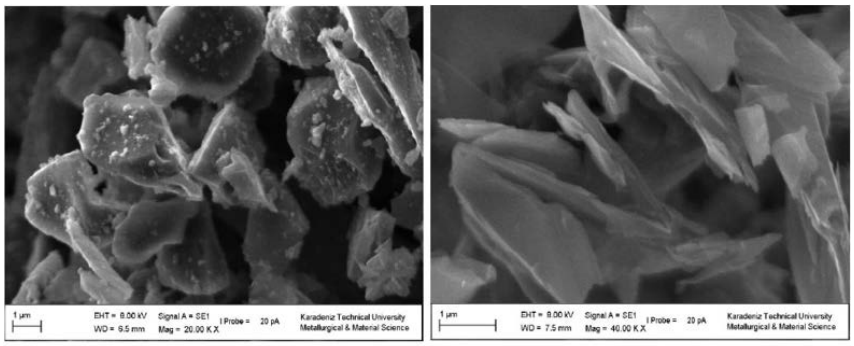


Figure 2. The SEM images of powder morphologies of (a) b4C and (b) Graphene

The hybrid nanocomposites powders were produced by mechanical alloying. The ZnAl40Cu2 alloy matrix powders, graphine and B4C nanoparticles were milled (for 1, 2,4,6 and 8 h) with tungsten balls (10 mm) and vials (125 ml) using high energy ball-mill (Retsch PM 100). The rotational speed and the ball to powder weight ratio were respectively 300 rpm and 5:1. To prevent cold welding and oxidation methanol (wt 3%) was used as process control agent (PCA). Initially, the hybrid nanocomposite powders were consolidated at room temperature under a constant pressure of 300 MPa to form green compacts and then green hybrid nanocomposite materials were consolidated under a pressure of 300 MPa at 455 ○C.
Microstructures of each nanocomposites sample, distribution of the B_4C and graphene nanoparticles in the ZnAl40Cu2 matrix alloy and morphologies of nanocomposite powders after the milling process were investigated by using scanning electron microscopy (SEM, Zeiss Evo LS10) equipped with elemental X-ray microanalysis (EDS).

3 RESULTS

3.1. Powder Morphology

The uniform distribution of nano graphene and nano B_4C particles in the ZnAl40Cu2 matrix is an important factor affecting the physical and mechanical properties of the final product. The morphology of the hybrid nanocomposite powders milled at different times is shown in Figure 3. When the figures are examined, it is seen that while the powders initially had a ligament structure, they returned to pulse structure after the first 6 hours of milling process

(Figure 3 d). This is because nano-graphene has a lubricating effect, reducing breakage and cold-welding phenomena. Thus, after 6 hours of grinding time, the powder size decreased from 42 μm to 34.74 μm, which means that there was a significant change in the powder size. As the grinding process continued, the powder morphology pulse structure was maintained, but reductions in powder size occurred. After 8 hours of grinding, the powders have a relatively equiaxial structure and a significant decrease in powder size is observed.

