Agronomy Research **16**((S1), 1289–1294, 2018
https://doi.org/10.15159/AR.18.135

Production and characterization of Al-BN composite materials using by powder metallurgy

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Abstract. Aluminum matrix composites containing 3, 6, 9, 12 and15% BN has been fabricated by conventional microwave sintering at 550 °C temperature. Compounds formation between Al and BN powders is observed after sintering under Ar shroud. XRD, SEM (Scanning Electron Microscope), mechanical testing and measurements were employed to characterize the properties of Al + BN composite. Experimental results suggest that the best properties as hardness 42, 62 HV were obtained for Al+12% BN composite.

Key words: Powder metallurgy, Sintering, Ceramic-Metal Composites.

INTRODUCTION

Al matrix composites produced by powder metallurgy (PM) have been receiving more attention than conventional melting-casting methods in aerospace, military and car industries, due to the improved physical, chemical and mechanical properties (Harding, M.D et al., 2015). Boron nitride (BN) is a synthetically refractory material, which is widely applied due to its fascinating physical and chemical properties (Guo et al., 2005; Zhang et al., 2005; Yang et al., 2005). It has key properties such as high thermal conductivity, low thermal expansion, good, high electrical resistance, low dielectric constant, nontoxic, easily machined-nonabrasive and lubricious (Chen et al., 2004; Chen et al., 2005; Lin et al., 2007). Hexagonal boron nitride, either in its pure form or as a composite, is an extremely suitable material for special applications at high temperatures. Gas seals for oxygen sensors, parts for high-temperature furnaces (Kalaiselvan et al., 2011). Metals are very useful in making different components and their properties can be improved by adding reinforcement like B_4C and BN e.t.c. Aluminium matrix composites (AMCs) are the competent material in the industrial world (Yuan et al., 2009). These composite materials also offer outstanding properties such as high strength to- weight ratio, good corrosion resistance and versatility to the designer. Two major processing techniques that have been found suitable for these composites are powder metallurgy and solidification processing (Yang et al., 2003). The hardness is affected not only by the uniformity of distribution of particles in the matrix but also by the strength of the particle-matrix boundary and the mechanical properties of the matrix (Maiti et al., 2008). Various reinforcement particles such as boron carbide (B_4C), titanium carbide (TiC), have been incorporated in aluminum matrix composites by direct melt reaction or by a combined method of self-propagating reaction and casting, ball-milling and reactive sintering and hot extrusion, cold isostatic press and hot extrusion, wet milling, cold isostatic pressing and hot extrusion (Chawla et al., 1987; Li et al., 2007).

The metal matrix composites derive good demand for their use in automobile and aerospace applications (Kennedy et al., 2001). However, the application of these materials is often limited by their poor ductility which is generally associated with in homogeneous size and distribution of the reinforcing particles (Kennedy et al., 2001).

BN particles have not good wettability in liquid aluminium and strong interfacial bonding with Aluminium matrix even though inmate metal- ceramic contact is not too easily achieved in composites fabricated from metal powders Albitera et al., 2003; Karantzalis et al., 2009).

In the present work, Composites work Al-%3BN, Al-%6BN, Al-%9BN. Al-%12BN and Al-%15BN were fabricated, microstructure were characterized and mechanical properties such as hardness and density were studied. It was observed that the best properties as hardness 42, 65 HV were obtained for Al+12% BN composite.

MATERIALS AND METHODS

Starting powders employed in this study were as follows: the purity of 99.8% for Al powders with a particle size lower than 70 µm, the purity of 99.9% for BN ceramic powders a particle size lower than 75 µm The composition of -%3BN, Al-%6BN, Al-%9BN. Al-%12BN and Al-%15BN, powders specimens were prepared in 10g square prism compressed pre-form. They were mixed homogenously for 24 hours in a mixer following the weighing. The mixture was shaped by single axis cold hydraulic pressing using high strength steel die. A pressure of 200 Bar was used for the compacting all the powder mixtures. The cold pressed samples underwent for a sintering at 550 °C for 2 hours in a traditional tube furnace using Argon gas atmosphere. The specimens were cooled in the furnace after sintering and their micro hardness and shear strengths measurements were carried out using METTEST-HT (Vickers) micro hardness tester machine, respectively.

