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PRODUCTION AND PROPERTIES OF AL2024-2 WT.% (SiC-B_4C) HYBRID NANOCOMPOSITE

ABSTRACT

In this paper, production and properties of Al2024-SiC-B_4C hybrid nanocomposite produced using mechanical alloying and hot pressing by powder metallurgy method. First of all, Al2024, SiC and B_4C powders were alloyed in planetary ball mill at room temperature with 8 hours to be obtained homogeneous powder distribution. After, the hot pressing technique was used for producing hybrid nanocomposite with 2 weight percentage (1 wt.% SiC and 1 wt.% B_4C respectively) of SiC and B_4C reinforcements. The mechanical (hardness, tensile strength, bending strength, fracture surface), physical (density, porosity) of properties and microstructure of Al2024-SiC-B_4C hybrid nanocomposite were investigated. It was showed that the uniform distribution of dispersion of SiC-B_4C nano particles within Al2024 matrix.

Keywords: Powder metallurgy, SiC, Nanocomposite, B_4C, Hybrid

1. INTRODUCTION

Metal matrix composites (MMCs) have attracted increasing attention to applications in marine, automobile, marine, aerospace, electronics, and nuclear industries. MMCs present good mechanical properties in the three orthogonal directions coupled with comparatively low cost availability of reinforcement. Metals and alloys such as Al, Ti, Mg, Cu, Ni and intermetallics has been used as matrix material [1 and 2]. The use of aluminum-based composites has increased dramatically in recent times. Some of the reinforcement used in the aluminum matrix are B_4C, TiC, Al_2O_3, SiC, TiO_2, TiB_2 and MgO [3]. SiC having continuous network structure are a very promising ceramic material for use in semiconductor processing, nuclear fusion reactors, heat-sink plates, and high temperature thermo-mechanical applications because of their excellent chemical and thermal stability, high thermal conductivity, and good mechanical properties [4]. However, a problem of Al/SiC composites is that the microstructure shows a non-uniform distribution of SiC particles [5]. Al-B_4C composites have a potential to be used as armor materials in body protection, helicopters, military aircrafts and vehicles where lightweight is of utmost importance [6]. For example, Alizadeh et al. [7] compared the mechanical properties of aluminum matrix composites reinforced with 1,

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2 and 4 wt.%B_4C nanoparticles fabricated via stir casting method. Their results show that with increasing amount of B_4C nanoparticles yield strength and tensile strength increased but elongation to fracture decreased. Al–B_4C composites are produced by three different methods: solid state methods (such as mechanical milling and powder metallurgy), molten methods (such as stir casting) and semi-solid methods [8 and 9]. Powder metallurgy is considered as an efficient technique in producing metal-matrix composites. Low processing temperature compared to melting techniques is an important advantage of this method. Besides, the reinforcing particles in the matrix are distributed good by powder metallurgy technique. Another advantage of powder metallurgy technique is its ability to manufacture near net shape product with low cost [10]. To our knowledge, effect of the nano SiC and nano B_4C content on mechanical properties of composites has not been investigated. Therefore, the purpose of this work is to produce Al2024/B_4C-SiC composites by powder metallurgy and hot pressing and to investigate effect of nano particles content on the microstructure and mechanical properties of the Al2024/B_4C-SiC composites.

2. RESEARCH SICNIFICANCE

The aluminum composite is a material having mechanical properties changeable values depending on the reinforcing particle. However, looking at the work done, it is desirable to change the properties with a reinforcement material. In this study, two different reinforcing materials whose properties were almost similar were used. At the same time, it is advantageous to produce materials with a net shape by using the powder metallurgy method during the production of materials. Therefore; the processing cost is reduced and the use rate of the produced material is greatly increased.