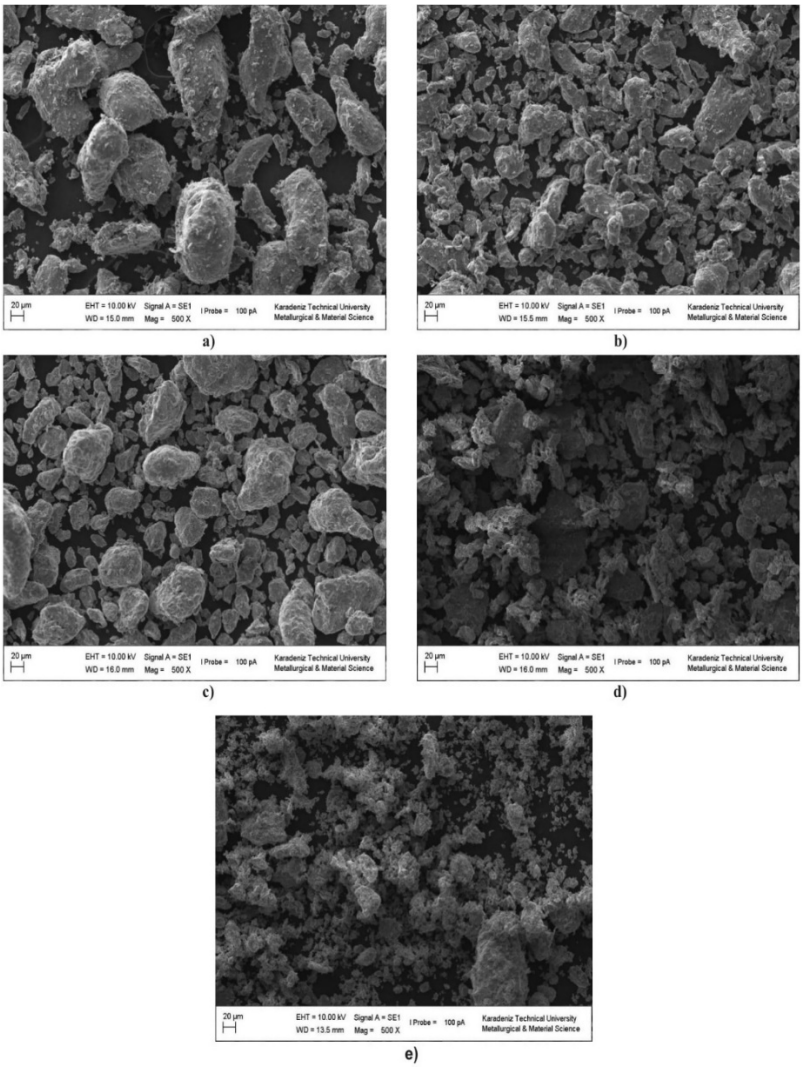


Figure 3. SEM images at 500X magnification of hybrid nanocomposite powders a) 1, b) 2, c) 4, d) 6 and e) 8 hours of mechanical alloying time

In the MA process, the powder particles subjected to the milling process using high energy ball mills exhibit both morphological and dimensional changes as a result of high energy collisions between the ball-powder-ball, ball-powder-mill surface. As a result of the studies on MA, the general opinion is that in the first stages of milling, powder size increases as a result of cold welding and in later milling periods it decreases and becomes stable. However, this formation also depends on factors such as the initial size, the morphology of the starting powders, the amount of process control additive and the manner of administration. Thus, it was found that the stabilized HNK powders were reached at a grinding time of 8 hours and the powder size reached its minimum values. Although the average particle size of the starting powders used in the study was ~ 42-43 μm, the powder size of the composite powders decreased to 28 μm after 8 hours of grinding. This is shown in Figure 4.

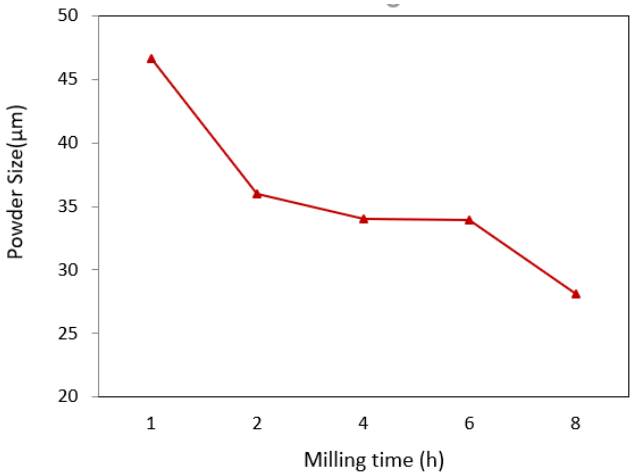


Figure 4. The effect of milling time on the particle size of hybrid nanocomposite

3.2. Microstructure

The SEM image of pure ZnAl40Cu2 alloy produced by powder metallurgy method at 1000X magnification is given in Fig. 5. The light gray regions in the figure represent aluminum-rich $Al_{6.1}(Cu, Zn)_{1.2}$ (Figure 4, number 1). The areas seen as small white dendritic regions in the figure represent the phase (Figure 4, number 2) with high saturated aluminum and a small amount of dissolved copper (Figure 4, number 2), and the small bright white areas (Figure 4, number 4) represent the $CuZn_5$ phase. the parts seen as black represent the porosity within the structure (number 3).

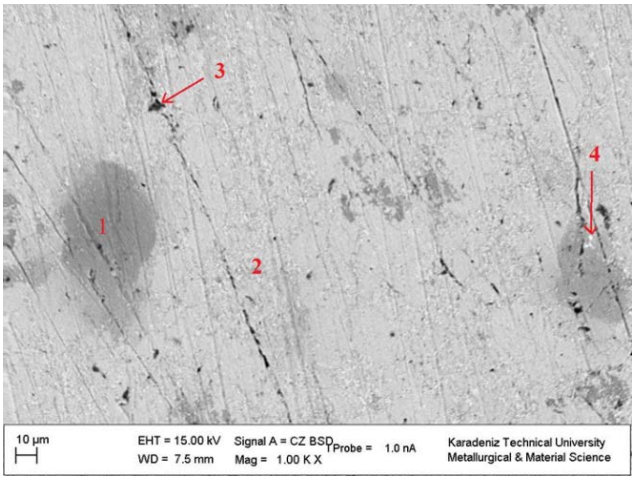


Figure 5. SEM image of pure ZnAl40Cu2 alloy produced by powder metallurgy method at 1000X magnification

SEM images of hybrid nanocomposite samples produced with powders milled with different mechanical alloy durations with ZnAl40Cu2 alloy matrix graphene and B_4C nano particle reinforcement are given in Figure 6. The small black bright spots seen in the figures were found to be B_4C particles. When the figures are examined, it is seen that these points start to move into the grain at the grain boundaries with increasing mechanical alloy time and are distributed more homogeneously. It is also evident from the figures that the grain size decreases with increasing mechanical alloying time.