LEO 1430 VP model Scanning Electron Microscope fitted with Oxford EDX analyzer was used for micro structural and EDX compositional analysis.

The volumetric changes of -%3BN, Al-%6BN, Al-%9BN. Al-%12BN and Al-%15BN, composites material after sintering were calculated by using ($d = m/V$) formula (Fig. 1). The volume of post-sintered samples was measured with Archimedes principle. All the percentages and ratios are given in weight percent unless stated otherwise.

Experimental Results and Discussion

Characterization of specimens

In the study, the samples prepared and shape were sintered at 550 °C in conventional furnace and made ready for physical, mechanical and metallographic analyses. Density-composition change curve is shown in Fig. 1. The highest sintered density was achieved at Al-%3BN composition as 2,975 g cm^{-3}.

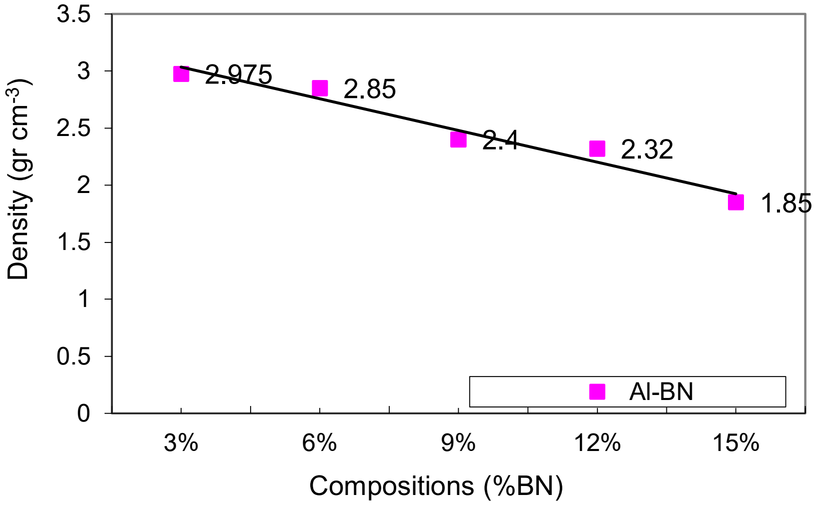

Figure 1. The density change with respect to composition at 550 °C.

The micro hardness-temperature change diagram is shown in Fig. 2. The micro hardness values of the composite samples produced using conventional sintering technique within the temperature at 550 °C. According to this, the highest microhardness value in the composite samples fabricated using powder metallurgy method was observed to be 42.65HV at composition of Al-%12BN composites.

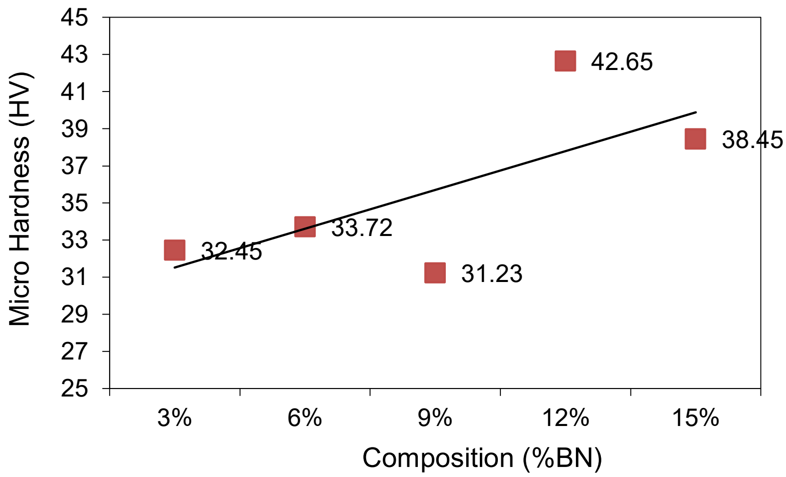

Figure 2. The micro hardness tests results from sintered specimens treated at different compositions.