3. RELATED WORK

Al2024 alloy powders, nano B_4C and nano SiC particles used as raw materials to fabricate the composites. The as-atomized Al2024 powders were supplied commercially with the chemical composition (in wt.%) of 4.85 Cu, 1.78 Mg, 0.385 Si, 0.374 Fe, 0.312 Mn, 0.138 Zn, 0.042 Cr, 0.005 Ti and Al (balance). Al2024 alloy powders with an average particle size of 72µm were used as the matrix materials, SiC powders with an average particle size of 40 nm and B_4C powders with an average particle size of 45-55nm (Alfa Aesar, Germany) were used as the reinforcement material. Al2024 matrix powders, SiC and B_4C particles (1wt.% SiC and 1 wt.% B_4C respectively) were blended in a planetary ball-mill (Fritsch Gmbh, model "Pulverisette 7 Premium line") at room temperature using a tungsten carbide bowl and a high argon atmosphere for 8h in order to break up the hard agglomerates. The milling medium was tungsten carbide balls with diameters of 10mm. The ball-to-powder weight ratio and rotational speed were selected to be 5:1 and 400rpm, respectively. The milling atmosphere was argon which was purged into a bowl before milling. Hot pressing was used for preparation of the Al2024-SiC-B_4C composites in mold. The microstructure and elemental distribution of cross-section of composites were investigated using Zeiss Evo LS10 scanning electron microscope. The tensile and three-point bending test was performed using a MTS Universal Materials Testing Machine at room temperature. The crosshead speeds were maintained respectively at the speed of 0.3mm/min and 0.5mm/min for tensile test and three-point bending. The microhardness of these composite samples was measured using the Binell hardness (BS) method under a load of 32 kg for a dwell time of 15s. The geometry of tensile and three-point bending test samples are 6mm×10mm×65mm. The density of hybrid nanocomposite samples were determined by the Archimedes method.

Theoretical densities of hybrid nanocomposites were calculated using rule-of-mixture. The porosity was calculated by using the theoretical and experimental densities.

4. RESULTS AND DISCUSSION

4.1. Microstructure

EDX analysis of Al2024 matrix composites reinforced with wt. 2% SiC-B_4C hybrid nanoparticles are shown in the Figure 1. The most important factor in the fabrication of Al2024 matrix composites is the uniform dispersion of the reinforcements. As seen in the Figure 1 and Figure 2, the distribution of the reinforcing particles points to a tendency that a lot of particles are mostly placed in the particle boundary area. No macro porosity was observed in the Al2024 matrix composites and the distribution of the particles is not uniform in the matrix.

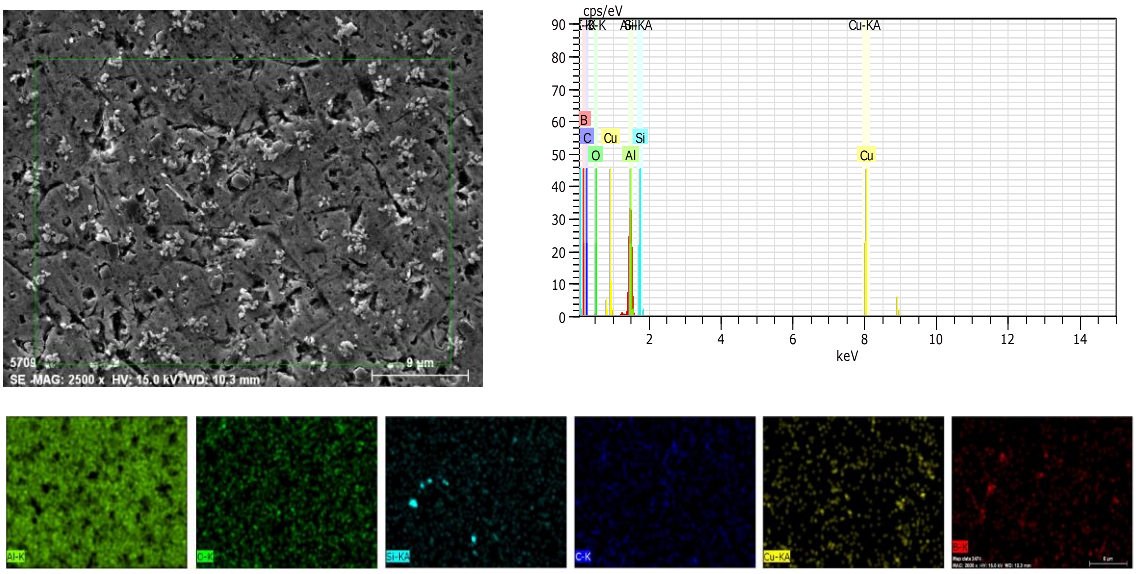


Figure 1. EDX analysis of Al2024 matrix composites reinforced with wt. 2% SiC-B_4C hybrid nanocomposite bulk sample