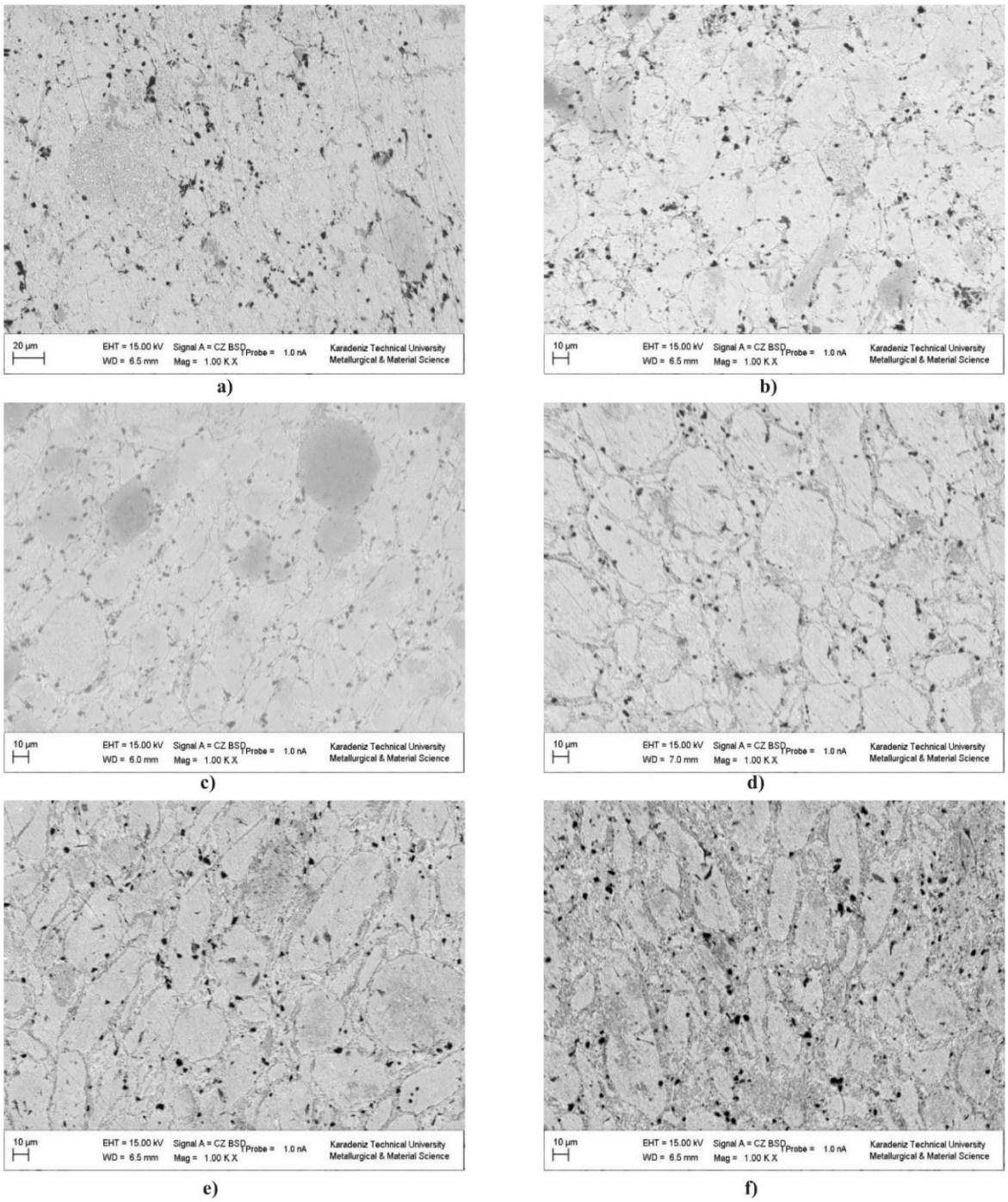


Figure 6. SEM images of 1000X magnifications hybrid nanocomposite samples produced with different milling time (a) 0h, (b) 1h, (c) 2h, (d) 4h, (e) 6h and (f) 8h

4 CONCLUSION

1. ZnAl40Cu2 matrix graphene and B_4C reinforced hybrid nanocomposite materials can be produced by mechanical alloying and hot-pressing method.
2. The samples produced by the conventional powder metallurgy method; the reinforcing elements are generally deposited at the grain boundaries. With MA, nanoparticles are located both within the grain boundaries and within the beads.
3. The particle size of hybrid nanocomposites decreased with increasing milling time.

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