Metallographic Analysis

The SEM analysis result of the metal matrix composite specimen obtained from Al-%3BN powders sintered at 550 °C is shown in Fig. 3. Grain growth is observed and a homogeneous structure and grain boundaries can be seen that the pores very smaller. This density and hardness values are confirmed.

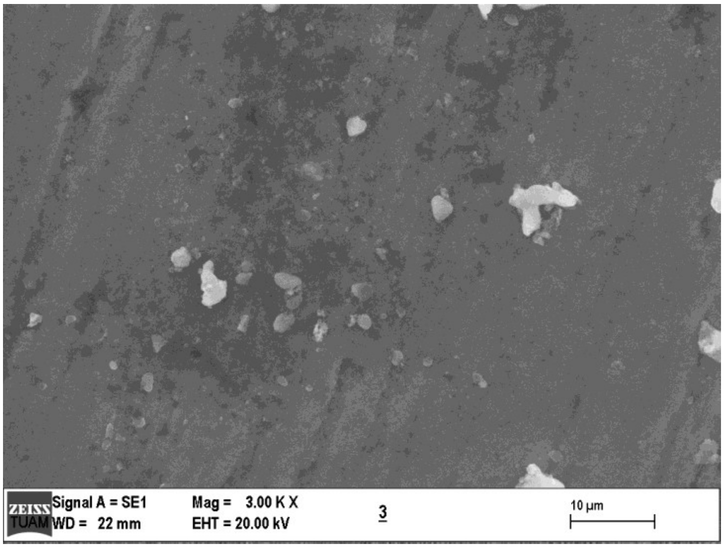

Figure 3. SEM view of Al-%3BN composite 550 °C.

The SEM analysis result of the metal matrix composite specimen obtained from Al-%15BN powders sintered at 550 °C is shown in Fig. 4. grain growth is observed. It is not a homogeneous structure and grain boundaries can be seen that the very pores. This density and hardness values are confirmed.

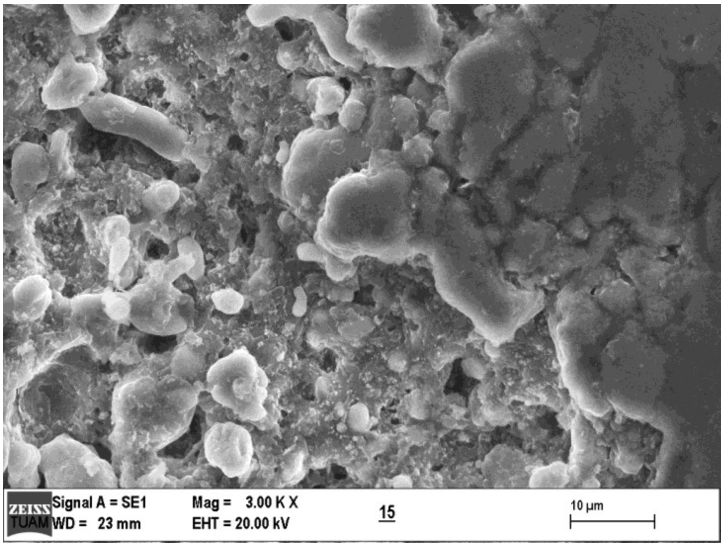

Figure 4. SEM view of Al-%15BN composite 550 °C.