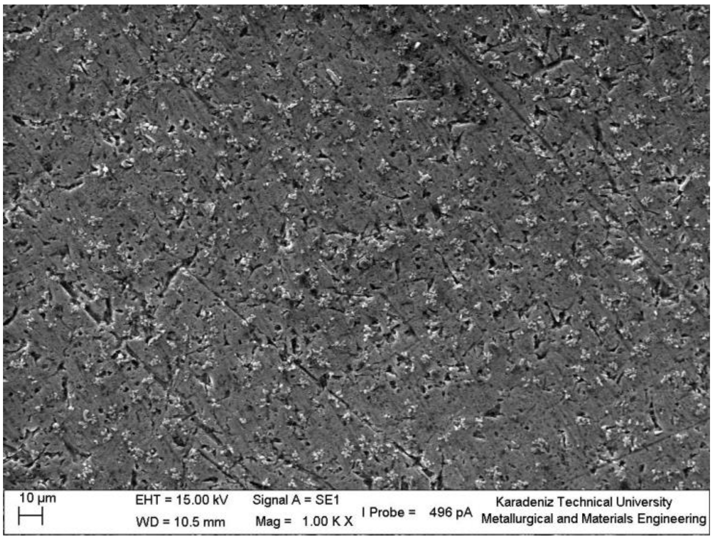


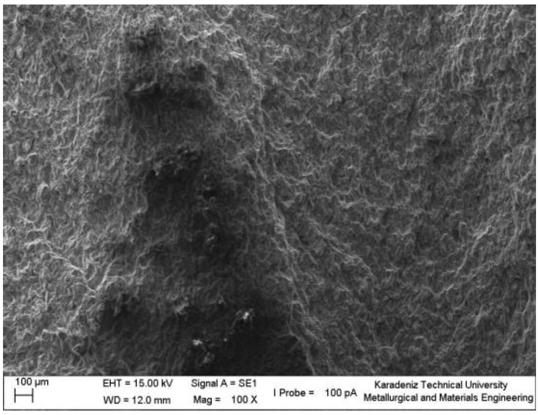
Figure 2. SEM image of Al2024 – wt. 2% SiC-B_4C hybrid nanocomposite sample

4.2. Mechanical Properties

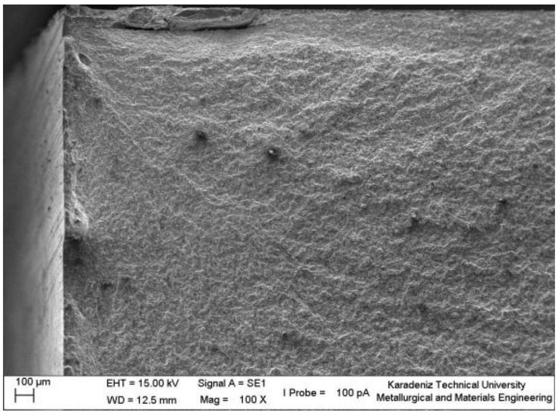
In the attempt to better evaluate mechanical properties of nanocomposites, bending tests tensile strength were conducted at room temperature and the results of tests are shown in Table 1. It is seen that for the initial stages of ceramic particle reinforcement, the reinforcement, milling and hot pressing provided an increase in bending strength and tensile strength of Al2024 nanocomposite. The bending and tensile strength values of Al2024/2 wt.% SiC-B_4C hybrid nanocomposite is respectively 742.3 MPa and 397.54MPa, while that of Al2024 alloy is 700.2MPa and 202MPa.