The Al and BN phases, which was the main addition in the composite, has evidently the highest peak intensity over the other phases present in the XRD analysis in the Al-%3BN composites. Fig. 5 which shows the presence of Al and BN phases in the fabricated ceramic-metal composites

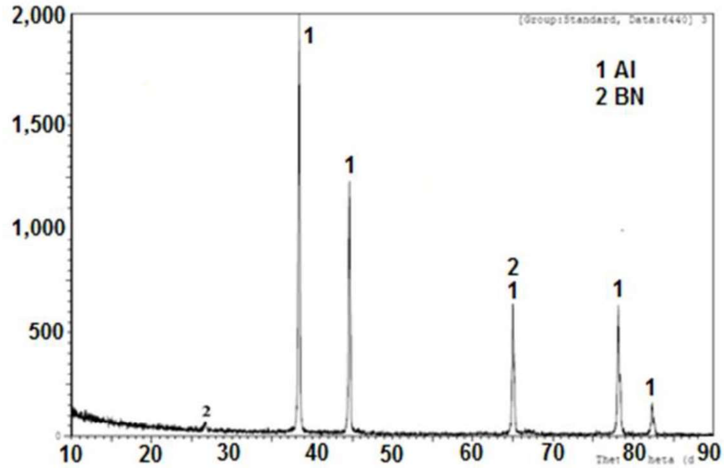

Figure 5. Present the XRD analysis results of Al-%3BN composites at 550 °C.

Fig. 6 present the XRD analysis results of Al-%15BN composites at 550 °C. The Al and BN phases, which was the main addition in the composite, has evidently the highest peak intensity over the other phases present in the XRD analysis in the Al-%15BN composites. Fig. 4 which shows the presence of Al and BN phases in the fabricated ceramic-metal composites.

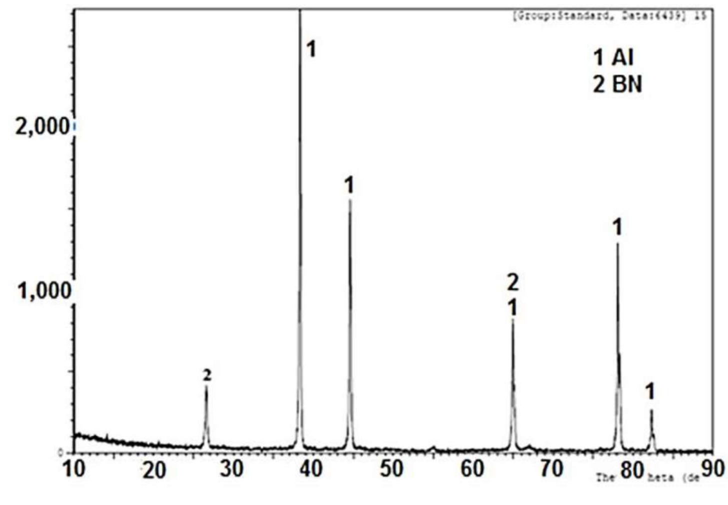

Figure 6. Present the XRD analysis results of Al-%15BN composites at 550 °C.

RESULTS AND DISCUSSION

The following results were concluded from the experimental findings

- The highest density in composite made from Al-%3BN, Al-%6BN, Al-%9BN, Al-%12BN and Al-%15BN powders sintered at 550°C temperatures was obtained as 550 °C The highest density sample was found as 2, 975gr cm^{-3} at 550 °C.

– The highest micro hardness in Al-%12BN composite samples fabricated using powder metallurgy method was found as 42.65HV at 550 °C.
– It was also found out for composition Al-%12BN at 550 °C suggest that the best properties. As the composition ratio of BN in aluminium increases, the porosity increases. A decrease in hardness was observed due to porosity.

ACKNOWLEDGEMENTS. This research was supported by the University of Afyon Kocatepe project no: 17.KARIYER.158 We would like to extend our gratitude to the Scientific Research Coordination Unit.

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