Table 1. Mechanical properties of the Al2024/wt.2% SiC-B_4C hybrid nanocomposite

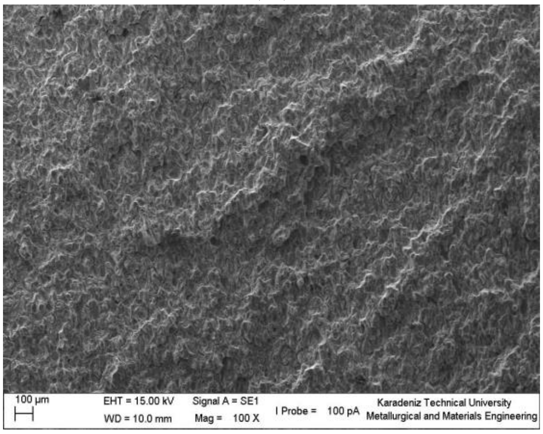
Composition Gredient (%wt.) Al2024/SiC+B_4C	Bending Strength (MPa)	Tensile Strength (MPa)	Hardness (BHN)	Density ($g.cm^{-3}$)	Porosity (%)
%100/%0+%0	700.2	202	101.6	2.7392	0.7
%98/%1+%1	742.3	397.54	171.2	2.8132	2.4



(a)



(b)



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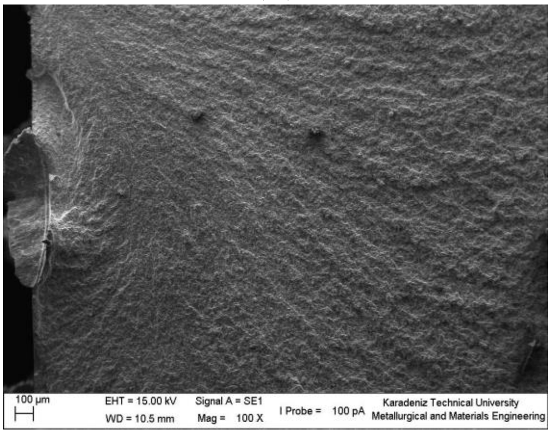

(d)

Figure 3. SEM image of bending strength fracture surface (a)Al2024, (b)Al2024/wt.2% SiC-B_4C hybrid nanocomposite and SEM image of tensile strength fracture surface (c)Al2024, (d)Al2024/wt.2% SiC-B_4C hybrid nanocomposite samples

The variation of Brinell hardness values of Al2024 and Al2024/wt. 2% SiC-B_4C hybrid nanocomposites is shown in Table 1. The hardness of the nanocomposites increased with reinforced SiC-B_4C particle weight fraction. The hardness values of Al2024 and Al2024/2 wt.% SiC-B_4C

hybrid nanocomposite is respectively 101.6 HB and 171.21 HB. Density and porosity values of Al2024 metal matrix composite that was reinforced with SiC and B_4C are given in Table 1. Both the density values and porosity values of Al2024/SiC-B_4C hybrid nanocomposites increases with increasing SiC-B_4C content. The density and porosity values of SiC-B_4C hybrid nanocomposite is respectively 2.8132g.cm^{-3} and %2.

5. CONCLUSIONS AND DISCUSSION

- SiC and B_4C nanoparticles reinforced, Al2024 matrix hybrid nanocomposites were produced by mechanical alloying and hot-pressing method.
- Increase in reinforcement content resulted in increase in bending strength and tensile strength of Al2024 hybrid nanocomposite up to wt.%2 SiC-B_4C.
- Increase in hardness of Al2024/SiC-B_4C hybrid nanocomposites was observed with increase in SiC and B_4C reinforcement nanoparticles.
- Porosity and density measurments showed that the addition of SiC and B_4C nanoparticles caused an increase in density and porosity in hybrid nanocomposite.

NOTICE

This study was presented as an oral presentation at the International Conference on Advanced Engineering Technologies (ICADET) in Bayburt between 21-23 September 2017.

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